




UTC Semi-Annual Progress Report (SAPR#10)



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INTRODUCTION

This document constitutes the UTC Semi-Annual Progress Report (SAPR) for the Center for Teaching Old Models New Tricks (TOMNET), a Tier 1 University Transportation Center sponsored by the US Department of Transportation. The center commenced operation on November 30, 2016 and has been active since. This SAPR, the tenth produced under this grant, covers work accomplished, collaborations with academic, government, and industry partners, and the center outputs, outcomes, and impacts for the period of October 1, 2021, through March 31, 2022.

1. ACCOMPLISHMENTS

The TOMNET University Transportation Center's mission is to advance the state-of-the-art and state-of-the-practice in transportation demand modeling by collecting and incorporating data about human attitudes, behavioral processes, perceptions, values, and preferences in travel models. The center collects comprehensive datasets by administering in-depth surveys regarding users' attitudes, perceptions, and behaviors in the present and the future, considering all of the recent and expected transformative changes in transportation systems. Additionally, the center leverages a number of analysis methods and tools to advance its mission, including the application of data fusion and machine learning algorithms to integrate data sets, including third-party or external/secondary data sets, with disparate information – thus facilitating the development of comprehensive models of travel demand that reflect the effects of human attitudes.

What are the major goals of the program?

Previous Semi-Annual Progress Reports (SAPR) provide information about the goals, and hence the information is not repeated in this report. The *research* mission of TOMNET is to advance the science of activity-travel behavior modeling by developing new methods for incorporating the effects of people's attitudes, values, preferences, and perceptions in transportation demand forecasting models. The *education* and *workforce development* mission of TOMNET is to train a transportation planning and modeling workforce for the future that is capable of solving complex multi-disciplinary challenges confronting the profession. In addition, a critical mission of TOMNET is to attract a *diverse body* of students into the transportation profession by undertaking a number of K-12 education outreach activities, particularly in under-represented communities. Finally, TOMNET aims to empower the current transportation workforce by offering a number of workshops, continuing education (short) courses, symposia, and professional development seminars/webinars on cutting edge topics and methods that will help professionals address emerging and complex transportation issues. The *technology transfer* mission of TOMNET is to disseminate information about research findings, methods, tools, and data to a global audience of transportation professionals, students, researchers, policymakers, and the broader public. The knowledge gained helps move advanced data fusion approaches and modeling methods into practice but also builds a richer understanding of travel behavior which supports the public and private sector stakeholders making policy and investment decisions about transportation.

What was accomplished under these goals?

Within the reporting period, TOMNET researchers launched, made progress on, and completed several research projects. Projects launched in previous years have been completed (28 projects) or are continuing into their subsequent phases (21 projects). Additionally, 3 new projects have been launched during the reporting period. The list of all active and accomplished TOMNET projects is provided in Table 1 with the active period for each project (total of 49 projects). The status column indicates whether the project is accomplished or is still in progress. The new TOMNET projects are in the process of getting entered into the RiP database. Moreover, at this stage in the life of the center, we are at a point where

numerous completed project reports are getting finalized and entered into the TRID database. The TOMNET website [project page](#) is being regularly updated to present the research projects categorized by year and the lead university. Several reports for the projects that have been completed recently are under review and will be posted to TRID and the TOMNET Website within the next reporting period. Further details about progress made on a sample of active projects are provided below.

Table 1. TOMNET Research Projects

| Project Topic/Title | | Institution (PI) | Active Period | Status |
|---------------------|---|------------------|---------------------|--------|
| 1* | How Do Perceptions and Adoption of Emerging Transportation Technologies Vary by Residential Preferences? | ASU (Khoeini) | Aug 2021- July 2022 | |
| 2* | The Influence of Mode Use on Level of Satisfaction with Daily Travel Routine: A Focus on Automobile Driving in the United States | ASU (Pendyala) | Aug 2021- July 2022 | ✓ |
| 3* | Assessing the Impact of Ridehailing Service Use on Bus Ridership: A Joint Modeling Framework Accounting for Endogeneity and Latent Attitude | ASU (Pendyala) | Aug 2021- July 2022 | |
| 4* | Accounting for the Influence of Attitudes in Modeling the Adoption and Usage of On-Demand Transportation and Electric Vehicles | ASU (Pendyala) | Aug 2021- July 2022 | ✓ |
| 5* | Development of an Integrated Model of Daily Activity-Travel Behavior and Well-Being | ASU (Pendyala) | Aug 2017- July 2019 | ✓ |
| 6 | To What Extent Are Millennials Really Different in Their Vehicle Miles of Travel Compared to Generation X? | ASU (Pendyala) | Aug 2018- July 2019 | ✓ |
| 7 | Do Attitudes Affect Behavioral Choices or Vice-Versa: Uncovering Latent Segments within a Heterogeneous Population | ASU (Pendyala) | Aug 2019- July 2020 | ✓ |
| 8* | Attitudes Towards Mobility Options/Technologies – A Multi-region Survey Design and Data Collection Effort | ASU (Khoeini) | Oct 2017- July 2020 | ✓ |
| 9 | Interaction of Transportation and Health, Wellbeing, and Safety – A National Survey Design and Data Collection | ASU (Khoeini) | Aug 2020 – Present | |
| 10 | Transportation Policies, Pricing, and Priorities – A National Survey Design and Data Collection | ASU (Pendyala) | Aug 2020 – Present | |
| 11 | Transportation Electrification – A National Survey Design and Data Collection | ASU (Pendyala) | Aug 2020 – Present | |
| 12 | The Effect of Survey Methodology on The Collection of Attitudinal Data | ASU (Pendyala) | Aug 2020- July 2021 | ✓ |
| 13 | Investigating the Contributing Factors to Willingness to Share Automated Vehicles with Gender Focus | ASU (Khoeini) | Aug 2020- July 2021 | ✓ |
| 14 | Interaction of Familiarity, Safety Perceptions, and Willingness to Use Autonomous Vehicles in A Structural Equation Modeling Framework | ASU (Khoeini) | Aug 2020- July 2021 | ✓ |
| 15 | Effects of Attitudes Towards COVID On Travel Behavior During the Pandemic | ASU (Pendyala) | Aug 2020- July 2021 | ✓ |
| 16 | Expected Change in US Air Travel after the COVID-19 Pandemic | ASU (Khoeini) | Aug 2020- July 2021 | ✓ |
| 17* | Integrated Household Energy Analysis Tool (iHEAT) | ASU (Pendyala) | Aug 2020 – Present | |
| 18* | How Will Use of Autonomous Vehicles for Running Errands Affect Future Autonomous Vehicle Adoption and Ownership? | ASU (Pendyala) | Aug 2020- July 2021 | ✓ |
| 19 | Assembling Integrated Data Sets for Analyzing Connections between Travel Behavior, Attitudes, and the Built Environment | ASU (Salon) | Aug 2017- July 2018 | ✓ |
| 20 | Heterogeneity in the Relationship Between the Built Environment and Bicycling | ASU (Salon) | Aug 2018- July 2019 | ✓ |
| 21 | The role of transport in how we choose where to live: A qualitative investigation of residential location choice in the Phoenix, AZ region | ASU (Salon) | Aug 2018- July 2019 | ✓ |
| 22 | Comprehensive Review of Attitudes-Travel Behavior Literature | ASU (Salon) | Aug 2018- July 2019 | ✓ |
| 23 | The impact of non-transportation attitudes, preferences, and personality characteristics on residential location and travel choices | ASU (Salon) | Aug 2019- Present | |

| Project Topic/Title | | Institution (PI) | Active Period | Status |
|---------------------|--|-------------------|----------------------|--------|
| 24 | Investigating Attitudinal and Behavioral Changes in U.S. Households Before, During, and After the COVID-19 pandemic | ASU (Salon) | Aug 2019- Present | ⚙️ |
| 25 | The Stability of Transport-Related Attitudes over Time: A Case Study During COVID-19 | ASU (Salon) | Aug 2021- July 2022 | ⚙️ |
| 26 | Consumer Attitudes and Behavioral Implications in the New Era of Shared Mobility | ASU (Zhang) | Aug 2019 – Present | ⚙️ |
| 27 | Emerging Approaches to Autonomous Vehicles in Transportation Policy and Planning | ASU (Thad Miller) | Aug 2019 – Present | ⚙️ |
| 28 | Teaching The Travel Demand Flow Estimation Models: A New Deep-Learning Approach Using Multi-Source Data | ASU (Zhou) | Aug 2019 – Present | ⚙️ |
| 29 | Real-time Transportation Social Media Analytics using Pulse (Pulse-T) | ASU (Kandala) | Aug 2019 – Present | ⚙️ |
| 30* | Assessing the Influence of Attitudes and Perceptions of Ridehailing Services on the Frequency of Ridehailing Service Usage | ASU (Grimm) | Aug 2020 – Present | ⚙️ |
| 31* | Attitudes Towards Mobility Options/Technologies – A Multi-region Survey Design and Data Collection Effort | GT (Circella) | Oct 2017- July 2020 | ✓ |
| 32 | An Investigation of the Contribution of Targeted Marketing Data to the Prediction of Attitudes | GT (Mokhtarian) | Oct 2017- - Present | ⚙️ |
| 33 | Latent Vehicle Type Propensity Segments: Considering the Influence of Household Vehicle Fleet Structure | GT (Mokhtarian) | Aug 2018- July 2019 | ✓ |
| 34 | Combining Disparate Surveys Across Time to Study Satisfaction with Life | GT (Mokhtarian) | Aug 2019- July 2020 | ✓ |
| 35 | Mode Substitutional Patterns of Ridehailing and Micro-mobility Services | GT (Circella) | Aug 2020 – Present | ⚙️ |
| 36* | Response Willingness in Consecutive Travel Surveys | GT (Mokhtarian) | Aug 2020- July 2021 | ✓ |
| 37* | Drivers' Attitudes Toward Rerouting: Impacts on Network Congestion | GT (Laval) | Aug 2021 – July 2023 | ⚙️ |
| 38* | What is the New Normal? An Analysis of Post-COVID-19 Commute and Work Patterns | GT (Mokhtarian) | Aug 2021 – July 2023 | ⚙️ |
| 39 | Attitudes Towards Mobility Options/Technologies – A Multi-region Survey Design and Data Collection Effort | USF (Maness) | Oct 2017- July 2020 | ✓ |
| 40 | An Exploration of Contemporary Issues in Highway Safety, Evolving Transportation Alternatives, and Activity and Travel Behavior Modeling | USF (Maness) | Aug 2019- July 2020 | ✓ |
| 41 | Investigation of the Role of Attitudinal Factors on Adoption of Emerging Automated Vehicle and Vehicle Safety Technologies | USF (Mannering) | Aug 2017- July 2018 | ✓ |
| 42 | Emerging Econometric and Data Collection Methods for Capturing Attitudinal and Social Factors In Activity And Travel Behavior Modeling | USF (Mannering) | Aug 2018- July 2019 | ✓ |
| 43* | Exploration of the Relationships between Leisure Activity Participation Frequency and Social Capital | USF (Maness) | Aug 2020- July 2021 | ✓ |
| 44* | Valuation of Free Electric Vehicle Charging Bundles | USF (Maness) | Aug 2020- July 2021 | ✓ |
| 45* | Addressing Potentially Missing Relevant Information on Behavioral Elements as Unobserved Heterogeneity in Highway Safety Studies | USF (Mannering) | Aug 2020- July 2021 | ✓ |
| 46* | An Empirical Assessment of The Role of Attitudes and Identification in Safety Research | USF (Mannering) | Aug 2020 – Present | ⚙️ |
| 47 | Attitudes and Trust in Leveraging Integrated Sociotechnical Systems for Enhancing Community Adaptive Capacity (Phase 1-3) | UW (Chen) | Oct 2017- July 2020 | ✓ |
| 48* | Meeting Everyday Needs in A Disaster Scenario: The Potential for Resource Sharing Through Local Networks (Phase 4) | UW (Chen) | Aug 2020 – Present | ⚙️ |
| 49* | Effects of Big Data Analysis Methods on Mobility Patterns: Building Mobility Analysis Workflows (MAWs) | UW (Chen) | Aug 2021 – July 2023 | ⚙️ |

ASU = Arizona State University; GT = Georgia Institute of Technology; USF = University of South Florida; UW = University of Washington. ✓= Accomplished; ⚙️ =In progress; * = Narrative provided below.

TOMNET center's topical expertise and center goals were very conducive to allowing the center's activities to include addressing emerging issues, specifically, the impacts of COVID on travel behavior. This capability has enabled our efforts to add significant insight into emerging travel behaviors and support industry efforts to update planning and modeling efforts to respond to post COVID conditions. Those activities, including numerous presentations and publications, are enumerated above.

A Sampling of Progress on Active Research Projects

Project #1: How Do Perceptions and Adoption of Emerging Transportation Technologies Vary by Residential Preferences?

PI: Sara Khoeini (ASU), **Co-PI:** Ram Pendyala (ASU), Deborah Salon (ASU)

Progress: When it comes to the future of emerging transportation modes such as ride-hailing services and autonomous vehicles (AVs), various survey-based studies have explored the role of socioeconomics and attitudes in shaping people's perceptions and adoption of these innovative mobility options. However, the role of residential preferences and other spatial/geographical attributes has not been explored as much. A better understanding of such relationships will help in the design of land use patterns and residential developments of the future that are conducive to the adoption and use of transportation innovations (while minimizing unintended consequences). The proposed study utilizes T4 survey data to clarify the spatial variability in perceptions and choices related to emerging transport technologies, the transferability of data across different locations, and the geographic factors that merit enhanced attention in the future. This project has been launched during this reporting period. The team is currently undertaking a comprehensive explanatory analysis to investigate the bivariate relationships between residential preferences, ridehailing services use, and intentions to purchase an autonomous vehicle as well as other socio-economic, demographic, travel, and built-environment attributes. Based on this analysis a structural equation model will be formulated to unmask the true magnitude of these relationships. The initial results of this project will be presented at the upcoming (May 30, 2022) [ASCE International Conference on Transportation & Development](#) in Seattle, WA.

Project #2: The Influence of Mode Use on Level of Satisfaction with Daily Travel Routine: A Focus on Automobile Driving in the United States

PI: Ram Pendyala (ASU), **Co-PI:** Sara Khoeini (ASU) (collaboration with D-STOP, Uni of Texas at Austin)

Progress: How does the extent of automobile use affect the level of satisfaction that people derive from their daily travel routine? This is the research question addressed by this project. Utilizing data collected through the T4 Survey, this research effort recognizes the presence of endogeneity when modeling multiple behavioral phenomena of interest and the role that latent attitudinal constructs reflecting lifestyle preferences play in shaping the association between behavioral mobility choices and degree of satisfaction. Results show that latent attitudinal factors representing an environmentally friendly lifestyle, a proclivity towards car ownership and driving, and a desire to live close to transit and in diverse land use patterns affect the relative frequency of auto-driving mode use for non-commute trips and level of satisfaction with daily travel routine. This project was completed in the summer of 2021, but the technology transfer activities took place during this reporting period. A paper based on this study was presented at the 2022 TRB annual meeting and was accepted for publication in *Transportation Research Record: Journal of the Transportation Research Board*.

Project #3: Assessing the Impact of Ridehailing Service Use on Bus Ridership: A Joint Modeling Framework Accounting for Endogeneity and Latent Attitudes

PI: Ram Pendyala (ASU), **Co-PI:** Sara Khoeini (ASU) (collaboration with D-STOP, Uni of Texas at Austin)

Progress: Transit ridership has been on the decline for several years. One key contributing factor is the rise of ridehailing service usage and its impact on transit use. This study provides a comprehensive and

holistic assessment of the impacts of ridehailing service use on transit ridership while controlling for a host of socio-economic, demographic, and attitudinal factors. The study utilizes the T4 Survey data set. Study results indicate that ridehailing use frequency is significantly associated with a decrease in bus use, suggesting that ridehailing serves as a substitute for bus use (more than it serves as a complement). The findings suggest that transit agencies need to explore pathways towards leveraging ridehailing services to better complement transit usage. The preliminary study results were presented at [Environmental Health Matters Initiative](#) in July 2021, the full analysis has been completed in the previous reporting period. In this reporting period, the paper on the full analysis was presented at the 2022 TRB annual meeting. Based on the feedback received during the meeting, the research team has been working to improve the paper and plans to submit it to Transportation Research Part D for publication in the next reporting period.

Project #4: Accounting for the Influence of Attitudes in Modeling the Adoption and Usage of On-Demand Transportation and Electric Vehicles

PI: Ram Pendyala (ASU) (collaboration with D-STOP, Uni of Texas at Austin)

Progress: This project explored the identifying factors that contribute to the adoption of on-demand transportation services and electric vehicle (EV) ownership in the Indian context. While there is an extensive and growing body of research related to these transportation innovations in the developed world, evidence-based research on these topics remains sparse in the Indian context. Using a unique survey data set collected in 2018 across 20 cities in India, this project developed a holistic integrated modeling framework to shed light on the factors that affect the adoption of on-demand transportation services and electric vehicles. Not only did this project consider socio-economic and demographic variables that affect these behavioral choices, but the study placed a special emphasis on understanding the important role played by attitudes, values, and perceptions in determining the adoption of on-demand transportation services and EVs. Although this project was completed in the preceding period, technology transfer efforts continued in this reporting period. The study findings were presented at the 2022 TRB annual meeting. The paper, which has been revised based on the reviewers' comments, is accepted for publication in the Transportation Research Record: Journal of the Transportation Research Board.

Project #5: Development of an Integrated Model of Daily Activity-Travel Behavior and Subjective Well-Being

PI: Ram Pendyala (ASU)

Progress: This project is an effort to develop models of well-being that explicitly accounts for time allocation to different in-home, out-of-home, and travel activities. The models are estimated using the 2010, 2012, and 2013 well-being modules of the American Time Use Survey (ATUS). The data set includes activity-time use information for an entire day together with feelings on six different emotions using a seven-point scale for three random activity-travel episodes pursued in the day. A wellbeing score indicated by these emotion measures is jointly modeled for in-home, out-of-home, and travel activities as a function of a detailed set of activity-travel episode attributes and socio-economic characteristics. The developed models are then used to estimate individual-level wellbeing scores (to uncover equity challenges of certain individuals in the society and to assess how much mobility choices can contribute to the individual wellbeing). This project also consists of another major component that estimates a multiple discrete-continuous extreme value (MDCEV) model to allocate total in-home time to various activities for the surveys that do not report on in-home time allocations of the respondents. NHTS 2017 activity-travel database is used to demonstrate the efficacy of this model. The final product of this well-being model system is called WBEAT (Well-Being Estimator for Activities and Travel) which provides a robust behavioral approach to assess the quality-of-life implications of transportation investments and policies for all segments of society. As stated in the previous reporting periods, the technology transfer activities for this project have been continuing. The TOMNET researchers presented the project findings at the TRB2020

Annual Meeting and the paper from this project is at the final stages of publication by *Transportation Letters*. In this reporting period the project team has worked on developing an open-source software tool (WBEAT) for public usage. The alpha version of the software tool is available at this [link](#).

Projects #8, #31, #39: Attitudes Towards Emerging Mobility Options and Technologies (T4 Survey)

PI: Sara Khoeini (ASU), Giovanni Circella (GT), Michael Maness (USF)

Co-PI: Ram Pendyala (ASU), Deborah Salon (ASU), Patricia Mokhtarian (GT), Fred Mannering (USF)

Progress: Survey design, sample recruitment, data collection, data cleaning and weighting, and dissemination of initial results have all been completed during the 2017-2020 time period. During the reporting period, the research team continued work on data analysis and behavioral choice modeling, presenting the results at various venues and writing scientific papers. The project [webpage](#) reflects all of the activities and outputs related to the TOMNET Transformative Technologies in Transportation (T4) Survey products. Further analysis of T4 survey data is underway (projects #1, #2, #3, #12, #13, #14, #18, #23, #30, and #35 in Table 1); these efforts are in progress or have been completed during this reporting period and resulted in the preparation of papers for presentation at the 2022 Transportation Research Board Annual Meeting and (possible) publication in the Transportation Research Record: Journal of the Transportation Research Board and in the other journals.

Project #17: Integrated Household Energy Analysis

PI: Ram Pendyala (ASU)

Progress: Integrated models of activity-travel demand and transport energy consumption often do not consider the mix of vehicle types owned and used by households, thus making it difficult to assess the energy implications of shifting vehicle/fuel type choices – particularly in a rapidly evolving marketplace. More importantly, integrated models of activity-travel demand and transport energy consumption do not consider the residential energy consumption implications of travel. To obtain a holistic picture of household energy footprints, this project thus aimed at developing an integrated model system that tightly connects activity-travel demand, travel energy consumption (sensitive to vehicle fleet/fuel type), and residential energy consumption (sensitive to activity-travel choices). The developed model fuses information between two survey data sets, namely, the National Household Travel Survey (NHTS) data set and the Residential Energy Consumption Survey (RECS) data set and is applied to a synthetic population for the Greater Phoenix area in Arizona to illustrate its efficacy. The project findings have been disseminated at the TRB2020 annual meeting and the paper out of this research effort is currently under review by the Transportation Research Record for a possible publication. In addition, an online calculator called Integrated Household Energy Analysis Tool (iHEAT) has been developed based on this project to estimate household energy footprints as a function of home and travel attributes of the users. The alpha version of this calculator will be released soon and the researchers have been working to improve the modeling method, as well as the tool's application and visualization features, during this reporting period.

Project #18: How Will Use of Autonomous Vehicles for Running Errands Affect

Future Autonomous Vehicle Adoption and Ownership?

PI: Ram Pendyala (ASU) (collaboration with D-STOP, Uni of Texas at Austin)

Progress: Concerned with the potentially deleterious effects of having personal AVs running errands autonomously, this research project aims to shed light on the level of interest in sending AVs to run errands and how that variable affects the intent to own an AV. Using data from the T4 Survey, the relationship is explored through a joint model system estimated using the Generalized Heterogeneous Data Model (GHDM) methodology. Results show that even after accounting for socio-economic and demographic variables as well as latent attitudinal constructs, the level of interest in having AVs run

errands has a positive and significant effect on AV ownership intent. The findings point to the need for policies that would steer the entry and use of AVs in the marketplace in ways that avoid a dystopian future where personally owned AVs would be personally owned by households – enabling people to live farther away from destinations, inducing additional travel, and roaming roadways with zero occupants. The project has been fully completed in the preceding reporting period. However, the technology transfer activity is still ongoing. The research paper based on this project was presented at the [International Road Federation World Meeting](#) in Dubai in November 2021 and at the 2022 TRB Annual Meeting in January 2022. The paper has also been submitted to the Transportation Research Record: Journal of the Transportation Research Board and is currently in the final stages of publication. In addition, the project results (with a focus on the sustainability implications) will be presented at the [TRB Conference on Sustainability and Emerging Transportation Technology](#) (in Irvine between May 31 and June 2, 2022).

Project #30: Assessing the Influence of Attitudes and Perceptions of Ridehailing Services on the Frequency of Ridehailing Service Usage

PI: Kevin Grimm (ASU) **Co-PI:** Ram Pendyala (ASU)

Progress: The overall goal of this project is to use latent variable models to examine the factor structure of participant attitudes toward the adoption of ridehailing services. In this reporting period, the project team carried out a preliminary analysis to formulate a structural modeling framework for investigating the study objectives. The research team undertook an exploratory factor analysis based on general attitudes, perceptions, and lifestyles of respondents as well as a latent cluster analysis to classify the respondents into distinct categories based on their attitudes and perceptions of ridehailing services. The team will determine model specifications in the next reporting cycle to carry out the full analysis. Multiple conference and journal articles identifying the latent elements contributing to the adoption of new transportation technology are expected to be produced as a result of this research project.

Project #36: Response Willingness in Consecutive Travel Surveys

PI: Patricia Mokhtarian (GT), **CO-PI:** Kari Watkins

Progress: This project addresses the following questions: (1) Who is more likely to respond to a follow-up survey? (2) How does recruiting respondents based on their willingness expressed in a preceding travel survey bias the follow-up survey sample? (3) What survey sample could we expect if we recruited respondents from the 2017 NHTS respondents in different geographic regions in the U.S.? As mentioned in our preceding SAPR, a master's thesis based on this study was completed and filed in Spring 2021, and a paper summarizing the study was submitted to the journal Transportation in July 2021. During the present reporting period, we received peer-review comments on the paper. A revised version of the paper has been prepared and will be resubmitted. We have also applied the models developed in this study to predict the response to a new survey being fielded in the State of Georgia (see Project #38), for which we recontacted willing 2017 NHTS respondents (among other recruitment strategies). Responses to the new survey are still being received at the time of this writing, but preliminary results suggest that the models' predictions are refreshingly close to the actual realization.

Project #37: Drivers' Attitudes Toward Rerouting: Impacts on Network Congestion

PI: Jorge A. Laval (GT)

Progress: This project aims to answer the following questions: (1) What machine learning (ML) approaches are useful to help people make rerouting decisions in congestion? (2) What properties of congested urban networks influence the ML result? (3) How do the rerouting decisions influence the bifurcation phenomena in macroscopic fundamental diagrams (MFDs)? The team conducted a literature review and identified deep reinforcement learning (DRL), one of the advanced RL methods, to analyze rerouting behavior. In congested urban networks, the team found some factors have a huge impact on the DRL

result. (1) The density of the network influences the performance of DRL significantly. Especially when the network is close to jam density, DRL cannot learn in such situations. (2) The DRL result is affected by the driver's rerouting probabilities, or rerouting intention. (3) The blocking area distribution is an important value for the demand matrix because it is the reward in each iteration. The team aims to make the blocking area distributed averagely in the network. Literature on the bifurcation phenomenon in MFDs suggests some factors potentially cause this phenomenon. Since the project's focus is on the effect of adaptive driving behavior, a more realistic network in SUMO is built to perform simulations. In the next period, the team will wrap up the literature review, and assess how each factor above affects the results and if there are other factors that also influence the results. A signal control assignment for the simulation will be found as next since the rerouting behavior cannot be independent of signal control. The team considers the effectiveness of signal control on the bifurcation phenomenon. The team plans to submit a paper summarizing these findings to the 2023 Annual Meeting of the Transportation Research Board.

Project #38: What is the New Normal? An Analysis of Post-COVID-19 Commute and Work Patterns

PI: Patricia Mokhtarian (GT), **Co-PI:** Giovanni Circella

*Note that this project is partially funded through UTC match funding provided by the Georgia Department of Transportation (GDOT); however, TOMNET funding is also being used, to augment the sample size and to enable launching the survey in a timely manner despite a 9-month delay in receiving the GDOT funding.

Progress: The study is addressing the following questions: (1a) What are the adoption rates and frequencies of working from home in Spring 2022 (representing at least the "back side" of the COVID-19 pandemic, if not yet completely post-COVID), and what are the intentions to continue to work remotely in the future? (1b) What demographic, geographic, and attitudinal characteristics are associated with adoption/non-adoption, higher or lower frequencies? (2a) What is the distribution of one-way commute lengths, and how has that distribution changed since before COVID-19? (2b) Putting one-way commute lengths together with commute frequencies, what is the distribution of total weekly commute distance traveled, and how has that distribution changed since before the pandemic? (2c) What socio-economic and other characteristics are associated with one-way commute lengths and total weekly commute distances? (3) How have the shares of commute modes changed since before the pandemic, and what characteristics are associated with those changes? To address these questions, we have designed, and are in the process of fielding, an online survey of employed Georgia residents. We are recruiting approximately 2000 respondents through an online opinion panel vendor (Qualtrics). Ultimately, we will also develop models of key behavioral indicators, to enable us to control for multiple behavioral influences simultaneously.

Project #43: Exploration of the Relationships between Leisure Activity Participation Frequency and Social Capital

PI: Michael Maness (USF)

Progress: The research team conducted a longitudinal analysis of two datasets on leisure activity behavior and social capital – before and during the pandemic. This paper examines the temporal influence of social capital, mobility, personalities, and demographics on leisure variety using samples collected in 2019 and 2020. Social capital constructs, specifically instrumental support, have substantial and significant effects on increasing leisure activity variety and remain temporally stable. This result supports the robustness and importance of social capital in activity variety, which further provides evidence for the valuable resources offered by one's social network under drastic changes and restrictions. Age, household size, and extraversion are among the factors that exhibit temporal instability. Model inference shows negative impact of the pandemic on activity variety, especially for people aged 60 or older. A short paper on this was submitted and accepted for presentation at the 10th Symposium of the European Association for Research in Transportation. Additionally, an extended abstract was submitted to the 2022 International

Choice Modeling Conference and accepted.

Project #44: Valuation of Free Electric Vehicle Charging Bundles

PI: Michael Maness (USF)

Progress: The modeling effort for the vehicle choice experiment was enhanced with a latent class error component structure to account for attribute and alternative non-attendance. Results from latent class discrete choice models showed heterogeneity in the sensitivity to free charging time scale (at two to three years) with a significant share of the population showing no sensitivity to a single year of free charging. Respondents valued free charging between about \$1100 to \$3000 per year depending on class (attentiveness to free charging). A significant proportion of the population showed no interest in electric vehicles. A short paper on this was submitted and accepted for presentation at the 10th Symposium of the European Association for Research in Transportation. The charger choice results were presented at the 2021 Behavior, Energy, and Climate Change conference with a talk entitled: A National Estimate of the Value of a Free EV Charging Event in the US.

Project #46: An Empirical Assessment of The Role of Attitudes & Identification in Safety Research

PI: Fred Mannering (USF) **Co-PI:** Michael Maness (USF)

Progress: The research team has developed a questionnaire to collect individuals' retrospective driving behavior data before and during the pandemic. The team developed questions on: (1) driving status and tenure, (2) vehicle miles traveled (VMT), (3) VMT changes due to pandemic, (4) incidents, (5) moving violations, and (6) attitudes towards safety. Additionally, the survey acquires information on people's attitudes and concerns with the pandemic. The research team performed a test of the survey during the previous reporting period where it was found that respondents could reliably answer the questions given. The team administered the survey in the current reporting period the data are currently being analyzed.

Project #48: Meeting Everyday Needs in a Disaster Scenario: The Potential for Resource Sharing

PI: Cynthia Chen (UW), **Co-PI:** Dan Abramson

Progress: In this study, we assess individuals' willingness to share essential resources following a large disaster using data gathered from three communities in the Pacific Northwest, a region that anticipates experiencing a magnitude 9.0 megaquake based on historical patterns of seismic activity. This study attempts to the following questions: (1) how willing are people to share different types of resources? (2) what factors affect people's willingness to share? Thus far, both questions have been answered and analyses have been completed. In terms of analysis methods, we used descriptive analysis, factor analysis and ordered probit models. We found people anticipated being willing to share resources differently depending on resource type and the nature of their social ties to the recipient. And we examined differences in the influence of trust using an ordered response probit model, finding it to be a key factor affecting willingness to share. The model quantified the association of various factors with the probability of being willing to share a specific resource with: nobody; family and close friends only; family, close friends, or acquaintances; or anyone in need. The results suggest that an individual's level of social trust has a significant and consistent influence on willingness to share for all resources in both contexts. People with higher levels of trust indicate being more willing to share with others across all resources included in the survey. The results will be organized into a journal article for publication in the next reporting period.

Project #49: Effects of Big Data Analysis Methods on Mobility Patterns: Building Accessible, Interoperable, Reproducible and Reusable Mobility Analysis Workflows (MAWs)

PI: Cynthia Chen (UW), **Co-PI(s):** Ka Yee Yeung, Ling-Hong Hung, Wes Lloyd

Progress: Recent rise of using passively generated mobile data from mobile devices have raised questions

on using such data for capturing the mobility patterns of a population because: 1) such data is self-selected and thus violates the fundamental requirement for representativeness; 2) there is a great variety of different kinds of mobile data and their respective properties are unknown; and 3) data pre-processing and analysis methods are often not explicitly reported, while at the same time, different pre-processing and analysis methods have been used and their impacts on the inferred mobility patterns are unclear. The high stakes involved with mobility analysis and issues associated with the passively generated mobile data call for mobility analysis to be accessible to all, interoperable across different computing systems, reproducible and reusable by others. In this study, a Mobility Analysis Workflow (MAW) that integrates data, methods and results, is developed. MAW allows its users to easily create, configure, modify, execute and share their methods and results. Using MAW allows comparative analyses of quantifying the impacts of different pre-processing and analysis methods on inferred mobility patterns. This study confirms that different data pre-processing and analysis methods do have impacts on the resulting mobility patterns derived. In the next reporting period, the research team plans to use the developed MAW dockers to test additional data to see their effects on the derived mobility metrics.

What opportunities for training and professional development has the program provided?

In the *education* and *workforce development* domain, all of the TOMNET partners offered a number of undergraduate and graduate courses at their respective institutions during Fall 2021 and Spring 2022. Table 2 offers a detailed summary of the courses offered by faculty members closely affiliated with the TOMNET center. It should be noted that there are many additional transportation-related courses taught at each institution at both undergraduate and graduate levels; however, the scope of activities reported in this SAPR is limited to the activities of faculty members who comprise the *core* group of TOMNET and are *deeply engaged* in advancing the activities and mission of the center.

Table 2. Courses Offered by Mission-Critical Faculty Members of TOMNET (Winter 2021 & Spring 2022)

| Semester | Course Level | Course No | Course Title | No | Instructor | Unit |
|--|----------------------|---------------|--|-----|---------------|-------|
| Arizona State University | | | | | | |
| Spring 22 | Undergrad | PUP 424 | Planning Methods | 17 | Salon | SGSUP |
| Spring 22 | Undergrad | CEE372 | Transportation Engineering | 105 | Zhou | SSEBE |
| Spring 22 | Grad | CEE598 | Traffic Flow Theory | 15 | Zhou | SSEBE |
| Georgia Institute of Technology | | | | | | |
| Spring 22 | Grad | CEE 6632 | Simulation in Transport | 13 | Laval | CEE |
| Spring 22 | Undergrad | CEE 3770 | Statistics & Applications | 42 | Mokhtarian | CEE |
| Spring 22 | Grad | CEE 6650 | Discrete Choice Analysis | 6 | Mokhtarian | CEE |
| University of South Florida | | | | | | |
| Spring 22 | Graduate | TTE6930 | Graduate Transportation Seminar | 20 | Xiaopeng Li | CEE |
| Spring 22 | Graduate | TTE5501 | Transportation Planning and Economics | 23 | Peng Chen | MURP |
| Spring 22 | Undergrad | TTE4005 | Transportation Engineering II | 70 | Yu Zhang | CEE |
| Spring 22 | Graduate | TTE6315 | Transportation Safety | 22 | Zhenyu Wang | CUTR |
| Spring 22 | Undergrad | TTE4004 | Transportation Engineering I | 19 | Kourtellis | CEE |
| Spring 22 | Graduate | CGN6311 | Introduction to Data Science | 24 | Qing Lu | CEE |
| Spring 22 | Graduate | CGN6933 | Sustainable Transportation | 16 | Jason Jackman | CEE |
| Spring 22 | Graduate | CGN6933 | Automated and Connected Transportation | 11 | Xiaopeng Li | CEE |
| Spring 22 | Undergrad | CGN4933 | Automated and Connected Transportation | 8 | Xiaopeng Li | CEE |
| Spring 22 | Graduate | TTE6501 | Statistical and Econometric Methods II | 6 | Mannering | CEE |
| University of Washington | | | | | | |
| Fall 21 | Graduate | CET581 | Travel Demand Forecasting | 15 | Nichols | CEE |
| Winter 22 | Graduate | CET512 | Transportation Data Collection | 15 | Cynthia Chen | CEE |
| Fall 21 | Graduate & Undergrad | URBDP 524/424 | Site Planning | 25 | Abramson | URBDP |
| Winter 22 | Graduate & Undergrad | BE 405/505 | Built Environments Studio | 20 | Abramson | CBE |

Notes: Notes: Arizona State University: SSEBE = School of Sustainable Engineering and the Built Environment; SGSUP = School of Geographical Sciences and Urban Planning. Georgia Institute of Technology: CEE = School of Civil and Environmental Engineering. University of South Florida: CEE = Department of Civil and Environmental Engineering; University of Washington: CEE = Civil & Environmental Engineering; Urban Pln = Urban Planning

In addition, TOMNET faculty supervised a number of students and post-doctoral scholars, providing them guidance and mentorship necessary to pursue independent research and discovery or secure positions in academia or government and industry. Students currently engaged in TOMNET related research and education activities are listed in Table 3. Besides graduate students pursuing Master’s and PhD degrees, the TOMNET consortium engages undergraduate students in various research endeavors in an effort to provide research experiences for undergraduate students and inspire them to pursue advanced studies and a career in transportation systems engineering and planning.

Table 3. Students and Research Staff Engaged in TOMNET-Related Research and Education Activities

| Name of Scholar | Level | Major/ Unit | Supervisor/ Advisor |
|--|----------------------|----------------|----------------------------------|
| ARIZONA STATE UNIVERSITY | | | |
| Irfan Batur | PhD Student | SSEBE | Pendyala |
| Tae Hooie Kim | PhD Student | SSEBE | Pendyala |
| Tassio Bezerra Magassy | PhD Student | SSEBE | Pendyala |
| Shivam Sharda | PhD Student | SSEBE | Pendyala |
| Denise Capasso da Silva | PhD Student | SSEBE | Pendyala/Khoeini |
| Danielle Manapat | PhD Student | Psychology | Grimm |
| Harsha Vamsi Kalluri | MS Student | Comp Science | Pendyala |
| Christina Galanis | Undergrad Student | SSEBE | Pendyala |
| GEORGIA INSTITUTE OF TECHNOLOGY | | | |
| Ziming Liu | PhD student | CEE | Laval |
| Xinyi Wang | MS & PhD student | CEE | Mokhtarian |
| Sung Hoo Kim | PhD student/ postdoc | CEE | Mokhtarian |
| Regan Buchanan | MS student | SCaRP | Mokhtarian |
| Ilsu Kim | PhD student | CEE | Mokhtarian/Circella |
| UNIVERSITY OF SOUTH FLORIDA | | | |
| Asim Alogaili | Graduate Student | CEE | Fred Mannering |
| Suryaprasanna Balusu | Graduate Student | CEE | Fred Mannering and Abdul Pinjari |
| Nawaf Alnawmasi | Graduate Student | CEE | Fred Mannering |
| Qianwen Li | Graduate Student | CEE | Xiaopeng Li and Fred Mannering |
| Trang Luong | Graduate Student | CEE | Michael Maness |
| Divyamita Mishra | Graduate Student | CEE | Michael Maness |
| Tung Vo | Graduate Student | CEE | Michael Maness |
| UNIVERSITY OF WASHINGTON | | | |
| Ekin Ugurel | PhD student | CEE | Chen |
| Grace Jia | PhD student | CEE | Chen |
| Cristina Cano-Calhoun | Research coordinator | Urban planning | Abramson/Chen |
| Xiangyang Guan | Postdoc | CEE | Chen |
| Eddie De La Fuente | MS student | Urban planning | Abramson |
| Ameer Hamza Shakur | PhD student | ISE | Shuai Huang |
| Ryan Lin | PhD student | ISE | Shuai Huang |

In the *technology transfer* domain, Arizona State University continued the [TOMNET webinar series](#) that is presented to a worldwide audience. Due to the pandemic, the webinars were provided in a hybrid or full remote format with recordings available on the TOMNET website. In addition to ASU, USF was also active in organizing transportation webinars. These events are advertised widely and very well attended. Table 4 presents a list of ASU and USF TOMNET sponsored seminars for the period covered by this SAPR.

Further, Dr. Sara Khoeini presented findings of the T4 survey at various conferences and Dr. Deborah Salon presented results of the COVID Future survey in different venues. These presentations are listed later.

Table 4. Key TOMNET-Sponsored Technology Transfer Events

| Inst. | Title of Seminar/ Webinar | Speaker Name and Affiliation | Date |
|-------|--|---|------------|
| ASU | Developing Structural Equation Models for Commuter Rail while Analyzing Underlying Attitudes | De’Von Jennings, PhD, PE, University of California, Irvine | 02/10/2022 |
| USF | Customized AI and Edge Computing for Safer and Smarter Transportation Infrastructure Systems | Yinhai Wang, UW | 10/29/2021 |
| USF | Physics Regularized Machine Learning for Smart Mobility | Xianfeng Yang, University of Utah | 11/05/2021 |
| USF | Advanced Technologies in Transportation | Kevin J. Thibault, Florida Department of Transportation | 11/12/2021 |
| USF | Using Data and Public Outreach to Achieve Positive Outcomes in Transportation | Jake Mirabella, Jennifer Musselman, and Franco Saraceno, Kittelson and Associates, Inc. | 11/19/2021 |
| USF | Smart Mobility in Tampa | Brandon Campbell, City of Tampa | 02/04/2022 |
| USF | Roadmap to Cooperative & Automated Transportation: Theory, Modeling, and Experiments | Xiaopeng Li, USF | 02/11/2022 |
| USF | Engineering Professionalism and Ethics | Kimberlee Bernson DeBosier, WGI | 02/18/2022 |
| USF | Future-Proofing Transportation Systems to meet 21st Century Transportation Needs | Christopher Francis, Marlin Engineering Inc. | 02/25/2022 |
| USF | Challenging the Supremacy of the Automobile Mode: An Exercise in Futility? | Ram M. Pendyala, ASU | 03/25/2022 |

Note: ASU = Arizona State University; GT = Georgia Institute of Technology; USF = University of South Florida; UW = University of Washington

What do you plan to do during the next reporting period to accomplish the goals?

TOMNET has several activities planned for the next reporting period to ensure rapid growth in the portfolio of accomplishments of the center. In the research domain, TOMNET faculty members will continue making progress on research projects and the results will be disseminated widely through various channels. Particularly, TOMNET has so far contributed to, or fully funded, four surveys on new transportation technologies, community resilience and disaster-response, leisure and social-capital activity engagement, and COVID-19 travel implications. Moreover, TOMNET is in the process of collecting additional national survey data on transport pricing and priorities, health and transportation interaction, and electrification. Considering the availability of diverse and rich datasets, it is expected that the next two reporting periods will see the production of tangible research outputs that can significantly benefit policy and decision making of the transport sector, particularly in the wake of recent natural and technological disruptions. Dissemination of these research products will further contribute to the TOMNET education and workforce development goals as well as technology transfer domain.

TOMNET core faculty members will continue to teach undergraduate and graduate courses at their respective institutions while enhancing the content to reflect discoveries and trends in the profession. TOMNET faculty members will continue to mentor students and guide them to the completion of their studies and appropriate career pathways. In the technology transfer domain, TOMNET will continue to organize webinars and in-person seminars such as those listed previously in the report.

Discussions are underway to organize a symposium, called the A⁴ Symposium. This symposium will focus on Attitudes, Automation, Autonomy, and Access (hence, A⁴) and bring together the many key themes addressed by TOMNET. TOMNET scholars will continue to engage in considerable K-12 outreach activities. Due to the pandemic, TOMNET in-person summer outreach activities were canceled; but online platforms have been used to continue K-12 outreach programs. In the next reporting period, TOMNET will continue taking advantage of successful online modules to disseminate information about careers in transportation. Sara Khoeini delivered a webinar entitled “Narrative of Transportation” to approximately

150+ high school students as part of the AZ Transportation YOU program organized by the WTS Phoenix Chapter to explain how the transportation industry has evolved through the years. Researchers at Georgia Tech plan to continue giving presentations to academic and practitioner audiences on the post-pandemic outlook for teleworking, and other topics of current research interest. In July 2022, Dr. Mokhtarian will be a keynote speaker at a symposium in honor of the late Joseph Prashker, hosted by the Technion in Haifa, Israel. In June 2022, Dr. Circella will be the co-chair of the Sustainability and Emerging Transportation Technologies (SETT) conference organized by the Transportation Research Board in Irvine, CA, where he will co-chair two plenary sessions and discuss the results from his research.

University of South Florida researchers will continue to perform research and disseminate their work through journal and conference papers. The research team has working papers in preparation and planned for submission to peer-reviewed journals in the following topic areas: (1) social resources and social leisure activity frequency, (2) safety perceptions and the pandemic, and (3) bundled free charging in vehicle ownership scenarios. With the current COVID-19 crisis, there is some uncertainty regarding planned conference travel and the student research seed grant competition.

2. PARTICIPANTS & COLLABORATING ORGANIZATIONS

TOMNET researchers have been actively collaborating with a number of organizations and partners in academia and industry. These partnerships have created many opportunities for the impact of TOMNET to be felt on a broad scale. TOMNET researchers work very closely with Atlanta Regional Commission, Maricopa Association of Governments, and the Georgia Department of Transportation.

What organizations have been involved as partners?

- *Oak Ridge National Laboratory – National Transportation Research Center: Collaborative research*
- *Northwestern University: Collaborative research*
- *Atlanta Regional Commission, Atlanta, Georgia: Collaborative research and personnel exchange, impacted by pandemic.*
- *Georgia Department of Transportation, Atlanta, Georgia: In-kind support, data sets, collaborative research, funding of matching-project research.*
- *Universidad de Chile and Universidad de Concepcion (Chile), University of Leeds (UK) and German Aerospace Institute – DLR (Germany): Collaborative research*
- *World Conference for Transport Research Society (WCTRS): Writing of a chapter, larger international collaboration.*
- *Asian Development Bank Institute (ADBI): Collaborative research*
- *Laurelhurst Earthquake Action Preparedness, Seattle, WA: Collaborative research*
- *City of Westport, Westport, WA: Collaborative research, supplied facilities*
- *Westport Tsunami Safety Committee, Westport, WA: Collaborative research*
- *City of Seattle Office of Emergency Management: Collaborative research*
- *Maricopa Association of Governments, Phoenix, Arizona: In-kind support, data sets, collaborative research*
- *The AAA Foundation for Traffic Safety*

Have other collaborators or contacts been involved?

TOMNET core research members are actively collaborating with researchers across the world to produce cutting-edge research products and advance the discipline of traveler behavior and attitudes. The list of researchers that work closely with TOMNET researchers include:

- | | |
|---|---|
| - <i>Dr. Chandra Bhat, PhD, University of Texas at Austin, TX</i> | - <i>Dr. Yongsung Lee, University of Hong Kong, Hong Kong</i> |
| - <i>Dr. Abolfazl Mohammadian, University of Illinois-Chicago, IL</i> | - <i>Dr. Shin-Hyung Cho, Seoul National University, S. Korea</i> |
| - <i>Dr. Sybil Derrible University of Illinois-Chicago, IL</i> | - <i>Dr. Calvin Thigpen, e-scooter Lime</i> |
| - <i>Dr. Laurie Garrow, Georgia Tech, Atlanta, GA</i> | - <i>Baiba Pudane, PhD Candidate, TU Delft, the Netherlands</i> |
| - <i>Dr. Brian German, Georgia Tech, Atlanta, GA</i> | - <i>Jia Tang, PhD student from Nanjing University</i> |
| - <i>Dr. Joseph Saleh, Georgia Tech, Atlanta, GA</i> | - <i>Executive Board of the International Association for Travel Behaviour Research</i> |
| - <i>Dr. Patrick Singleton, Utah State University, Logan, UT</i> | - <i>South Park Information and Resource Center</i> |
| - <i>Dr. Lauren Steimle, Georgia Tech, Atlanta, GA</i> | |

- Dr. Dima Nazzal, Georgia Tech, Atlanta, GA
- Dr. Timor Besedes, Georgia Tech, Atlanta, GA
- Dr. Rolf Moeckel, Technical University of Munich, Germany
- Dr. Alejandro Tirachini, University of Chile, Chile
- Dr. Konstantinos Antoniou, Technical University of Munich, Germany
- Dr. Barbara Lenz, German Aerospace Institute
- Dr. Dick Ettema, Utrecht University, Utrecht, Netherlands
- Dr. Clark Miller, Arizona State University, Tempe, AZ
- Dr. Vivien K. G. Lim, the National University of Singapore
- Dr. Bert van Wee, TU Delft, the Netherlands
- Washington Emergency Management Division
- Washington State Parks
- Shoalwater Bay Tribe
- Westport Police Department
- Grays Harbor County Emergency Management
- South Beach Regional Fire Authority
- Ocosta Public School District
- Northwest Healthcare Response Network
- University of Washington School of Public Health
- Seattle Emergency Hubs

3. OUTPUTS

The following is a list of **publications, conference papers, and presentations** produced by TOMNET core faculty members during the reporting period covered by this SAPR. To the extent possible, papers and presentations likely to be listed in other UTC SAPR documents have been omitted.

Arizona State University

Papers Published Within Reporting Period

1. Magassy, T.B., I. Batur, A. Mondal, K.E. Asmussen, S. Kheini, R.M. Pendyala, and C.R. Bhat. (Forthcoming). The Influence of Mode Use on Level of Satisfaction with Daily Travel Routine: A Focus on Automobile Driving in the United States. *Transportation Research Record*.
2. Sharda, S., X. Ye, A. Raman, R.M. Pendyala, A. Pinjari, C.R. Bhat, A. Srinivasan, and G. Ramadurai. (Forthcoming). Accounting for the Influence of Attitudes and Perceptions in Modeling the Adoption of Emerging Transportation Services and Technologies in India. *Transportation Research Record*.
3. Bhat, C. R., Mondal, A., Pinjari, A. R., Saxena, S., & Pendyala, R. M. (2022). A multiple discrete continuous extreme value choice (MDCEV) model with a linear utility profile for the outside good recognizing positive consumption constraints. *Transportation Research Part B: Methodological*, 156, 28-49.
4. Cheng, Q., Liu, Z., Guo, J., Wu, X., Pendyala, R., Belezamo, B., & Zhou, X. S. (2022). Estimating key traffic state parameters through parsimonious spatial queue models. *Transportation Research Part C: Emerging Technologies*, 137, 103596.

Presentations Within Reporting Period

1. Batur, I., K. E. Asmussen, A. Mondal, S. Kheini, R. M. Pendyala, and C. R. Bhat. Assessing the Impact of Ridehailing Service Use on Bus Ridership: A Joint Modeling Framework Accounting for Endogeneity and Latent Attitudes. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
2. Batur, I., K. E. Asmussen, A. Mondal, S. Kheini, R. M. Pendyala, and C. R. Bhat. Understanding Interest in Personal Ownership and Use of Autonomous Vehicles for Running Errands: An Exploration Using a Joint Model Incorporating Attitudinal Constructs. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
3. Magassy, T., I. Batur, A. Mondal, K. E. Asmussen, S. Kheini, R. M. Pendyala, and C. R. Bhat. The Influence of Mode Use on Level of Satisfaction with Daily Travel Routine: A Focus on Automobile Driving in the United States. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
4. Baker, D., T. Magassy, S. Kheini, P. Stopher, I. Batur, and R. M. Pendyala. Autonomous Vehicles: The Role of Familiarity and Perceptions in Expected Adoption. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
5. Bhat, C., A. Mondal, A. Pinjari, S. Saxena, and R. M. Pendyala. A Multiple Discrete Extreme Value Choice Model with a Linear Utility Profile for the Outside Good Recognizing Positive Consumption Constraints. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
6. Baker, D., T. Magassy, S. Kheini, D. Salon, R. M. Pendyala, and C. Bhat. Measuring Population Attitudes, Preferences, and Values: A Tale of Weighting Two Surveys Reveals an Exercise in Futility. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
7. Kheini, S., S. Sharda, D. Baker, R. M. Pendyala, M. Bhagat-Conway, D. Salon, L. Mirtich, R. Chauhan, S. Derrible, E. Rahimi, M. Javadinasr, and A. Mohammadian. Expected Change in U.S. Air Travel After the COVID-19 Pandemic. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
8. Javadinasr, M., T. Magassy, E. Rahimi, M. Mohammadi, A. Davatgari, A. Mohammadian, R. Chauhan, M. Bhagat-Conway, R. M. Pendyala, D. Salon, S. Derrible, and S. Kheini. Observed and Expected Impacts of COVID-19 on Travel Behavior in the United States: A Panel Study Analysis. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.

9. Sharda, S., X. Ye, A. Raman, R.M. Pendyala, A. Pinjari, C.R. Bhat, A. Srinivasan, and G. Ramadurai. Accounting for the Influence of Attitudes and Perceptions in Modeling the Adoption of Emerging Transportation Services and Technologies in India. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
10. Kim, T., X. Zhou, and R.M. Pendyala. Computational Graph-Based Mathematical Reformulation and Automatic Differentiation-Based Solution Methods for Consistent Integrated Travel Demand and Supply Modeling. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
11. Mirtich, L., M. Bhagat-Conway, D. Salon, P. Kedron, R. Chauhan, S. Derrible, S. Khoeini, A. Mohammadian, E. Rahimi, and R. M. Pendyala. The Stability of Transport-Related Attitudes Over Time: A Case Study During COVID-19. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
12. Salon, D., M. Bhagat-Conway, L. Mirtich, A. Costello, E. Rahimi, A. Mohammadian, R. Chauhan, S. Derrible, D. Baker, S. Khoeini, and R. M. Pendyala. The Stability of Transport-Related Attitudes Over Time: A Case Study During COVID-19. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
13. Mohammadi, M., E. Rahimi, A. Davatgari, M. Javadinasr, A. Mohammadian, M. Bhagat-Conway, D. Salon, R. Chauhan, S. Derrible, D. Baker, and R. M. Pendyala. The Stability of Transport-Related Attitudes Over Time: A Case Study During COVID-19. Presented at the 101st Annual Meeting of the Transportation Research Board, Washington, DC, January 9-13, 2022.
14. Batur, I., D.C. da Silva, S. Khoeini, and R. M. Pendyala. How Will Use of Autonomous Vehicles for Running Errands Affect Future Autonomous Vehicle Adoption and Ownership?. Presented at the 18th IRF World Meeting & Exhibition, Dubai, Nov 7-10, 2021.

Georgia Tech

Papers Published Within Reporting Period

1. "Combining Disparate Surveys across Time to Study Satisfaction with Life: The Effects of Study Context, Sampling Method, and Transport Attributes", by Xinyi Wang, F. Atiyya Shaw, Patricia L. Mokhtarian, Giovanni Circella, and Kari Watkins. Forthcoming, Transportation.
2. "Students' Preferences for Returning to Colleges and Universities During the COVID-19 Pan-demic: A Discrete Choice Experiment", by Lauren Steimle, Yuming Sun, Lauren Johnson, Tibor Besedeš, Patricia Mokhtarian, and Dima Nazzal. Forthcoming, Socio-Economic Planning Sciences.
3. "Longitudinal Analysis of COVID-19 Impacts on Mobility: An Early Snapshot of the Emerging Changes in Travel Behavior", by Grant Matson, Sean McElroy, Yongsung Lee and Giovanni Circella. Forthcoming, Transportation Research Record, Journal of the Transportation Research Board.
4. "Changes in Online Shopping Frequency During COVID-19: Who is Responsible and Are These Changes Temporary or Long-lasting?", by Mischa Young, Jaime Soza-Parra and Giovanni Circella. Forthcoming, Regional Science Policy & Practice.
5. "Substitution or Complementarity? A Latent-Class Cluster Analysis of Ridehailing Impacts on the Use of Other Travel Modes in Three Southern U.S. Cities", by Yongsung Lee, Grace Yun-Hsuan Chen, Giovanni Circella, and Patricia L. Mokhtarian. Transportation Research D 104, 2022, 103167.
6. "What Travel Modes Do Shared E-Scooters Displace? A Review of Recent Research", by Kailai Wang, Xiaodong Quian, Dillon T. Fitch, Yongsung Lee, Jai Malik and Giovanni Circella. Transport Reviews, 2022, 1-27.

Forthcoming Book Chapters Accepted for Publication in Reporting Period

1. "Changes in Active Travel During the COVID-19 Pandemic", by Sean McElroy, Dillon T. Fitch, and Giovanni Circella. Forthcoming, book chapter in "Pandemic in the Metropolis: Transportation Impacts and Recovery. Tracts on Transportation and Traffic", Springer.
2. "Adoption of Telecommuting and Changes in Travel Behavior in Southern California during the COVID-19 Pandemic. Changes in Active Travel During the COVID-19 Pandemic", by Jai Malik, Bailey Affolter, and Giovanni Circella. Forthcoming, book chapter in "Pandemic in the Metropolis: Transportation Impacts and Recovery. Tracts on Transportation and Traffic", Springer.

Presentations Within Reporting Period

1. Xinyi Wang: Teleworking Behavior Pre-, During, and Expected Post-COVID: Identification and Empirical Description of Trajectory Types. STEPS+ seminar, University of California, Davis, Jan. 26, 2022.
2. Xinyi Wang: Teleworking Behavior Pre-, During, and Expected Post-COVID: Identification and Empirical Description of Trajectory Types. SERMOS lab seminar, University of Florida, Jan. 20, 2022.
3. Xinyi Wang, Sung Hoo Kim, & Patricia Mokhtarian: Panel presentation: Integrating Aggregate and Disaggregate Approaches to Assess the Post-COVID-19 Impacts of Teleworking on Vehicle Travel: Methodology and Key Results. Session #1433 of the 101st Annual Meeting of the Transportation Research Board, Jan. 13, 2022.
4. Xinyi Wang: Teleworking Behavior Pre-, During, and Expected Post-COVID: Identification and Empirical Description of Trajectory Types. Session #1396 of the 101st Annual Meeting of the Transportation Research Board, Jan. 12, 2022.
5. Patricia Mokhtarian: Why do we travel? Understanding human movement and its importance for policy making. 2021 Annual Lecture of the Independent Transport Commission, "the UK's leading independent research charity", November 18, 2021. Introduction by Permanent Secretary to the Department for Transport, Bernadette Kelly CB, and response by The Rt

Hon Lord Adonis PC, Member of Parliament, former UK Secretary of State for Transport, and first chair of Britain's National Infrastructure Commission.

6. Patricia Mokhtarian: Keynote speaker: It's not the destination but the journey: Highlights of a journey through the land of travel behavior. 20th Chilean Conference of Transport Engineering, October 27, 2021.
7. Patricia Mokhtarian & Xinyi Wang: Response Willingness in Consecutive Travel Surveys: An Investigation Based on the National Household Travel Survey Using a Sample Selection Model. ITE Student Chapter Joint Seminar (UMD, TAMU, UTK), Oct. 13, 2021.
8. Giovanni Circella: Impact of the COVID-19 Pandemic on Mobility: Key Findings, Policy Implications and Topics for Further Research. ECTRI Assembly of Members, November 22, 2021.
9. Giovanni Circella: A Longitudinal Analysis of the Heterogeneous Changes in Travel Behaviors in Response to the COVID-19 Pandemic in the United States. 2022 Transportation Research Board Conference, January 2022.
10. Giovanni Circella: Teleworking and Commute Patterns During the COVID-19 Pandemic in Canada, Chile, Germany, and the United States. 2022 Transportation Research Board Conference, January 2022.
11. Giovanni Circella: The Growth in online shopping frequency during COVID-19: who is responsible and is this increase temporary or long-lasting? 2022 Transportation Research Board Conference, January 2022.
12. Giovanni Circella: Pandemic Impacts on Passengers' Mobility. 2022 Transportation Research Board Conference, January 2022.

University of South Florida

Papers Published Within Reporting Period

1. Vo, T., Barbour, N., Palaio, L.B., and Maness, M. (forthcoming). Impacts of the COVID-19 Pandemic on Bikeshare Usage by Rider Membership Status across Selected U.S. Cities. Transportation Research Record: Journal of the Transportation Research Board.
2. Li, Q., Li, X., Mannering, F., 2021. An assessment of discretionary lane changing decisions using a random parameters approach with heterogeneity in means and variances. Transportation Research Record 2675(6), 330-338
3. Hou, Q., Huo, X., Leng, J., Mannering, F., 2022. A note on out-of-sample prediction, marginal effects computations, and temporal testing with random parameters crash-injury severity models. Analytic Methods in Accident Research 33, 100191.
4. Alogaili, A., Mannering, F., 2022. Differences between day and night pedestrian-injury severities: Accounting for temporal and unobserved effects in prediction. Analytic Methods in Accident Research 33, 100201.
5. Alnawmasi, N., Mannering, F., 2022. The impact of higher speed limits on the frequency and severity of freeway crashes: Accounting for temporal shifts and unobserved heterogeneity. Analytic Methods in Accident Research 34, 100205.
6. Ahemd, S., Alnawmasi, N., Anastasopoulos, P., Mannering, F., 2022. The effect of higher speed limits on crash-injury severity rates: A correlated random parameters bivariate tobit approach. Analytic Methods in Accident Research 34, 100213.
7. Alnawmasi, N., Mannering, F., 2022. A temporal assessment of distracted driving injury severities using random parameters and latent class models. Analytic Methods in Accident Research 34, 100216.

Presentations Within Reporting Period

1. L.B. Palaio, T. Vo*, M. Maness, R. Bertini, and N. Menon (2022). Impacts of the COVID-19 Pandemic on Bikeshare Usage by Rider Membership Status across Selected U.S. Cities. Presentation at the 2022 Annual Meeting of the Transportation Research Board, Washington, DC.
2. M. Maness*, D. Mishra, and Z. Lin (2021). A National Estimate of the Value of a Free EV Charging Event in the U.S., Presentation at the 2019 Behavior, Energy, and Climate Change Conference, Sacramento, CA.

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Papers Published Within Reporting Period

1. Guan, X.; Chen, C.; Ren, I.; Yeung, K.; Hung, L. and Lloyd, Wes (2022) Mobility Analysis Workflow (MAW): An Accessible, Interoperable, and Reproducible Container System for Processing Raw Mobile data. <http://arxiv.org/abs/2204.09125>

Presentations Within Reporting Period

1. Guan, X. and Chen, C. (2022) Bayesian estimation of origin-destination trips using multiple biased datasets in the presence of heterogeneity and model uncertainty. 100th annual meeting of the Transportation Research Board, Washington DC.
2. Guan, X. and Chen, C. (2022) Building and testing accessible, interoperable, reproducible and reusable mobility analysis workflows with big data from mobile devices. 100th annual meeting of the Transportation Research Board, Washington DC.
3. Lin, J.; Chen, C.; and Angah, O. (2022) Socioeconomic and spatial disparity of bus ridership impacts in King County, Washington during COVID-19. 101st annual meeting of the Transportation Research Board, Washington DC.
4. Seattle, WA. A general methodology to infer failure propagations across interdependent networks. Industrial and Systems Engineering, University of Washington. March 1st, 2022.

In summary, TOMNET core faculty generated 18 journal publications and 2 book chapters within the reporting period covered by this SAPR. These publications are directly attributable to funding provided by the TOMNET UTC. During the reporting period of this SAPR, the TOMNET researchers delivered 32 presentations at various venues.

Website(s) or other Internet site(s)

One major product of the center is the [TOMNET website](#) that has been updated during the reporting period. A separate webpage has been dedicated to the [TOMNET T4 Survey](#) to organize all of the project documentation and outputs in one place. All of the presentations and final project reports are available on this webpage. Additionally, the link to the TOMNET COVID-19 survey and the released data (Wave 1) is embedded on the first page of the TOMNET website, enabling visitors to download the first wave of the COVID Future National Survey data (No. 24 in Table 1). The research page of the TOMNET website has also been updated to reflect project scopes and reports, with additional updates scheduled to be made in the next reporting period. In addition, a [TOMNET Briefs](#) page has been designated to publicize policy briefs produced by TOMNET members.

Software Programs, Codes, and Products

As noted in prior progress reports, the TOMNET team at ASU has been heavily involved in the development and application of open-source tools that reflect model outputs of the TOMNET projects. So far, the beta version of the synthetic population generator called [PopGen](#), the alpha version of the integrated Household Energy Analysis Tool (iHEAT), and the final models of the Wellbeing Estimator for Activities and Travel ([WBEAT](#)) have been created and will be released soon. These tools have been explained in previous reports in detail. Updated versions of these tools are being developed in open-source format and will be posted on the TOMNET website. Moreover, R and Python codes associated with other TOMNET transportation model estimation and implementation efforts as well as data fusion procedures are being documented in various publications. The software codes enable the estimation of advanced econometric choice models (such as integrated choice latent variable or ICLV models) that are most suited to jointly modeling attitudes and behaviors in a simultaneous equations framework. The University of Washington has developed Mobility Analysis Workflows Tutorials, available at <https://github.com/UW-THINKlab/Mobility-Analysis-Workflows-tutorial>.

Databases and Research Materials

In a number of TOMNET projects, integrated datasets have been developed (or are under development) using data fusion techniques with a view to studying the impact of attitudes on different transportation-related choices such as residential location choice, mode choice, vehicle ownership, and adoption of emerging mobility services and automated vehicle technologies. Some of the data sets are based on native survey data collection efforts undertaken by the TOMNET team. Other data sets have been assembled by integrating and fusing data that is already available in the public domain. All data sets assembled by TOMNET will be made available (without personally identifiable information) via the TOMNET website for the broader community. In the meantime, findings from the surveys will be disseminated to the community through a series of webinars and research papers. So far, the COVID Future wave 1 dataset has been made available to the public via this [link](#) on the ASU data repository called Dataverse.

It should be noted that the majority of TOMNET core team publications include applicable model specifications that can be used by practitioners easily to better model the recent transformations in traveler behavior and values due to new transport technologies as well as the pandemic. These model specifications showcase robust and statistically viable solutions to integrate attitudes in travel behavior analysis. A key TOMNET research project “An Investigation of the Contribution of Targeted Marketing Data to the Prediction of Attitudes” has increased awareness of the importance of attitudes to individuals’

transportation decisions. The insights gained in this project (#32 by the GT team) are improving the ability of regional travel demand forecasting models to incorporate attitudes, thereby improving their predictions of behavioral trends and responses to policy. Due to the significance of this research and the broad spectrum of Targeted Marketing Data available to provide useful variables related to personal attitudes and lifestyle choices, this study is counted as a research product/material as it highlights the opportunities and challenges of using Targeted Marketing Data in travel demand forecasting in practice.

Table 5. TOMNET Metrics on Products

| Metric | Annual Target | Previous Reporting Period | This Reporting Period | Annual Total | Assessment |
|--|---------------|---------------------------|-----------------------|--------------|---|
| Number of software products, data sets, or model specifications released | 2 | 1 | 1 | 2 | Datasets are being cleaned, weighted, and documented. The codes are in beta versions. |
| Number of publications in refereed journals | 15 | 17 | 18 | 33 | Greatly exceeded the annual target. |

4. OUTCOMES

The TOMNET Transformative Technologies in Transportation (T4) Survey is creating the much-needed knowledge base to understand the potential evolution of travel choices of residents in several major cities in the sunbelt (where transit is generally not very mature) in the wake of changes brought about by the advent of new mobility services, e.g., shared mobility and ridehailing, as well as automated vehicles and micromobility. Data and insights from the T4 survey, and subsequent publications documenting survey results, help provide critical information that agencies need to minimize the potential negative impacts and maximize the potential positive impacts of new transportation technologies. Four studies out of the T4 survey were presented at various venues during the past six months. Presenting the results of the T4 survey in different venues counts as a significant outcome of TOMNET research. As a result of this series of presentations, European [WISE-ACT](#) researchers approached Sara Khoeini (T4 Survey Project Lead) for further collaboration to study the behavioral implications of AV adoption in the future.

The community resilience survey that the TOMNET team at the University of Washington has implemented is also very beneficial in understanding the mental and physical elements that impact community disaster preparedness and resilience, and the survey is particularly relevant to the current pandemic situation. The findings from this research can inform strategies for enhancing community adaptive capacity using social and transportation networks to accomplish essential activities, both on an everyday basis and during times of disruptions wrought by disasters.

Finally, TOMNET researchers are studying the potential impacts of COVID-19 on people's travel behavior, time use, and activities before, during, and after the pandemic to help decision-makers plan and adapt transportation systems to the pandemic and new normal. The COVID-19 wave 1 dataset has been released to the public and it is envisioned that the data will help in planning a strong recovery as well as retaining positive behaviors (e.g., more walking and bicycling) that occurred during the pandemic. The data paper which accompanies the released data has been published in [Nature Scientific Data](#). It is worth highlighting that the summary of the collected data during Wave 1 has been published in [PNAS Policy Report](#), by a team led by TOMNET Associate Director Deborah Salon.

Improved techniques in addressing transportation issues

Previous SAPRs discussed the significance of TOMNET research to understand the role of attitudes in the adoption of new transport technologies, response to disasters and pandemics, and safety research. Other ongoing TOMNET research efforts shed light on best practices for travel survey data collection and analysis. The project titled “The Effect of Survey Methodology on the Collection of Attitudinal Data”

suggests that the weighting of survey data based on socioeconomic attributes cannot completely remove the potential bias of the respondent sample when it comes to analyzing attitudes and lifestyle preferences. This project illustrates the importance of studying attitudes through multivariate econometric and statistical model estimation. Similarly, the project titled “Response Willingness in Consecutive Travel Surveys” is highlighting the advantages and disadvantages of recruiting survey respondents from among those responding to previous surveys. TOMNET research shows that it can be very cost-effective to do so, which is welcome news for budget-limited planning agencies and researchers. However, new respondents should also be recruited, with an eye to counteracting the demographic biases that tend to be amplified at successive stages of the repeated recruitment. The results of this study can be used to estimate specifically the magnitude of the biases, and accordingly determine how best to counteract them. Considering the TOMNET study to evaluate the usefulness of targeted marketing data in attitudinal travel behavior research as well, these research outcomes have collectively enhanced knowledge regarding data collection and utilization, and advance the profession’s ability to make maximum use of available data in accurately modeling behavioral processes.

Enlargement of the pool of trained transportation professionals

TOMNET has been very successful and productive in engaging undergraduate and graduate students, besides post-doctoral researchers. TOMNET trainees include minorities and women, and the number of students engaged in TOMNET activities has grown considerably. These students are unlikely to have been involved in transportation research and education in the absence of TOMNET. The updated [TOMNET website](#) now includes the name, affiliation, degree, and profile pictures of all 66 students and scholars that have been deeply engaged in TOMNET research during their education. During this reporting period, MS degrees were awarded to Xinyi Wang & Regan Buchanan (Georgia Tech); PhDs were awarded to Denise Capasso da Silva, Taehooie Kim, and Shivam Sharda (ASU), and Rafegh Aghamohammadi of Georgia Tech. Denise Capasso da Silva and Taehooie Kim are working for prominent transportation consulting firms, Shivam Sharda is a postdoctoral scholar at Lawrence Berkeley National Laboratory. Drs. Sung Hoo Kim and Atiyya Shaw (former TOMNET PhD graduates) will start as an Assistant Professor at Hanyang University in Korea and the University of Michigan, respectively. Dr. Sara Khoeini, TOMNET’s Assistant Director since 2017, has accepted a job offer from a prestigious transportation consulting firm. Moreover, two Georgia Tech TOMNET students, Dr. Atiyya Shaw and Ms. Xinyi Wang, won the Council of University Transportation Centers’ 2022 Charley V. Wootan awards for best PhD dissertation and best MS thesis in transportation planning and policy! TOMNET has been tracking progress in achieving outcomes relative to targets established in the Technology Transfer Plan. A summary of progress is shown in Table 6.

Table 6. TOMNET Metrics on Outcomes

| Metric | Annual Target | Previous Reporting Period | This Reporting Period | Annual Total | Assessment/notes |
|---|---------------|---------------------------|-----------------------|--------------|--|
| Number of unique individuals that downloaded/used TOMNET data/codes | 100 | 150 | 150 | 300 | The main published data source in this reporting period is COVIDFuture Survey (wave 1) and T4 Survey Results |
| Number of students/scholars participating in TOMNET research | 50 | 42 | Additional 3 | 45 | Some students are the same across the periods; so, the total number reflects the unique cases. |

Dr. Sung Hoo Kim went through the commencement ceremony on Dec. 17, 2021; the photo shows Dr. Mokhtarian hooding him. Right photo, L to R: Drs. Patricia Mokhtarian, Sung Hoo Kim, Giovanni Circella, and PhD student Ms. Xinyi Wang



5. IMPACTS

What is the impact on the effectiveness of the transportation system?

Charting a sustainable pathway for smart cities of the future requires detailed data about people's movements, transportation preferences, and attitudes and perceptions towards new mobility options and technologies. The data and tools being developed under the auspices of TOMNET are making it possible for agencies to more accurately forecast the potential impacts of transformative transportation technologies, resulting in a more effective and **equitable** transportation system that is characterized by data-driven informed decision-making about transportation investments and improvements that will advance mobility for all. The overall impacts of multiple surveys funded by TOMNET, in understanding the interactions between travelers and new disruptive technologies including mobility-on-demand services, automation, electrification, health and wellbeing, pricing and taxation, safety, COVID-19 pandemic, leisure activities, and community resilience is very significant and difficult to be quantified. So far, wave 1 of COVID Future dataset which is partially funded by TOMNET has been released to the public and more than 300 unique individuals have downloaded the data. The other TOMNET surveys will also be released to the public after initial assessment and data analysis have been completed. It is envisioned that the findings, analytical models, and raw datasets can significantly reveal people's behaviors, perceptions, and choices and therefore substantially enlighten the future of transport system planning and policymaking. Table 7 illustrates the number of agencies that have used TOMNET products annually as a quantitative metric to measure TOMNET impact. However, it is difficult to determine the exact number because some agencies use published findings and data sources without notifying TOMNET team. However, this table presents the number of agencies that have adopted TOMNET data sources and/or modeling tools, to the best of the team's knowledge and awareness.

At the University of Washington, analysis of the data gathered from our surveys and community outreach activities will help to inform both transportation and emergency planners about what actions people anticipate they will take in the event of a large earthquake (and, for the coastal areas, accompanying tsunami). Where will they seek health care and medications? What resources are located within communities that could serve alternative purposes in a time of need? And how are they willing to share resources within a community? How can different kinds of transportation and communications sources be enhanced or better leveraged through social relationships and local knowledge? In addition to the earthquake and tsunami scenarios upon which we focused in earlier phases of the study, we now add understanding transportation behavior changes during a pandemic.

What is the impact on the adoption of new practices, or instances where research outcomes have led to the initiation of a start-up company?

ASU/GT/USF: Results from the T4 Survey are helping to craft realistic future scenarios that can drive travel forecasts. Several agencies have expressed interest in adopting and implementing the integrated household energy analysis tool (iHEAT) and well-being estimation and analysis tool (WBEAT). TOMNET research has also led to improved specification of transportation forecasting models in agencies by demonstrating the presence of market segments that follow different causal structures in decision-making and have different proclivities towards multitasking. A number of agencies have adopted the latest version of the synthetic population generator called PopGen, which is currently supported and enhanced continuously through the support of TOMNET funding. The Travel Forecasting Resource (tfresource.org) was enabled through funding provided by TOMNET; this resource is used by practitioners, students, scholars, and researchers worldwide (including thousands of individuals in the United States) to learn about best practices in transportation demand forecasting, planning, and network modeling. TOMNET research is helping to craft new and improved transportation safety campaigns, with explicit recognition that different messaging is required for different market segments (due to heterogeneity in safety behaviors). TOMNET has also provided guidance to ADOT for weighting the Arizona sample of the National Household Travel Survey (NHTS) using PopGen. Lastly, COVIDFuture survey data and findings are very informative in shaping the vision for a new normal, and how the profession can maximize the positive aspects and minimize the negative impacts of the pandemic.

This project is building upon earlier work to test and promote an appreciative inquiry approach to disaster mitigation planning that highlights community strengths over vulnerabilities. Such an approach to hazard planning has the potential to help communities develop mitigation strategies that will benefit them on an everyday basis as well as in the case of a disaster. The analysis of the work during this reporting period also highlights the importance of trust in supporting community during a disaster. Trust turns out to be more important than other factors tested including socio-demographics, level of preparedness, and place attachment.

What is the impact on the body of scientific knowledge?

Table 7 illustrates the number of citations for research papers that were produced during 2018, 2019, 2020, and 2021 thus far by the core TOMNET team. During these four complete years, the TOMNET core research was sponsored by TOMNET and so the citations are credited to TOMNET that provided the financial resources for these studies and products. The two distinguished TOMNET faculty that have a huge contribution to these highly cited works are Fred Mannering and Patricia Mokhtarian. During the reporting period, **Professor Fred Mannering** received the **2021 HNTB-CUTC lifetime achievement award in transportation research and education**. This award has been presented since 2015 to honor individuals who have had a long history of significant and outstanding contributions to university transportation education and research resulting in a lasting contribution to transportation. **Professor Patricia Mokhtarian** has been named the **2021 recipient of the Lifetime Achievement Award from the International Association for Travel Behaviour Research** for her significant contributions to the field. Mokhtarian is the first woman to receive this prestigious honor, which has only been awarded to nine others since its creation in 2003.

At Georgia Tech, using data collected for a different project, Xinyi Wang (with TOMNET funding for her dissertation research), Sung Hoo Kim, and Patricia Mokhtarian have analyzed the pre-pandemic, during-pandemic, and (expected) post-pandemic teleworking frequency profiles of more than 2,000 workers, and classified them into 8 segments. We then used these segments to intelligently temper respondents' often over-optimistic expectations of post-pandemic teleworking. Our analysis suggests that the average post-COVID teleworking frequency will only be about twice its pre-COVID counterpart, rather than the tripling that is predicted on the basis of taking self-reported expectations at face value. In the upcoming reporting period, we will be comparing respondents' expected post-COVID teleworking engagement with their actual engagement in Spring 2022. If our analysis proves correct, it will offer a

more reliable prediction of post-COVID teleworking engagement, with widespread implications for a number of transportation indicators.

Work at the University of Washington is expected to contribute to several areas of research:

- *Resource sharing.* Resource sharing and matching has been studied under normal times. We showed that community-based peer-to-peer resource sharing has great potential to support community self-reliance during a disaster. Furthermore, we show that the resource sharing shall consider users’ preferences—there is great amount of heterogeneity in terms of the types of resources one wants to share and with whom.
- *Urban and hazard mitigation planning.* The development of appreciative inquiry-based approaches for hazard mitigation planning is an area of growth that holds much promise for informing future hazard planning approaches that can better take local needs, resources, knowledge, and strengths into account. Furthermore, the collection of ephemeral data during the COVID-19 epidemic will help to build an understanding of household- and community-level preparedness actions and attitudes regarding pandemic scenarios.

What is the impact on transportation workforce development?

To date, various TOMNET project activities have engaged undergraduate, graduate, and PhD students in research about transportation in various domains including emerging transportation technologies, impacts of the pandemic, resilience issues in rural and remote areas, survey data collection, advanced statistical modeling, and data fusion. In most of these studies, researchers studied the role of attitudes in shaping travel behavior and choices. In the outreach activities to date, TOMNET provided opportunities for professionals and academics to learn about findings of the research undertaken by the center through various webinars, conference presentations, reports, and publications.

Table 7. TOMNET Metrics on Impacts

| Metric | 2018 | 2019 | 2020 | 2021 | 2022 | Total |
|---|-------|-------|-------|-------|-----------|--------|
| Number of new agencies adopting TOMNET data/tools | 2 | 1 | 1 | 1 | 0 | 5 |
| Citations of TOMNET Publications | 3,381 | 3,825 | 4,565 | 5,108 | 2,103 (+) | 18,982 |

At the University of Washington, the project activities have engaged undergraduate, graduate and PhD students in community-engaged research about transportation issues in rural and remote areas, particularly as related to emergency planning and hazard mitigation. In previous phases of the project, students were trained to use WeTable participatory GIS equipment to engage collaboratively with experts in urban planning, transportation planning, and hazard mitigation planning on potential planning interventions for remote coastal communities. In the community workshop activities to date, we provided opportunities for the public to learn about disaster planning best practices and to share local knowledge with planners and hazard mitigation specialists. We have also engaged multiple NSF REU students in this project who have learned technical skills relevant to data collection and analysis.

6. CHANGES/PROBLEMS

There are no changes to or problems with the scope, mission, budget, or operations of TOMNET.

7. SPECIAL REPORTING REQUIREMENTS

The institution has submitted all required financial and progress reports to date.