TOMNET Transportation Center
Teaching Old Models New Tricks

UTC Semi-Annual Progress Report (SAPR#11)

Arizona State University

Georgia Tech

UNIVERSITY of WASHINGTON

UNIVERSITY of SOUTH FLORIDA

Submitted to:	Office of the Assistant Secretary for Research and Technology US Department of Transportation
Prime Federal Grant No:	69A3551747116
Center Title:	Center for Teaching Old Models New Tricks (TOMNET)
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Submission Date:	October 31, 2022
DUNS Number:	943360412
Employer Identification Number:	86-01-96696
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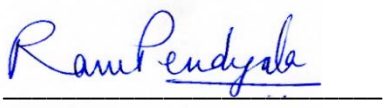
Recipient Organization:	Arizona State University Office of Research and Sponsored Projects Administration PO Box 876011, Tempe, AZ 85287-6011
Grant Period:	December 1, 2016 – September 30, 2023
Reporting Period:	April 1, 2022 – September 30, 2022
Report Frequency:	Semi-Annual
Submitting Official:	 Ram M. Pendyala, PhD, Director

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 11th 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 April 1, 2022 through September 30, 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 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 datasets (e.g., 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 outreach activities that would attract students from diverse backgrounds to the professon. 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 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 not only 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 (41 projects) or are continuing into their subsequent phases (12 projects). Additionally, seven new projects have been launched during the reporting period. The list of all active and completed TOMNET projects is provided in Table 1 with the active period for each project (total of 60 projects). The status column indicates whether a project is accomplished or is still in progress. The new projects are in the process of getting entered into the RiP database. Moreover, the completed projects' reports are being finalized and entered into the TRID database. The TOMNET website project page is regularly updated to provide information and deliverables

for the research projects, categorized by year and lead university. Several reports for projects completed recently are under review and will be posted to TRID and the TOMNET website within the next reporting period. Further details about the progress made for a sample of active projects are provided below.

Table 1. TOMNET Research Projects

Project Topic/Title		Institution (PI)	Active Period	Status
1*	Does Ridehailing Use Affect Vehicle Ownership or Vice Versa? An Exploratory Investigation of the Relationship Using a Latent Market Segmentation Approach	ASU (Batur)	2022 - Present	⚙
2*	An Analysis of Changes in Time Use and Activity Participation in Response to the COVID-2019 Pandemic in the United States: Implications for Well-being	ASU (Polzin)	2022 - Present	⚙
3*	Access to Food in a Severe Prolonged Disruption: The Case of Grocery and Meal Shopping During the COVID-19 Pandemic	ASU (Pendyala)	2022 - Present	⚙
4*	A Multidimensional Analysis of Willingness to Share Rides in a Future of Autonomous Vehicles	ASU (Batur)	2022 - Present	⚙
5*	Evolution of Mode Use Due to COVID-19 Pandemic in the United States: Implications for the Future of Transit	ASU (Pendyala)	2022 - Present	⚙
6*	Accounting for the Influence of Attitudes in Modeling the Adoption and Usage of On-Demand Transportation and Electric Vehicles	ASU (Pendyala)	2021 - 2022	✓
7*	Assessing the Impact of Ridehailing Service Use on Bus Ridership: A Joint Modeling Framework Accounting for Endogeneity and Latent Attitudes	ASU (Pendyala)	2021 - 2022	✓
8*	The Influence of Mode Use on Level of Satisfaction with Daily Travel Routine: A Focus on Automobile Driving in the United States	ASU (Pendyala)	2021 - 2022	✓
9	The Stability of Transport-Related Attitudes over Time: A Case Study During COVID-19	ASU (Salon)	2021 - 2022	✓
10*	Investigating Attitudinal and Behavioral Changes in U.S. Households Before, During, and After the COVID-19 pandemic	ASU (Salon)	2020 - Present	⚙
11	Latent Variable Models of Attitudes and Preferences, and Their Prediction of Autonomous Vehicle Adoption Intent	ASU (Grimm)	2020 - Present	⚙
12	Integrated Household Energy Analysis Tool (iHEAT)	ASU (Pendyala)	2020 - Present	⚙
13*	Expected Change in US Air Travel after the COVID-19 Pandemic	ASU (Khoeini)	2020 - 2022	✓
14*	How Will Use of Autonomous Vehicles for Running Errands Affect Future Autonomous Vehicle Adoption and Ownership?	ASU (Batur)	2020 - 2022	✓
15	Interaction of Familiarity, Safety Perceptions, and Willingness to Use Autonomous Vehicles in A Structural Equation Modeling Framework	ASU (Khoeini)	2020 - 2022	✓
16	Investigating the Contributing Factors to Willingness to Share Automated Vehicles with Gender Focus	ASU (Khoeini)	2020 - 2022	✓
17	The Effect of Survey Methodology on The Collection of Attitudinal Data	ASU (Pendyala)	2020 - 2022	✓
18	Real-Time Transportation Social Media Analytics Using Pulse (Pulse-T)	ASU (Kandala)	2019 - 2021	✓
19	Consumer Attitudes and Behavioral Implications in the New Era of Shared Mobility	ASU (Zhang)	2019 - 2021	✓
20	Emerging Approaches to Autonomous Vehicles in Transportation Policy and Planning	ASU (Miller)	2019 - 2021	✓
21	Teaching the Travel Demand Flow Estimation Models: A New Deep-Learning Approach Using Multi-Source Data	ASU (Zhou)	2019 - 2021	✓
22	Causal Relationships Between Transportation Attitudes and Behaviors: Uncovering Latent Segments within a Heterogeneous Population	ASU (Pendyala)	2019 - 2021	✓
23	The Impact of Non-Transportation Attitudes, Preferences, and Personality Characteristics on Residential Location and Travel Choices	ASU (Salon)	2019 - Present	⚙
24*	Attitudes Towards Emerging Mobility Options and Technologies – Phase 3: Survey Data Compilation and Analysis for Phoenix, AZ	ASU (Khoeini)	2019 - Present	⚙
25	How Important are Attitudes in Travel Behavior Models? A Comprehensive Review	ASU (Salon)	2018 - 2019	✓

Project Topic/Title		Institution (PI)	Active Period	Status
26	Heterogeneity in the Relationship Between the Built Environment and Bicycling	ASU (Salon)	2018 - 2019	✓
27	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)	2018 - 2019	✓
28	A Comparison of Vehicle Miles of Travel Between Two Generations: Millennials versus Generation X	ASU (Pendyala)	2018 - 2019	✓
29	Attitudes Towards Emerging Mobility Options and Technologies – Phase 2: Data Collection in Phoenix, AZ	ASU (Khoeini)	2018 - 2019	✓
30	Assembling Integrated Data Sets for Analyzing Connections between Travel Behavior, Attitudes, and the Built Environment	ASU (Salon)	2017 - 2018	✓
31*	An Integrated Model of Daily Activity-Travel Behavior and Well-Being	ASU (Pendyala)	2017 - Present	⚙
32	Comprehensive Literature Synthesis on the Role of Attitudes in Shaping Mobility/Location Choices	ASU (Salon)	2017 - Present	⚙
33	Attitudes Towards Emerging Mobility Options and Technologies – Phase 1: Survey Design for Phoenix, AZ	ASU (Khoeini)	2017 - 2018	✓
34	Drivers' Attitudes toward Rerouting: Impacts on Network Congestion	GT (Laval)	2021 - Present	⚙
35*	What is the New Normal? An Analysis of Post-COVID-19 Commute and Work Patterns	GT (Circella)	2021 - Present	⚙
36	Mode Substitutional Patterns of Ridehailing and Micro-Mobility Services	GT (Circella)	2020 - Present	⚙
37*	Response Willingness in Consecutive Travel Surveys	GT (Mokhtarian)	2020 - 2021	✓
38	Combining Disparate Surveys across Time to Study Satisfaction with Life	GT (Mokhtarian)	2019 - 2020	✓
39*	Attitudes Towards Emerging Mobility Options and Technologies – Phase 3: Survey Data Compilation and Analysis for Atlanta, GA	GT (Circella)	2019 - Present	⚙
40	Latent Vehicle Type Propensity Segments: Considering the Influence of Household Vehicle Fleet Structure	GT (Mokhtarian)	2018 - 2019	✓
41	Attitudes Towards Emerging Mobility Options and Technologies – Phase 2: Data Collection in Atlanta, GA	GT (Circella)	2018 - 2019	✓
42	An Investigation of the Contribution of Targeted Marketing Data to the Prediction of Attitudes	GT (Mokhtarian)	2017 - 2019	✓
43	Attitudes Towards Emerging Mobility Options and Technologies – Phase 1: Survey Design for Atlanta, GA	GT (Circella)	2017 - 2018	✓
44	An Empirical Assessment of the Role of Attitudes and Identification in Safety Research	USF (Mannering)	2020 - 2021	✓
45*	Addressing Potentially Missing Relevant Information on Attitudes and Other Behavioral Elements as Unobserved Heterogeneity in Highway Safety Studies	USF (Mannering)	2020 - 2022	✓
46*	Exploration of the Relationships between Leisure Activity Participation Frequency and Social Capital	USF (Maness)	2020 - 2022	✓
47	An Exploratory Analysis to Estimate the Value of Free Charging Bundle in Electric Vehicle Purchases	USF (Maness)	2020 - 2021	✓
48	An Exploration of Contemporary Issues in Highway Safety, Evolving Transportation Alternatives, and Activity and Travel Behavior Modeling	USF (Maness)	2019 - 2020	✓
49*	Attitudes Towards Emerging Mobility Options and Technologies – Phase 3: Survey Data Compilation and Analysis for Tampa, FL	USF (Maness)	2019 - Present	⚙
50	Emerging Econometric and Data Collection Methods for Capturing Attitudinal and Social Factors in Activity and Travel Behavior Modeling	USF (Mannering)	2018 - 2019	✓
51	Attitudes Towards Emerging Mobility Options and Technologies – Phase 2: Data Collection in Tampa, FL	USF (Maness)	2018 - 2019	✓
52	Investigation of the Role of Attitudinal Factors on Adoption of Emerging Automated Vehicle and Vehicle Safety Technologies	USF (Mannering)	2017 - 2018	✓
53	Attitudes Towards Emerging Mobility Options and Technologies – Phase 1: Survey Design for Tampa, FL	USF (Maness)	2017 - 2018	✓

Project Topic/Title		Institution (PI)	Active Period	Status
54*	Grid-Aware Robust Fast-Charging Station Deployment for Electric Buses Under Socioeconomic Considerations	UW (Zhao)	2022 - Present	⚙
55	Are On-Demand Mobility Services Cost-Effective for First/Last Mile Travel? A Comparative Analysis	UW (Shen)	2022 - Present	⚙
56	Mobility Analysis Workflow (MAW): An Accessible, Interoperable, and Reproducible Container System for Processing Raw Mobile Data	UW (Chen)	2021 - 2022	✓
57	Attitudes and Trust in Leveraging Integrated Sociotechnical Systems for Enhancing Community Adaptive Capacity – Phase IV	UW (Chen)	2020 - 2021	✓
58	Attitudes and Trust in Leveraging Integrated Sociotechnical Systems for Enhancing Community Adaptive Capacity – Phase III	UW (Chen)	2019 - 2020	✓
59	Attitudes and Trust in Leveraging Integrated Sociotechnical Systems for Enhancing Community Adaptive Capacity – Phase II	UW (Chen)	2018 - 2019	✓
60	Attitudes and Trust in Leveraging Integrated Sociotechnical Systems for Enhancing Community Adaptive Capacity – Phase I	UW (Chen)	2017 - 2018	✓

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 address emerging issues, specifically, the impacts of COVID on travel behavior. This capability has enabled critical projects that add significant insight into emerging travel behaviors and support industry efforts to update planning and modeling methods and tools to respond to post-COVID conditions. Those activities, including numerous presentations and publications, are enumerated in this report.

A Sampling of Progress on Active Research Projects

Project #1: Does Ridehailing Use Affect Vehicle Ownership or Vice Versa? An Exploratory Investigation of the Relationship Using a Latent Market Segmentation Approach
PI: Irfan Batur (ASU) **Co-PI:** Ram Pendyala (ASU) – in collaboration with D-STOP, Univ of Texas at Austin

Progress: This research project examines the inter-relationship between household vehicle ownership and ridehailing use frequency. While it is generally known that these two behavioral phenomena are inversely related to one another, the direction of causality is rather ambiguous. To explore the degree to which these causal relationships are prevalent in the population, a joint latent segmentation model system is formulated and estimated on a survey data set collected in four automobile-oriented metro areas of the United States. The findings reveal whether there is considerable structural heterogeneity in the population with respect to causal structures and whether ridehailing use could effect changes in vehicle ownership in the future. This project has been launched during this reporting period. The team has conducted an extensive literature review, completed an exploratory analysis to investigate the relationship between ridehailing use and vehicle ownership, and estimated the joint latent segmentation model system. The project findings will be presented at the 2023 TRB Annual Meeting and a manuscript is being reviewed by the Transportation Research Record journal for publication. In the next reporting period, the team will finalize the journal publication and continue to disseminate research findings.

Project #2: An Analysis of Changes in Time Use and Activity Participation in Response to the COVID-2019 Pandemic in the United States: Implications for Well-being
PI: Steve E. Polzin (ASU) **Co-PI:** Irfan Batur (ASU)

Progress: This research project aims to investigate the well-being implications of changes in activity-travel and time use patterns brought about by the COVID-19 pandemic. The study uses American Time Use Survey (ATUS) data from 2019 and 2020 to assess changes in activity-travel and time use patterns. It applies two methods – a wellbeing scoring method and a time poverty analysis method – to evaluate the impacts of these changes on society. The findings reveal how individuals allocated their time across a

limited set of activities available during the pandemic, as well as whether individuals experienced diminished (or improved) well-being as a result of changes in their activity time use patterns during the pandemic. In this reporting period, the research team reviewed the relevant literature, assembled data sets for the study, conducted an exploratory analysis , and applied wellbeing and time poverty methods to identify the *winners* and *losers* during the pandemic. The preliminary results from this project were presented on two occasions: WCTRS 2022 Virtual Meeting (July 27, 2022) and TU Munich Activity-Based Modeling Symposium (Sep 12-14, 2022). The project results will also be presented at the Transportation Research Board Annual Meeting in 2023, and the corresponding manuscript is currently being reviewed for publication in the Transportation Research Record journal. The team will finalize the journal publication and continue to disseminate research findings over the next reporting period.

Project #3: Access to Food in a Severe Prolonged Disruption: The Case of Grocery and Meal Shopping During the COVID-19 Pandemic
PI: Ram Pendyala (ASU) **Co-PI:** Irfan Batur (ASU) – in collaboration with D-STOP, Univ of Texas at Austin

Progress: The COVID-19 pandemic has revealed a few fault lines in society. Whether it be remote work, remote learning, online shopping, grocery and meal deliveries, or medical care, there are disparities and inequities among socio-economic and demographic groups that leave some segments of society behind. This project aims to identify vulnerable and less adaptable groups in the context of access to food, using a comprehensive survey data set collected during the height of the pandemic in 2020. The project provides insights on the groups that may have experienced food access vulnerability when businesses and establishments were restricted, the risk of contagion was high, and accessing online platforms required technology-savviness and the ability to afford delivery charges. The project presents estimation results for a simultaneous equations model of six endogenous choice variables defined by a combination of two food types (groceries and meals) and three access modalities (in-person, online with in-person pickup, and online with delivery). During this reporting period, the research team reviewed the relevant literature, assembled the data set, conducted exploratory analyses, and estimated the joint simultaneous equation model to identify user characteristics for each food-purchasing arrangement. The project's findings will be presented at the 2023 Transportation Research Board Annual Meeting, and a manuscript is currently being reviewed by the journal Travel Behavior and Society for publication. The team will finalize the journal article and continue to disseminate research findings over the next reporting period.

Project #4: A Multidimensional Analysis of Willingness to Share Rides in a Future of AVs
PI: Irfan Batur (ASU) **Co-PI:** Ram Pendyala (ASU) – in collaboration with D-STOP, Univ of Texas at Austin

Progress: The traveling public has historically shown a disinclination towards sharing rides and carpooling with strangers. In a future of AV-based ridehailing services, it will be necessary for people to embrace both AVs and true ridesharing to fully realize the benefits of automated and shared mobility technologies. This project investigates the factors influencing the willingness to use AV-based ridehailing services in the future in a shared (with strangers) mode. This is done through the estimation of a comprehensive behavioral model system on a survey data set that includes rich information about attitudes, perceptions, and preferences regarding the adoption of automated vehicles and shared mobility modes. During this reporting period, the project team reviewed the relevant literature, assembled the data set, performed an exploratory analysis of the variables of interest, and estimated a joint model to identify the impact of current ridehailing usage on the intentions to use AV-based ridehailing services in the future. The team presented the preliminary project findings at the ITS World Congress 2022 (Sep 21-25, 2022) and the Prof. N. R. Kamath Memorial Webinar by the Indian Institute of Technology in Bombay (Sep 28, 2022). The results of the project will also be presented at the TRB Annual Meeting in 2023, and the project manuscript is currently being considered for publication in the Transportation Research Record journal. The team will finalize the journal article during the next reporting period and continue to share the project findings.

Project #5: Evolution of Mode Use Due to COVID-19 Pandemic in the United States: Implications for the Future of Transit
PI: Ram Pendyala (ASU) **Co-PI:** Irfan Batur (ASU) – in collaboration with D-STOP, Univ of Texas at Austin

Progress: The COVID-19 pandemic has brought about transformative changes in human activity-travel patterns, which were naturally accompanied by and associated with changes in transportation mode use and work arrangements. In the U.S., most transit agencies are still grappling with lower ridership levels, thus signifying the onset of a new normal for the future of transit. This project aims to address this challenge by leveraging a novel panel survey data set to estimate a panel multinomial probit model of mode choice to capture both socio-economic effects and period (pre-, during-, and post-COVID) effects. This work provides rich insights into the evolution of commute mode use as a result of the pandemic, with a focus on public transit. The project team reviewed the relevant literature, compiled the data set, conducted exploratory analyses, and completed model estimation during this reporting period. The project results will be presented at the Transportation Research Board Annual Meeting in 2023, and a manuscript is currently being considered for publication in the Transportation Research Record journal. The team will finalize the journal article during the next reporting period and continue to engage in technology transfer activities to disseminate the project findings.

Project #6: Accounting for the Influence of Attitudes in Modeling the Adoption and Usage of On-Demand Transportation and Electric Vehicles
PI: Ram Pendyala (ASU) – in collaboration with D-STOP, Univ of Texas at Austin

Progress: This project explored the factors that contribute to the adoption of on-demand transportation services and electric vehicle (EV) ownership in a developing country 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 developing world. 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 paper based on the study findings was revised based on the reviewers' comments and published in the Transportation Research Record journal.

Project #7: 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, Univ 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 TOMNET's 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 study results were presented at Environmental Health Matters Initiative in July 2021 and at the 2022 TRB annual meeting. Based on the feedback received during these meetings, the research team has been working to improve the manuscript and plans to submit it to Travel Behavior and Society journal for publication in the next reporting period.

Project #8: 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, Univ 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 TOMNET's 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. Although this project was fully completed in the summer of 2021, the technology transfer activities have been continuing. During this reporting period, the paper based on this study was published in the Transportation Research Record journal. The paper also won the prestigious Pyke Johnson Award, given by the Transportation Research Board in recognition of the best paper in the field of Planning and Environment.

Project #10: Investigating Attitudinal and Behavioral Changes in U.S. Households Before, During, and After the COVID-19 pandemic **| PI:** Deborah Salon (ASU), **Co-PI:** Ram Pendyala (ASU)

Progress: This project is concerned with the following questions: (1) to what extent will American society "go back" to our pre-COVID-19 way of life after the threat of contagion is gone? (2) which behavioral changes will be long-lasting, and for whom? (3) how, if at all, are the attitudes that underpinned our American lifestyle shifting in this crisis, and will these shifts be long-term? (4) what are the largest impacts of confinement in terms of attitudes and behavior? During this reporting period, the project team presented an invited talk based on project results at the UCLA Lake Arrowhead conference; revised and received acceptance for publication for three papers submitted in the previous periods; submitted one new manuscript for publication at a peer-reviewed journal; and submitted three manuscripts for the 2023 TRB Annual Meeting, two of which have been confirmed to be accepted for presentation. During the next reporting period, the team will continue to present findings and evaluate data from the COVID Future survey, revise current publications, and prepare a limited number of additional pieces for publication.

Project #14: How Will Use of Autonomous Vehicles for Running Errands Affect Future Autonomous Vehicle Adoption and Ownership?
PI: Irfan Batur (ASU) (in collaboration with D-STOP, Univ 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 TOMNET's T4 Survey, the relationship is explored through a joint model system. 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 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 periods. However, the technology transfer activity is still ongoing. In this reporting period, a manuscript based on this research was published in the Transportation Research Record journal and the team presented the findings of this project at the ITS World Congress 2022 (Sep 21-25, 2022).

Projects #24, #39, #49: 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 has been continuing (projects #1, #4, #7, #8, #11, #14, #15, #16, #17, and #36 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 2023 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 #31: An Integrated Model of Daily Activity-Travel Behavior and Subjective Well-Being
PI: Ram Pendyala (ASU) **Co-PI:** Sara Khoeini (ASU), Irfan Batur (ASU)

Progress: This project is an effort to develop models of well-being that explicitly account 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 individual wellbeing). The final product of this well-being model 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. During this reporting period, the project team finished developing an open-source software tool (WBEAT) for public use, the beta version of which is available at this link.

Project #35: What is the New Normal? An Analysis of Post-COVID-19 Commute and Work Patterns
PI: Patricia Mokhtarian (GT) **Co-PI:** Giovanni Circella

Progress: The study addresses the following questions: (1a) What are the adoption rates and frequencies of working from home in Spring 2022 and what are the intentions to continue to work remotely in the future? (1b) What demographic, geographic, and attitudinal characteristics are associated with adoption frequencies? (2a) What is the distribution of one-way commute lengths, and how has that distribution changed since before COVID-19? (2b) Combining one-way commute lengths 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 are the associated characteristics? During this reporting period, the project team completed data collection and performed a great deal of data cleaning. Progress on data cleaning was far slower than expected, due to glitches in the data quality checks performed by the vendor. During the next reporting period, the team will finish data cleaning, weight the sample, and prepare descriptive statistics to address the key study questions. Ultimately, the team will develop models of key behavioral indicators to control for multiple behavioral influences simultaneously.

Project #37: Response Willingness in Consecutive Travel Surveys
PI: Patricia Mokhtarian (GT) **Co-PI:** Kari Watkins (GT)

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 the preceding progress reports, a master's thesis based on this study was completed and filed in the Spring of 2021, and a paper summarizing the study was submitted to the journal Transportation in July 2021. After a round of peer-review comments and revision, the paper was accepted for publication during the present reporting period and is currently in press. Thus, this project is essentially concluded.

Project #45: Addressing Potentially Missing Relevant Information on Attitudes and Other Behavioral Elements as Unobserved Heterogeneity in Highway Safety Studies | **PI:** Fred Mannering (USF)

Progress: This project explores the relationship between the pedestrian-injury severity and time of day over a five-year period using accident data from Kansas. Separate statistical models were estimated for different times of day and years to examine different pedestrian injury severity outcomes. Likelihood ratio tests were conducted to explore the temporal stability of the model estimations over different times of day and years. The findings indicate that the factors affecting pedestrian injury severities did change over time but that there is a clear day-night difference in the resulting injury severities of pedestrians, with nighttime crashes consistently resulting in more severe injuries over time. The team finished the project's final report during this reporting period, and a paper based on the project findings has been published in the journal Analytic Methods in Accident Research.

Project #46: Exploration of the Relationships between Leisure Activity Participation Frequency and Social Capital **| PI:** Fred Mannering (USF) **Co-PI:** Michael Maness (USF)

Progress: This study examines the effects of social capital on the increased frequency of leisure activity participation. It is hypothesized that leisure activity frequency is an expressive outcome of social capital which is used by people to maintain and strengthen their social connections. This study aims to test this hypothesis using insights gathered from a self-administered web-based survey designed specifically to test differences in social capital and its relevance in a leisure activity context. The project team completed the final report in June 2022, which is available on the TOMNET website. Results from this project were presented at the European Association for Transport Research's hEART 2022 conference in Leuven, Belgium and the International Choice Modelling Conference in Reykjavik, Iceland.

Project #54: Grid-Aware Robust Fast-Charging Station Deployment for Electric Buses Under Socioeconomic Considerations **| PI:** Chaoyue Zhao (UW) **Co-PI:** Cynthia Chen (UW)

Progress: The major objective of this project is to develop a comprehensive optimization model to select the optimal locations of fast-charging stations for electric buses. It intends to solve various conceptual and methodological complexities inherent in transportation-electricity infrastructure systems, as well as socioeconomic issues for deploying new charging stations in underserved neighborhoods. A robust optimization methodology will be employed to ensure that the chosen sites are reliable enough to handle any real-world scenario of uncertainty. This project has been launched during the reporting period. So far, the team has developed the study design, undertaken a thorough literature review on the subject, and started developing a two-stage mixed integer model for optimally selecting charging stations for electric buses. The optimization model will be finalized in the following reporting period, and the uncertainties considered in the selection problem will be incorporated into the model.

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 the Summer and Fall of 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 who are *deeply engaged* in advancing the activities and mission of the center.

Table 2. Courses Offered by Mission-Critical Faculty Members of TOMNET (Summer & Fall 2022)

Semester	Course Level	Course No	Course Title	No	Instructor	Unit
Arizona State University						
Fall 22	Grad	CEE 578	Activity-Travel Behavior Modeling	12	Pendyala	SSEBE
Fall 22	Undergrad	PUP 430	Transportation Planning and the Environment	69	Salon	SGSUP
Fall 22	Grad	PUP 550	Transportation Planning and the Environment	4	Salon	SGSUP
Fall 22	Grad	PUP 642	Urban Economics	20	Salon	SGSUP
Fall 22	Undergrad	PUP/GIS 394	Introduction to Data for Urban Planners and Geographers	14	Salon	SGSUP
Fall 22	Grad	CEE 598	Traffic Simulation Modelling and Applications	15	Zhou	SSEBE
Georgia Institute of Technology						
Fall 22	Undergrad	CEE 3770	Probability and Statistics	65	Laval	CEE
Fall 22	Grad	CEE 6623	Transportation Survey Methods	9	Mokhtarian	CEE
University of South Florida						
Fall 2022	Undergrad	TTE4004	Transportation Engineering I	60	Maness	CEE
Fall 2022	Grad	TTE6507	Travel Demand Modeling	6	Maness	CEE
Fall 2022	Grad	TTE6307	Statistical and Econometric Methods I	17	Mannering	CEE
Fall 2022	Undergrad	CGN4933	Sustainable Transportation	27	Yu Zhang	CEE
Fall 2022	Grad	CGN6311	Introduction to Data Science	21	Qing Lu	CEE
University of Washington						
Fall 22	Grad	CET581	Travel Demand Forecasting	15	Nichols	CEE
Fall 22	Undergrad	URBDP 423	Introduction to Urban Design	9	Abramson	URBDP
Fall 22	Grad	URBDP 523	Introduction to Urban Design	18	Abramson	URBDP

Notes: SSEBE = School of Sustainable Engineering and the Built Environment; SGSUP = School of Geographical Sciences and Urban Planning; CEE = Civil and Environmental Engineering; URBDP = 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			
Victor O. Alhassan	PhD Student	SSEBE	Pendyala
Irfan Batur	PhD Student	SSEBE	Pendyala
Tassio B. Magassy	PhD Student	SSEBE	Pendyala
Abbie Dirks	MS Student	SSEBE	Pendyala
P. Srikanth Kini	MS Student	Comp Science	Pendyala
Christina Galanis	Undergrad Student	SSEBE	Pendyala
Nicole Corcoran	PhD Student	SGSUP	Salon
Rababe Saadaoui	PhD Student	SGSUP	Salon

Laura Mirtich	MS Student	SGSUP	Salon
Adam Costello	Undergraduate Student	SGSUP	Salon
Holden Weisman	Undergraduate Student	SGSUP	Salon
Danielle Manapat	PhD Student	Psychology	Grimm
GEORGIA INSTITUTE OF TECHNOLOGY			
Jason Soria	Postdoc	CEE	Mokhtarian
Ziming Liu	PhD student	CEE	Laval
Xinyi Wang	MS & PhD student	CEE	Mokhtarian
Seung-Eun Choi	PhD student	CEE	Mokhtarian
Ilsu Kim	PhD student	CEE	Mokhtarian/Circella
Regan Buchanan	MS student	SCaRP	Mokhtarian
UNIVERSITY OF SOUTH FLORIDA			
Asim Alogaili	Graduate Student	CEE	Fred Mannering
Suryaprasanna Balusu	Graduate Student	CEE	Fred Mannering and Abdul Pinjari
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
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, TOMNET organized two notable events in this reporting period to spark ongoing discussions about autonomous vehicle technology and its societal implications. In collaboration with the AAA Foundation for Traffic Safety and Arizona Commerce Authority, TOMNET hosted the 2022 AAA Forum on the *Impact of Vehicle Technologies and Users* on April 5-6, 2022, at Arizona State University. The forum brought together dozens of experts from across the country to discuss a variety of subjects, including the state of automated driving technology, lessons learned from real-world deployments, and challenges and opportunities in moving forward. In another event, TOMNET collaborated with the ASU Office of Applied Innovation to organize a public panel "Autonomous Vehicles Serving Local Mobility Needs" in Downtown Los Angeles. The two-part event included a panel discussion open to the public, followed by a working session of key stakeholders on this critical topic. TOMNET will continue to disseminate findings from its pioneering research efforts to evaluate automated vehicle deployments in various contexts and contribute to ongoing discussions about this technology so that emerging transportation technologies can be deployed to improve mobility for all.

Table 4. Key TOMNET-Sponsored Technology Transfer Events

Inst.	Title of Seminar/ Webinar	Speaker Name and Affiliation	Date
ASU	A Multi-Day Activity Based Model Considering Inter-Household Interactions: The Case of India	Suchismita Nayak (IIT – Kharagpur)	9/26/2022
ASU	ASU Public Panel in Los Angeles, CA: Autonomous Vehicles Serving Local Mobility Needs	Moderator: M. Walker (ACA); Panelists: R.M. Pendyala (ASU), E. Blumenberg (UCLA), G.W. Torng (FTA), C. Ketcherside (Valley Metro), B. Tsuei (AS)	9/23/2022

ASU	Data Analytics and Prediction/Causality Trade-offs in Transportation Modeling: The Example of Highway-Safety Analysis	Fred Mannering (USF)	4/28/2022
ASU	AAA 2022 Forum: Impact of Vehicle Technologies and Automation on Users	70 attendees; hosted by ASU, Tempe Campus	4/5-6/2022
USF	Advanced Air Mobility/Urban Air Mobility Research at USF	Yu Zhang(USF)	9/9/2022
USF	Engineering Practice of Analytics in Logistics and Transportation	Yuan Wang (USF)	9/2/2022
USF	Possibilities of User Exchanges of Transportation Supply in a Shared-Connected-Autonomous Future	R. Jayakrishnan (UC-Irvine)	4/29/2022
USF	How Many Are Too Many? Analyzing Dockless Bikesharing Systems with a Parsimonious Model	Marco Nie (NU)	4/22/2022
USF	Studying Vehicle and Electric Scooter Conflicts via Naturalistic Data Collection and Analytics	Lingxi Li (IUPUI)	4/8/2022
USF	Urban Air Mobility in Tampa Bay Region	A. Yeah (Hillsborough County MPO), B. Campbell (City of Tampa), G. Evans (Hillsborough County Aviation Authority)	4/1/2022

Note: ASU = Arizona State University; USF = University of South Florida; N/A: Not Applicable

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. Using these diverse and rich datasets, in the next two reporting periods, TOMNET researchers will continue to produce tangible research outputs that can significantly benefit policy and decision making in the transport sector, particularly in the wake of recent natural and technological disruptions. The TOMNET research team will continue to pursue other research projects related to the TOMNET mission (besides research efforts based on these surveys), and publish findings in journal and conference papers. The working papers from TOMNET's active research projects are being finalized and planned for publication in books and peer-reviewed journals. 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 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 culminating symposium, called the A^4 Symposium. This symposium will focus on *modeling* Attitudes, Automation, Autonomy, and Access (hence, A^4) and bring together the many key themes addressed by TOMNET. TOMNET scholars will continue to engage in 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. 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. On October 18, 2022, Pat Mokhtarian will present early results from the "What is the New Normal? An Analysis of Post-COVID-19 Commute and Work Patterns" TOMNET project to an Atlanta Regional Commission audience. At the International Conference for Travel Behaviour Research in Chile in

December 2022, Pat Mokhtarian (who will be receiving a Lifetime Achievement Award at the conference) will give a keynote talk on the heart of TOMNET's mission: *Bringing attitudinal measures into regional travel demand forecasting models*. Over a dozen papers based on research activities of the TOMNET UTC will be presented at the Transportation Research Board Annual Meeting in January 2023.

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*
- *Culdesac Tempe, Tempe, AZ, Collaborative research*
- *D-STOP University Transportation Center, University of Texas at Austin*

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, values, and attitudes. The list of researchers that work closely with TOMNET researchers include:

- *Dr. Chandra Bhat, PhD, University of Texas at Austin, TX*
- *Dr. Abolfazl Mohammadian, University of Illinois-Chicago, IL*
- *Dr. Sybil Derrible University of Illinois-Chicago, IL*
- *Dr. Laurie Garrow, Georgia Tech, Atlanta, GA*
- *Dr. Brian German, Georgia Tech, Atlanta, GA*
- *Dr. Joseph Saleh, Georgia Tech, Atlanta, GA*
- *Dr. Patrick Singleton, Utah State University, Logan, UT*
- *Dr. Lauren Steimle, Georgia Tech, Atlanta, GA*
- *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. Konstadinos Antoniou, TU 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*
- *Dr. Yongsung Lee, University of Hong Kong, Hong Kong*
- *Dr. Shin-Hyung Cho, Seoul National University, S. Korea*
- *Dr. Calvin Thigpen, Lime*
- *Dr. Hue-Tam Jamme, Arizona State University, Tempe, AZ*
- *Dr. Natalia Barbour, TU Delft, the Netherlands*
- *Jia Tang, PhD student from Nanjing University*
- *Executive Board of the Intl Assoc of Trav Beh Research*
- *South Park Information and Resource Center*
- *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. Batur, I., Asmussen, K. E., Mondal, A., Khoeini, S., Magassy, T. B., Pendyala, R. M., & Bhat, C. R. (2022). Understanding Interest in Personal Ownership and Use of Autonomous Vehicles for Running Errands: An Exploration Using a Joint Model Incorporating Attitudinal Constructs. Transportation Research Record, 03611981221107643.
2. Sharda, S., Ye, X., Raman, A., Pendyala, R. M., Pinjari, A. R., Bhat, C. R., ... & Ramadurai, G. (2022). Accounting for the Influence of Attitudes and Perceptions in Modeling the Adoption of Emerging Transportation Services and Technologies in India. Transportation Research Record, 03611981221088203.
3. 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.
4. Magassy, T. B., Batur, I., Mondal, A., Asmussen, K. E., Khoeini, S., Pendyala, R. M., & Bhat, C. R. (2022). Influence of Mode Use on Level of Satisfaction with Daily Travel Routine: A Focus on Automobile Driving in the United States. Transportation Research Record, 03611981221088199.
5. 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.
6. Mohammadi M, Rahimi E, Davatgari A, Javadinasr M, Mohammadian A, Bhagat-Conway M, Salon D, Derrible S, Pendyala RM and Khoeini S. (2022). Examining the persistence of telecommuting after the COVID-19 pandemic. Transportation Letters. DOI: 10.1080/19427867.2022.2077582
7. Bhagat-Conway M, Mirtich L, Salon D, Harness N, Consalvo A, and Hong S. (2022). Subjective variables in travel behavior models: a critical review and Standardized Transport Attitude Measurement Protocol (STAMP). Transportation. DOI: 10.1007/s11116-022-10323-7
8. Javadinasr M, Maggasy T, Mohammadi M, Mohammadian A, Rahimi E, Salon D, Conway MW, Pendyala R, and Derrible S. (2022). The Long-Term Effects of COVID-19 on Travel Behavior in the United States: A Panel Study on Work from Home, Mode Choice, Online Shopping, and Air Travel. Transportation Research Part F: Traffic Psychology and Behavior. DOI: 10.1016/j.trf.2022.09.019
9. Salon, D., Mirtich, L., Bhagat-Conway, M. W., Costello, A., Rahimi, E., Mohammadian, A. K., ... & Pendyala, R. M. (2022). The COVID-19 Pandemic and the Future of Telecommuting in the United States. Transportation Research Part D: Transport and Environment, 103473.

Presentations Within Reporting Period

1. Pendyala, R.M. Autonomous Vehicles and the Future of Mobility: Advancing a Sustainable Self-driving Revolution. Presented at the Prof. N. R. Kamath Memorial Webinar by Indian Institute of Technology at Bombay, Sep 28, 2022.
2. Batur, I., T.B. Magassy, A. Dirks, and R.M. Pendyala. Future of Autonomous Vehicles: A Self-driving Revolution or Disaster?. Presented at ITS World Congress 2022, Sep 21-25, 2022.
3. Batur, I., A. Dirks, and R.M. Pendyala. Changes in Time Use and Activity Participation During the COVID-2019 Pandemic in the US: Implications for Wellbeing and Time Poverty. Presented at TU Munich Workshop, Sep 11-14, 2022.
4. Batur, I., A. Dirks, and R.M. Pendyala. Changes in Time Use and Activity Participation During the COVID-2019 Pandemic in the US: Implications for Wellbeing and Time Poverty. Presented at WCTRS 2022 Virtual Meeting, July 27, 2022.
5. Batur, I., K.E. Asmussen, A. Mondal, S. Khoeini, R.M. Pendyala, and C.R. Bhat. Sending Autonomous Vehicles to Pick-up, Deliver, and Run Errands: Sustainability Implications. Presented at the Conference on Sustainability and Emerging Transportation Technology, Irvine, CA, May 31 – June 2, 2022.
6. Magassy, T.B., S. Sharda, I. Batur, A. Dirks, S. Khoeini, and R.M. Pendyala. How Does Adoption of Emerging Transportation Technologies Vary by Residential Preferences?. Presented at the ASCE International Conference on Transportation & Development, Seattle, WA, May 31 – June 3, 2022.
7. Sharda, S., T.B. Magassy, I. Batur, R.M. Pendyala, and V.M. Garikapati. Differences in Utilization Patterns Between Electric and Gasoline Vehicles: Implications for Household Energy Consumption. Presented at the ASCE International Conference on Transportation & Development, Seattle, WA, May 31 – June 3, 2022.
8. Salon D. How will the COVID-19 pandemic affect public transit demand into the future? (2022) UCLA Lake Arrowhead Symposium, Los Angeles, CA.

Georgia Tech

Papers Published Within Reporting Period

1. Steimle L., Y. Sun, L. Johnson, T. Besedeš, P. Mokhtarian, and D. Nazzal. (2022). Students' Preferences for Returning to Colleges and Universities During the COVID-19 Pandemic: A Discrete Choice Experiment. Socio-Economic Planning Sciences, Volume 82, Part B, August 2022, 101266.
2. Young M., J. Soza-Parra, and G. Circella (2022). The Increase in Online Shopping during COVID-19: Who is Responsible, Will it Last, and What Does it Mean for Cities?. Regional Science Policy & Practice, https://doi.org/10.1111/rsp3.12514.
3. Matson, G., McElroy, S., Lee, Y., & Circella, G. (2022). Longitudinal Analysis of COVID-19 Impacts on Mobility: An Early Snapshot of the Emerging Changes in Travel Behavior. Transportation Research Record, https://doi.org/10.1177/03611981221090241.

Presentations Within Reporting Period

1. Xinyi Wang: Telecommuting in a world of uncertainty. 2022 Census Data for Transportation Planning (CTPP) Conference, Reno, Nevada, June 7, 2022.
2. Patricia Mokhtarian: Is teleworking always a 'treatment' for reducing distance traveled? Investigating the roles of telework motivations and frequency using switching regression models. 2nd Israeli Smart Transportation Research Center (ISTRC) Annual Conference. The Technion: Israel Institute of Technology, Haifa, July 3, 2022.
3. Patricia Mokhtarian: Is teleworking always a 'treatment' for reducing distance traveled? Investigating the roles of telework motivations and frequency using switching regression models. Activity-based Modeling Symposium, Kloster Seeon, Bavaria, Germany, September 14, 2022.

University of South Florida

Papers Published Within Reporting Period

1. Islam, M., & Mannering, F. (2022). An empirical analysis of how asleep/fatigued driving-injury severities have changed over time. Journal of Transportation Safety & Security, 1-24.
2. Tahlyan, D., Stathopoulos, A., & Maness, M. (2022). Disentangling social capital–Understanding the effect of bonding and bridging on urban activity participation. Transportation research interdisciplinary perspectives, 15, 100629.

Presentations Within Reporting Period

1. Mannering, D. Data Analytics and Prediction/Causality Trade-offs in Transportation Modeling: The Example of Highway-Safety Analysis. Presented at the TOMNET Seminar Series, Arizona State University, April 28, 2022.
2. T. Luong and M. Maness. A Temporal Analysis of Leisure Activity Variety and Social Capital Before and During the COVID-19 Pandemic. Presentation at the 10th Symposium of the European Association for Research in Transportation, Leuven, Belgium.
3. M. Maness, D. Mishra, and Z. Lin. A Random Parameters Latent Class Analysis to Estimate the Value of Free Charging Bundle in Electric Vehicle Purchases. Presentation at the 10th Symposium of the European Association for Research in Transportation, Leuven, Belgium.
4. D. Mishra and M. Maness. A Stated Preference Study Exploring the Zero Price Effect in Public Electric Vehicle Charging. Presented at the Sustainability and Emerging Transportation Technology (SETT) Conference, Irvine, CA.
5. T. Luong and M. Maness. A Testable Latent Variable Framework for Outcomes of Social Capital Mobilization. Presentation at the 2022 International Choice Modelling Conference, Reykjavik, Iceland.

University of Washington

Papers Published Within Reporting Period

1. Lin, J. Y. J., Chen, C., & Angah, O. (2022). Socio-Economic and Spatial Disparity of Bus Ridership Impacts in King County, Washington, During COVID-19. Transportation Research Record, 03611981221116366.

In summary, TOMNET core faculty generated 15 journal publications within the reporting period covered by this SAPR. These publications are attributable to funding provided by the TOMNET UTC. During the reporting period of this SAPR, the ***core*** TOMNET researchers delivered 12 presentations at various venues.

Website(s) or other Internet site(s)

One major product of the center is the TOMNET website that has been reorganized and updated during the reporting period. A new page is created on the website for policy briefs produced by TOMNET members. Also to effectively introduce software and tools developed within the TOMNET enterprise, a dedicated page has been developed. The research page of the TOMNET website has 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 disseminate policy briefs produced by TOMNET research groups.

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 made available for public use. These tools have been explained in previous reports in detail. Updated versions of these tools developed in open-source format are being 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 study 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 Survey Waves 1-3 data 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 to better model the recent changes 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 (#42 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 Period	This Period	Annual Total	Assessment
Number of software/ data/models	2	1	3	4	Datasets are being cleaned, weighted, and documented. The codes are in beta versions.
Number of journal publications	15	18	15	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 based on 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.

TOMNET researchers are also 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-induced new normal. The COVID-19 wave 1-3 datasets have 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. During the reporting period covered by this report, the team has published a series of additional papers documenting *changes* in traveler behavior and values that occurred over the course of the pandemic, and the likely changes that may stick into a new normal.

Finally, the TOMNET team at ASU has released the beta version of an interactive activity-based wellbeing assessment tool. This tool, called WBEAT, consists of two activity and time use-based wellbeing metrics that are designed to analyze how wellbeing varies over time and space for different population groups. Thus, WBEAT provides policymakers and public with much needed measures of wellbeing, which are critical to uncovering and addressing social disparities and thus effectively allocating resources to promote equitable and sustainable living.

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 who responded 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. Together with the TOMNET study to evaluate the usefulness of targeted marketing data in attitudinal travel behavior research, these research outcomes have collectively enhanced knowledge regarding data collection and utilization, and advance the profession's ability to maximize 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 81 students and scholars who have been deeply engaged in TOMNET research during their education. During this reporting period, Dr. Giovanni Circella, who has worked at TOMNET since the very beginning of the Center as a Senior Investigator, accepted a new faculty position at Ghent University in Belgium. Giovanni has worked with Pat Mokhtarian for 16 years, both at the University of California, Davis and for the 9 years that they have been at Georgia Tech. Moreover, one of the PhD students working in TOMNET since 2018, Irfan Batur has been hired as the Research Communications and Technology Transfer Coordinator of the Center. Mr. Batur, as a TOMNET student, also received the ASU Graduate Outstanding Research Award during this reporting period, which is given to outstanding graduate students at Arizona State University. 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 COVID Future Survey (wave 1-3) and T4 Survey Results
Number of students/scholars participating in TOMNET research	50	42	+3	45	Some students are the same across the periods; so, the total number reflects the unique cases.

On August 6, 2022, TOMNET members at Georgia Tech attended a delightful gathering to celebrate Giovanni Circella's new faculty position at Ghent University in Belgium. Giovanni has worked with Pat Mokhtarian for 16 years, both at the University of California, Davis and for the 9 years that they have been at Georgia Tech. Thus, we will miss having Giovanni down the hall and closely collaborating with us, but we are excited for him and his grand new adventure and are certain that he will be extremely successful in his new position. The photo shows Giovanni with the Georgia Tech "TOMNET team" at the party.

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 the ability to formulate policies and strategies that foster a more effective and ***equitable*** transportation system. TOMNET's work is accelerating a data-driven informed decision-making approach to transportation investments and improvements that will advance mobility for all. The overall impacts of multiple surveys funded by TOMNET, in understanding how travelers are affected by and respond to new technologies and disruptive forces including mobility-on-demand services, automation, electrification, health and wellbeing, pricing and taxation, safety, COVID-19 pandemic, leisure activities, and community networks are very significant, and yet difficult to quantify. So far, the three waves of COVID Future Survey dataset have 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 enhance our understanding of people's behaviors, perceptions, and choices and therefore substantially elevate 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 early 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, COVID Future 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.

Researchers at the University of Washington are 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 conducted during this reporting period also highlights the importance of trust in supporting communities during a disaster. Trust in community networks turns out be more important than other factors including socio-demographics, level of preparedness, and place attachment.

What is the impact on the body of scientific knowledge?

Table 7 presents 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, citations to publications are credited to TOMNET based on the financial resources provided by TOMNET for the specific studies and products. The two distinguished TOMNET faculty who have an outsized contribution to these citation statistics are Fred Mannering and Patricia Mokhtarian. Over the past year, **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 Behavior Research** for her significant contributions to the field. Mokhtarian is the first woman to receive this prestigious honor since its creation in 2003.

In a recent study, Ram Pendyala and his TOMNET research team at Arizona State University collaborated with Professor Chandra R. Bhat and his research group at the University of Texas at Austin to investigate why people travel the way they do and what it would take to convince them to use public transportation and other alternative modes of transportation rather than driving themselves. The findings of their study are documented in "The Influence of Mode Use on Level of Satisfaction with Daily Travel Routine: A Focus on Automobile Driving in the United States," a peer-reviewed article recently published in Transportation Research Record. Given the increased interest and emphasis on motivating people to use alternative and more sustainable modes of transportation for their travel as nations attempt to reduce greenhouse gas emissions, make communities more sustainable and livable, and combat the negative effects of climate change, this paper is very timely. The study finds that the common perception that people dislike driving and have a lower quality of life when they rely on the automobile for daily travel may be false; thus, planners and policymakers' aspirations to reduce private vehicle use are unlikely to be realized unless investments in, and incentives to promote the use of, alternative modes of transportation are combined with aggressive measures to penalize automobile mode use for daily travel. TOMNET's research has received widespread attention from the media, transportation researchers, policymakers, and the general public, earning it the prestigious Pyke Johnson Award, given by the Transportation Research Board in recognition of the best paper in the field of planning and the environment.

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

- *Resource sharing.* Resource sharing and matching have been studied during 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 resource sharing should consider users' preferences — there is a great amount of heterogeneity in terms of the types of resources that people are willing 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 activities have engaged undergraduate, graduate, and postdoctoral scholars in research and technology transfer activities related to emerging transportation technologies, impacts of the pandemic, resilience issues in rural and remote areas, survey data collection, advanced statistical modeling, and data fusion. Consistent with the central theme of TOMNET, 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 TOMNET research results, data and software products, and policy implications 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	4,553 (+)	21,432

At the University of Washington, TOMNET activities have engaged undergraduate, graduate and postdoctoral scholars 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 mega multiphase 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 undergraduate students in this project so that they learn 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.