2021 ScooterLab Workshop

Planning for the Development of a Community Testbed to Support Micromobility Research

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Disclaimer

The 2021 ScooterLab workshop was supported by the United States National Science Foundation (NSF) under award number 2016717. All opinions, findings, conclusions, and recommendations expressed at the event and in this report are those of the workshop participants and report authors, respectively, and do not necessarily reflect the views or position of NSF.

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Executive Summary

This report describes the planning, organization and outcomes of the workshop aimed at bringing together the broader computing, engineering, transportation, and urban planning research community to plan for the development and implementation of *ScooterLab*, a community research infrastructure initiative, currently under development at the University of Texas at San Antonio (UTSA). This publicly accessible micromobility testbed and crowd-sensing infrastructure will provide researchers with highly customizable access to a fully operational fleet of dock-less e-scooters, retrofitted with state-of-the-art sensors, and a community of riders, including data sensed/collected from (and during) their rides. Data collected from the various experiments on this testbed is expected to support and enable research in a variety of areas including, but not limited to, Machine Learning (ML) & Artificial Intelligence (AI), High-Performance Computing, Security and Privacy, Mobility Modeling, Urban Planning & Policy, and Civil & Transportation Engineering.

As a follow-up to the first workshop, which was organized locally, the goal of this nation-wide community engagement and planning event was to provide an overview of ScooterLab's primary mission and vision to the broader research community, and to understand their needs and expectations vis-à-vis micromobility-related and micromobility-supported research data collection. The overarching goal is to build a collaborative research community around the ScooterLab testbed. This workshop was organized virtually using Zoom (due to the COVID-19 pandemic related restrictions) on Friday, June 18th, 2021. It was attended by a diverse group of faculty and researchers, which enabled rich discussion in four thematic areas – (i) Engineering, development, and deployment of ScooterLab, (ii) Customizable data collection and research enabled by ScooterLab, (iii) Research data publication and best practices, and (iv) Data analysis and visualization. Besides breakout discussion sessions on these topics, the workshop program also included an introduction to ScooterLab and an update on the prototype development efforts, short lightning talks by workshop attendees, and research poster presentations by graduate students. This report summarizes the discussion on the above topics and the general feedback from the community on the various design and operational aspects of the planned testbed. The expectation is that the discussions and outcomes reported here will serve as an important guide towards building an open, inclusive and multi-disciplinary community research infrastructure.

1. Workshop Overview

ScooterLab is a community research infrastructure initiative currently under planning and development at the University of Texas at San Antonio (UTSA). This open and publicly-available micromobility testbed and crowd-sensing infrastructure aims to provide researchers with highly customizable access to a fully operational fleet of dock-less e-scooters and other types of micromobility vehicles, retrofitted with state-of-the-art sensors, and a community of riders, including data sensed/collected from (and during) their rides. Data collected from the various experiments on this testbed is expected to support and enable groundbreaking research in a variety of areas including, but not limited to, Machine Learning (ML) & Artificial Intelligence (AI), High-Performance Computing, Security and Privacy, Mobility Modeling, Urban Planning & Policy, and Civil & Transportation Engineering. The US National Science Foundation (NSF) funded the planning activity for this testbed under award number 2016717 with the goal of enabling the PIs (M. Jadliwala, G. Griffin, S. Prasad, and A. Maiti) to study the operational and technical feasibility of the planned testbed and to build a community of researchers around it. As part of this planning activity, the PIs first organized a local workshop in November 2020, comprising of researchers from UTSA and neighboring institutions, to discuss the interest and challenges of building ScooterLab on the UTSA campus. As a follow-up of the preliminary local community-building event, the PIs organized a second large-scale workshop involving a diverse group (from a research perspective) of national and international researchers to understand the requirements of the primary stakeholders and to identify the main roadblocks and challenges related to the development, deployment, and usage of such a community research infrastructure/testbed. This report outlines the organizational details, discussions and findings of this second ScooterLab planning and community development workshop.

1.1 Workshop Goals

Before outlining the organizational details and outcomes of the workshop, let us first present the three main goals/objectives of this nation-wide community engagement and planning event:

Goal 1: Provide an overview of ScooterLab's primary mission and vision to the community.

Goal 2: Understand the academic and research community's needs and expectations vis-à-vis micromobility-related and micromobility-supported research data collection.

Goal 3: Identify specific research and scientific advances that can be accomplished using the ScooterLab infrastructure and sensor data collected, and to build a collaborative research community around ScooterLab.

1.2 Workshop Organization

The workshop was organized by the PIs of the NSF award # 2016717, M. Jadliwala (UTSA), G. Griffin (UTSA), S. Prasad (UTSA) and A. Maiti (currently with University of Oklahoma), with significant help and assistance from the project's two research assistants, Mr. R. Wijewickrama (Computer Science, UTSA) and Mr. Jeffrey Jobe (Urban Planning, UTSA). The organization team met weekly (every Wednesday morning) starting in May to plan for the workshop agenda and content, potential invitees/participants, and other organizational processes. After finalizing the workshop date (Friday, June 18th, 2021) and a preliminary agenda, an invitation/call-for-participation template (see *Appendix 1*) was created, together with a website (https://scooterlab.utsa.edu/workshop2.php) outlining some preliminary details about the planned event. The PIs then used the invitation/call-for-participation template to advertise the workshop to the scientific community and to a diverse set of researchers, practitioners and students interested in the proposed research infrastructure or the sensor data collected using it. Besides emailing a targeted set of researchers (such as professional contacts, well-known researchers working in related areas, the NSF CCRI program PIs, and participants from the first workshop), the call-for-participation was also posted on relevant online forums (e.g., CPS-VO and TCCC). A registration page (https://utsa.az1.qualtrics.com/jfe/form/SV_dnlLQdrYNj0jWse) was created and linked to the Workshop website, which interested participants used to register for the event. As the workshop was planned as a virtual event (considering COVID-19 pandemic-related travel and health restrictions), a Zoom meeting was configured and thoroughly tested for functionality (including creation of break-out rooms). The Zoom meeting link and the workshop agenda and other useful information were emailed to all the registered participants a week prior to the workshop.

1.3 Workshop Activities and Discussion Themes

The workshop featured several informative and interactive activities to bring together the scientific community interested in micromobility related research and research supported by micromobility data. A detailed agenda for the workshop can be found in *Appendix 2*. Murtuza Jadliwala opened the workshop with a few introductory remarks, an outline of the workshop's goals, and a summary of the workshop agenda. Following that, Anindya Maiti summarized the primary mission, vision, and technical details of the planned ScooterLab testbed along with near-term and long-term objectives and plan. After that Raveen Wijewickrama summarized the progress made on ScooterLab Vehicle Prototype 1 (SLP1), the different categories of sensors onboard SLP1, and the Android application features that control SLP1. Next, the workshop featured a lightning talk session (approx. 1 minute per talk), chaired by Anindya Maiti, which included 16 short research overviews by senior workshop participants (primarily, faculty and senior researchers) on a diverse set of topics, ranging from mobility modeling to cybersecurity, safety, and urban planning. In addition to these short research talks, a poster session for graduate student researchers interested in presenting their research in micromobility or related topics was also organized (chaired by Raveen Wijewickrama). There was also an award for the best student poster presentation, adjudicated by Dr. Grant McKenzie, McGill University. Presentations by the PIs and the

participants are available online on the workshop website: https://scooterlab.utsa.edu/workshop2.php.

In addition to the informative sessions, the workshop also featured a significant interactive component in the form of breakout sessions, which were designed to solicit feedback from the participants on some of the most critical aspects of the proposed community testbed, its design and development plan, and the research that would be enabled by it. Specifically, the workshop featured four breakout sessions, each an hour long and exclusively focusing on a particular theme. Two breakout sessions ran in parallel, and all participants were requested to attend all breakout sessions in separate phases. Below, we describe the discussion theme related to each of the breakout sessions.

Theme #1 - Engineering, development, and deployment.

The ScooterLab testbed's foundation will be based on a fleet of e-scooters. Discussion under this theme covered topics including challenges in engineering, development, and deployment of these e-scooters. For example, challenges in enforcing area of operation, sensing hardware, and software integration.

As part of the breakout session associated with this theme (chaired by Murtuza Jadliwala), workshop participants were tasked with discussing and completing the following two tasks:

Task 1: *List and discuss at least three (more are preferred) main testbed development challenges. This could include challenges in the development of participant-facing entities of the testbed (e-scooters, mobile apps, etc.), researcher-facing entities of the testbed (e.g., Research Activities Management Portal) or the testbed owner/maintainer facing entities of the testbed (e.g., WBSC and Fleet Controller). In addition to listing challenges, participants should also discuss and identify potential mitigation strategies.*

Task 2: *List and discuss at least three (more are preferred) main testbed deployment challenges. This could include challenges in the day-to-day operation of the testbed, regulatory challenges, maintenance challenges, and availability (to researchers) challenges. In addition to listing challenges, participants should also discuss and identify potential mitigation strategies.*

The outcomes and results of these discussions are outlined in *Section 2.3*.

Theme #2 - Customizable data collection and research enabled.

The research community can utilize ScooterLab in two ways: (i) researchers may request specific deployment settings to collect data that can help test their research hypotheses, (ii) researchers may use already published data (from prior deployments) to test their research hypotheses. One of the goals of this theme was to preconceive some of the research directions that the community is looking forward to addressing through ScooterLab and the research data that may become available from it. Discussion under this theme covered opportunities and challenges associated with various operational parameters such as

custom sensing hardware, scheduling, area of operation, IRB requirements for custom deployments, insurance liabilities, and ride pricing.

As part of the breakout session associated with this theme (chaired by Anindya Maiti), workshop participants were tasked with discussing and completing the following two tasks:

***Task 1**: List and discuss at least three (more are preferred) different experimental settings that could be requested by researchers, and challenges related to configuring the testbed with those settings. These settings could include, but not limited to, specific types of sensing hardware and sensed data, specific category/groups of riders, and specific context (including, locations) of the rides. Discussions should also include specific research problems that the data collected from those settings would address.*

***Task 2**: List and discuss at least three (more are preferred) high-level research areas which will be most significantly impacted by (or benefit from) this testbed and the data collected from it. In addition to identifying these research areas, also discuss the current challenges facing those areas and how the ScooterLab testbed will positively help in overcoming those challenges. Note that while the earlier task asks you to list specific research problems, this task asks you to list/discuss high-level research areas/directions.*

The outcomes and results of these discussions are outlined in *Section 2.4*.

Theme #3 - Research data publication best practices.

Data collected from the ScooterLab testbed will be rich of sensory and actuation data. Under this theme, the research community was engaged in discussing the best practices for data publication. One of the most important discussion points was on how to preserve riders' privacy (such as identity and location privacy) without affecting research utility of the data.

As part of the breakout session associated with this theme (chaired by Greg Griffin), workshop participants were tasked with discussing and completing the following two tasks:

***Task 1**: List and discuss at least three (more are preferred) challenges that could hinder/prevent collection and open sharing (within the research/scientific community) of data from the ScooterLab testbed. These could be hardware/software specific challenges, rider/participant specific challenges, regulatory challenges, or any other challenges that you envision.*

***Task 2**: List and discuss at least three (more are preferred) practices that could be followed, both by researchers and testbed operators, to mitigate some of these challenges.*

The outcomes and results of these discussions are outlined in *Section 2.5*.

Theme #4 - Data analysis and visualization.

In addition to data publication, ScooterLab will also support fundamental data analysis and visualization tools. Discussion under this theme will ideate the most useful set of analysis and visualization tools that ScooterLab should offer to the research community. For accessibility, these analysis and visualization tools will most likely be delivered over a web interface.

As part of the breakout session associated with this theme (co-chaired by Murtuza Jadliwala and Anindya Maiti), workshop participants were tasked with discussing and completing the following two tasks:

***Task 1**: List and discuss at least three (more are preferred) different types of search, analysis and visualization tools that would be useful to analyze/visualize ScooterLab data. Discussions should also include potential applications for such tools and relevance to addressing related research problems.*

***Task 2**: List and discuss at least three (more are preferred) community-wide efforts that will be required to develop and maintain these tools.*

The outcomes and results of these discussions are outlined in *Section* 2.6.

2. Workshop Outcomes

2.1 Workshop Participant Details and Demographics

A diverse group of participants, demographically, geographically (see *Figure 1*) as well as from a technical background/interest point-of-view, registered and attended the workshop. In all, a total of 45 participants registered for the workshop through the online registration form. The list of registered participants contained 28 faculty, 9 graduate students, 2 professional practitioners and 2 others. Their research interests included transportation safety, computer science, cybersecurity, artificial intelligence, and urban planning. Out of the 45 registered participants, approximately 20 participants attended the entire workshop on Friday June 18th. The list of registered participants (names and affiliations) can be found in *Appendix 3*, while a screenshot of participants attending the workshop on Zoom can be found in *Appendix 4*.

2.2 General Discussions and Outcomes

The lightning talk session comprised of 15 short research overviews by a subset of the participants. Each talk was up to a minute long, with a 10-minute Q&A session at the end of the session. The session was chaired by Anindya Maiti. The topics of lightning talks included testbeds, mobility models and measurements, safety and access issues in micromobility, and outcomes of micromobility related measurement studies and surveys, among others. The entire list of lightning talks, together with the presentation slides (available for download), can be found on the workshop website: https://scooterlab.utsa.edu/workshop2-agenda.php.

The student research poster session saw participation by 3 graduate student researchers working on micromobility, mobile sensing, and related areas. Each poster presentation was

5 minutes long (4 minutes research talk + 1 minute for Q&A) and was well attended by all workshop participants. The topics of these poster presentations included the application of machine learning to predict temporal/spatial usage patterns, an empirical analysis of the impact of e-scooters on pedestrian safety, and results of a user-study studying the impact COVID-19 had on Bike-share services. The poster session also featured a Best Poster Presentation Award adjudicated by Dr. Grant McKenzie, McGill University. This award was won by Ms. Nisha Vinayaga Sureshkanth (UTSA) for her poster titled "Impact of E-Scooters on Pedestrian Safety: A Field Study Using Pedestrian Crowd-Sensing". The entire list of graduate student posters (available for download) can be found on the workshop website: https://scooterlab.utsa.edu/workshop2-agenda.php.

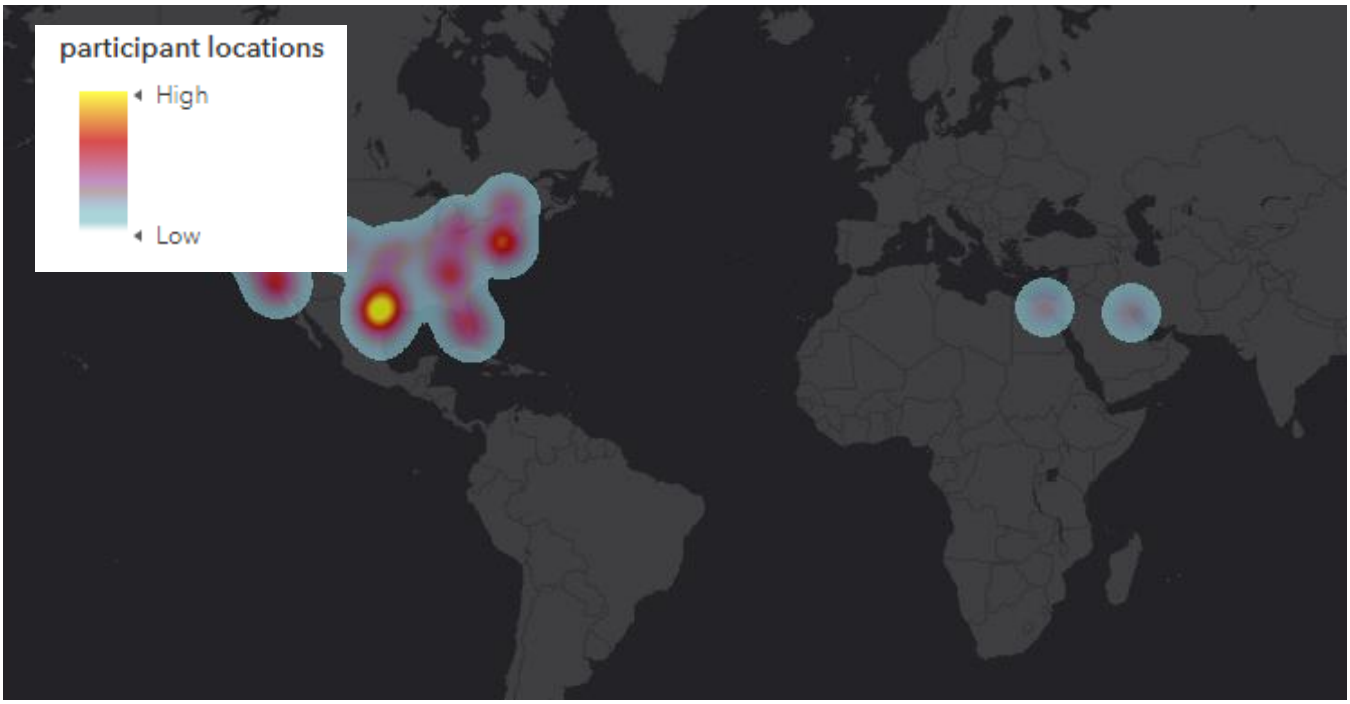


Figure 1. ScooterLab Workshop Participant Locations. Interactive version at https://scooterlab.utsa.edu/workshop2.php.

Next, the main discussions on each of the themes during the breakout sessions are summarized.

2.3 Theme #1 - Engineering, Development, and Deployment

As part of the breakout session related to Theme #1 – Engineering, Development and Deployment, workshop participants were asked to center their discussions around the following two tasks.

***Task 1**: List and discuss at least three (more are preferred) main testbed development challenges. This could include challenges in the development of participant-facing entities of the testbed (e-scooters, mobile apps, etc.), researcher-facing entities of the testbed (e.g., Research Activities Management Portal) or the testbed owner/maintainer facing entities of*

the testbed (e.g., WBSC and Fleet Controller). In addition to listing challenges, participants should also discuss and identify potential mitigation strategies.

Summary of Discussions for Task 1:

- **Sensors**: One important point that was discussed during this task was the feasibility of integrating various types of sensors on the e-scooters, and their ability to collect fine-grained data under different experimental conditions. For instance, workshop participants discussed various interesting research directions that could be addressed using video footage (video camera data) on the testbed e-scooters. One example is that video footage can be used to understand safety-related events such as crashes and near-crashes, similar to: https://csrc.toyota.com/projects/naturalistic-data-collection-analytics-vehicle-e-scooter-conflicts.html. Another example is to use video footage data to understand where riders are using e-scooters, for example, sidewalk, travel lane, etc. The participants were concerned that continuous video sensing, although required to enable several interesting research directions, would be challenging to develop, integrate and operate on the testbed. Another topic that was discussed in this direction was the feasibility of collecting data from sensors on existing devices. Specifically, participants wondered whether sensors onboard smartphones and wearables (of e-scooter riders) could be used to supplement the sensor data stream from sensors onboard the e-scooters.
- **Privacy**: Participant privacy was identified as a significant concern in developing the ScooterLab testbed by the workshop participants. Developing data collection strategies and tools that are not considered too intrusive by the testbed participants, yet provided data with reasonable utility, was considered a critical factor in the success of the ScooterLab testbed and was extensively discussed by the workshop participants. Potential strategies to have access to research data based on need and type of research was also discussed. For example, highly aggregated and fully anonymized data could be shared publicly to enable research focused on technology and mobility modeling, while researchers focused on user behavior could get secure access to more detailed data.
- **Cost**: Overall cost of sensors (and each research vehicle) was also discussed as an obstacle to effectively scale the testbed to a large number of vehicles. Workshop participants felt that high-performance video cameras and LIDAR sensors were important and required for many research studies. However, these cameras and sensors are expensive, and cost would be a factor while installing these on ScooterLab vehicles. Workshop participants also discussed using users' mobile phone cameras to collect video and motion data as an inexpensive alternative.
- **State laws and regulations**: Local regulations governing what data about testbed users can be collected, and at what granularity, was also discussed in this task. Workshop participants were concerned that researchers would not be allowed to collect certain types of data, such as precise GPS data, and link it to any other personal information due to local/state laws. This would prevent the design of experiments for research problems that require such fine-grained personal data.

***Task 2**: List and discuss at least three (more are preferred) main testbed deployment challenges. This could include challenges in the day-to-day operation of the testbed, regulatory challenges, maintenance challenges and availability (to researchers) challenges. In addition to listing challenges, participants should also discuss and identify potential mitigation strategies.*

Summary of Discussions for Task 2:

- **Vandalism and destruction of vehicles and onboard sensors**: Participants pointed out that vandalism and destruction of testbed e-scooters and onboard sensors was a significant concern. If not appropriately detected and mitigated, it would result in monetary losses (for the project) and significant downtime, which would impact data collection and experimentation. Efforts will need to be made to secure testbed property against such vandalism threats.
- **Reliability**: Workshop participants also pointed out that maintaining a reliable fleet of scooters and sensing hardware will be very important to prevent disruption with ongoing experiments and the deployment of new experiments. A team of technicians will be constantly needed to service and maintain scooters and replace faulty and failed parts and sensors. The cost of such hardware and fleet maintenance should be accounted for while deploying the testbed.
- **Scalability**: Workshop participants also identified scaling the fleet size to a large number of scooters, and maintaining it, as another significant challenge in the full-scale operationalization and deployment of the ScooterLab testbed. It was mentioned that scaling would increase the number of scooters in the fleet, and it would also multiply the maintenance efforts, which would require additional workforce and increase the operational expense. One suggestion would be to scale the testbed slowly and on a need basis.
- **Regulation and Liability**: A critical requirement for successfully operating the testbed on campus would ensure that testbed operators and the university are protected against liability claims. The workshop participants requested the ScooterLab team to connect with the university's risk management team to discuss this issue and identify options for purchasing liability insurance for the vehicle/e-scooter fleet.
- **Competition from commercial scooter providers**: Another point that was discussed during this task was the competition the testbed would face from existing commercial scooter service providers, and how will that competition affect the demand for the testbed's e-scooters. Workshop participants requested the ScooterLab team to study the commercial scooter providers operating on the university's campus and devise a plan to highlight the advantages of using the testbed scooters to students.
- **Ethics Review and IRB Approvals**: Workshop participants also noted that IRB approvals would not only be necessary but required for collecting sensitive user location and rider information from testbed users. It was mentioned that the scope of these approvals should be broad enough to responsibly collect diverse data that would enable a large variety of research investigations. An issue that would also need to be addressed is when and how often testbed users need to consent for data collection. It was noted that

requesting to sign a lengthy consent form too often would deter riders/users from using the testbed scooters.

Attendees:

(Phase 1)

- Grant McKenzie, McGill University
- Bob Noland, Rutgers
- Junghwan Kim, Harvard
- Wenwen Zhang, Rutgers
- William Barbour, Vanderbilt
- Mauricio Gomez, UTSA
- Lorne Platt, CSULA

(Phase 2)

- Mohammad Alattar, University of Aberdeen
- Terry Benzel, University of Southern California
- Dillon Fitch, UC Davis
- Greg Griffin, UTSA
- Clinton Andrews, Rutgers
- Louis Merlin, Florida Atlantic University
- Chris Cherry, University of Tennessee
- Ray Atkinson, Transportation Systems Analyst at Clackamas Community College

2.4 Theme #2 - Customizable Data Collection and Research Enabled

This breakout session explored community expectations and generated ideas related to customization of the ScooterLab testbed to collect tailored datasets, which would be necessary for fulfilling specific specialized research objectives.

***Task 1**: List and discuss at least three (more are preferred) different experimental settings that could be requested by researchers, and challenges related to configuring the testbed with those settings. These settings could include, but not limited to, specific types of sensing hardware and sensed data, specific category/groups of riders, and specific context (including, locations) of the rides. Discussions should also include specific research problems that the data collected from those settings would address.*

Summary of Discussions for Task 1:

- **Data collection using mobile devices**: One setting that was discussed during the workshop was data collection by employing testbed users' smartphones or smart watches through appropriately designed data collection apps that could be installed on the users' mobile devices. In addition to sensors fitted on the scooters, this alternate sensor data stream could be very useful, per the workshop participants. Both quantitative (sensor data) and subjective/qualitative data through user surveys could be collected. This data can shed light on users' travel behavior, safety perceptions, supply issues and track travel behavior outside of the testbed. All this data will be collected with users' consent and after obtaining appropriate IRB/Ethics approvals.
- **Road facing sensors**: Another setting that workshop participants discussed being useful is to have a video camera and ranging sensors (e.g., LIDAR) facing down towards the road. Participants noted that such a setup would be very useful in accurately determining road and riding conditions such as potholes and obstructions, and riding behavior such as riding on pavement versus riding on the street/road. Such a setup would be very useful in studying the usage of bike lanes for battery-powered micromobility vehicles such as e-scooters
- **Apps for activity/context detection**: Workshop participants proposed developing a ScooterLab mobile app, which in addition to enabling vehicle (e-scooter) control and check-out, also does some basic activity and context detection. Such an app would be useful in determining other interesting contexts related to the testbed users (e.g., connecting transit transportation before and after e-scooter rides, amount of walking before and after e-scooter rides, etc.). Auxiliary urban information, such as, availability and schedule of other transit options, when combined with the testbed data would also be very useful for certain research projects.
- **User data besides sensors**: In addition to collecting sensor data, workshop participants also argued that collecting demographic and other contextual and preference information about ScooterLab users and riders was also very important and should be linked with the ride data. It was noted that knowing who is using scooters across the (student) population and how different population segments use scooters differentially was an interesting research direction and would need such demographic data.

Task 2*: List and discuss at least three (more are preferred) high-level research areas which will be most significantly impacted by (or benefit from) this testbed and the data collected from it. In addition to identifying these research areas, also discuss the current challenges facing those areas and how the ScooterLab testbed will positively help in overcoming those challenges. Note that while the earlier task asks you to list specific research problems, this task asks you to list/discuss high-level research areas/directions.*

Summary of Discussions for Task 2:

The workshop participants identified several interesting projects and research directions that could be enabled using the ScooterLab testbed and the data generated by it.

- **Rider and pedestrian safety**: One direction that was discussed was how to make e-scooter rental services safe through policies, scooter design, and improved infrastructure. Effect of alternate pricing models for e-scooter rentals, and their effect on riding behavior and safety was also discussed. Besides the above two, the design of techniques to accelerate e-scooter riders' learning curve for safe riding through the collection of longitudinal riding data was also identified as an interesting research problem in the direction of safety.
- **Mobility modeling**: In the direction of mobility modeling, workshop participants discussed how generation and sharing of trend data from e-scooter rides, showing spatial and temporal patterns over time, can be used by researchers to compare individual trajectories to historical patterns. Participants also discussed research settings in which such a comparative analysis would be useful.
- **User privacy**: Workshop participants also argued that mobility and tracking data can be used for privacy research. For instance, it can be used to study what kind of personal information about riders (e.g., preferences, work-home pairs, demographic information, etc.) can be inferred from anonymized mobility and sensor data available from e-scooter rides.
- **Routing and infrastructure**: Workshop participants noted that understanding individual usage behavior regarding the selection of routes, given the knowledge of infrastructure and overall traffic patterns, as an interesting problem that can be addressed using ScooterLab data. Identifying what infrastructure is needed or preferred for scooter trips, and how it may vary by demographics was also discussed. Inferring demand for scooters based on built environment and demographic characteristics was also interesting to few.
- **Machine Learning and AI**: Participants agreed that video and image data from the testbed can be used to create image/video archives which can be used to improve machine learning models for object identification (from image and video data).

Attendees:

(Phase 1)

- Louis Merlin, Florida Atlantic University
- Mohammad Alattar, University of Aberdeen
- Luyu Liu, The Ohio State University
- Chris Cherry, University of Tennessee
- Dillon Fitch, UC Davis
- Greg Griffin, University of Texas at San Antonio
- Clinton Andrews, Rutgers University
- Ray Atkinson, Transportation Systems Analyst at Clackamas Community College

(Phase 2)

- Junghwan Kim, Harvard
- Mauricio Gomez, University of Texas at San Antonio
- William Barbour, Vanderbilt
- Lorne Platt, CSULA
- Bob Noland, Rutgers
- Wenwen Zhang, Rutgers
- Grant McKenzie, McGill University
- Neda Zand, University of Texas at San Antonio

2.5 Theme #3 - Research Data Publication Best Practices

This breakout session generated ideas and guidance for storing, archiving, and sharing data generated in ScooterLab studies, with a particular focus on preserving riders' privacy without impacting research utility of the data.

***Task 1**: List and discuss at least three (more are preferred) challenges that could hinder/prevent collection and open sharing (within the research/scientific community) of data from the ScooterLab testbed. These could be hardware/software specific challenges, rider/participant specific challenges, regulatory challenges, or any other challenges that you envision.*

Summary of Discussions for Task 1:

- **Data management and documentation challenge**: Workshop participants noted that as vast amounts of highly diverse data are expected to be collected from the ScooterLab testbed, appropriate documentation describing the data (including the associated datatypes and metadata), the expected usage policies and policies for ownership/storage of data should be created and made available to the researchers. Without such detailed documentation describing the data, researchers will find it hard to effectively use it in their research projects. Also, proper guidance needs to be given to the researchers on handling, storing, and using the data available from the testbed. A data curator position for the testbed could be appointed to answer questions when documentation is not clear.
- **Size of datasets**: Workshop participants also pointed out the large size of certain data types (e.g., video data) and the related challenges in storing them and sharing it with the community. Large video datasets can be replicated across multiple servers to improve accessibility and faster downloads.
- **Participant privacy**: Participant privacy was one of the main concerns pointed out by workshop participants, which could hinder the collection and sharing of certain types of data. There was unanimous agreement that all data should be collected and used

ethically by seeking prior approvals from the IRBs of the institutions where the data will be collected and used, and after obtaining consent from the testbed users. Video and other sensitive data collected may need to be fully anonymized before sharing with the community. Testbed users/riders should also be provided the opportunity to delete their data (or parts of it) by means of appropriate tools and web interfaces. Testbed users should also have an opportunity to opt out from future data collection if they so desire.

- **Software challenges**: Workshop participants noted that software used to collect and share ScooterLab testbed data could also present new challenges. Workshop participants noted that errors, faults, and vulnerabilities in data collection and sharing software could result in incorrect (or no) data being sensed and leakage of data to unauthorized entities, resulting in ethical/regulatory concerns for the project. Workshop participants also suggested that good version controlling for all testbed software is essential and will be required to improve the robustness and reliability of the data collection and sharing process. This, however, could prove to be challenging to accomplish.
- **Sensor challenges**: Workshop participants noted that faulty sensors could provide inaccurate data and such faulty data would need to be detected and removed from the production dataset. Similarly, faulty and non-functioning sensors will need to be promptly replaced to avoid significant gaps in the data collection. Participants also noted that accurate and fine-grain built environment data will be beneficial to research but will be challenging to collect.

Task 2: *List and discuss at least three (more are preferred) practices that could be followed, both by researchers and testbed operators, to mitigate some of these challenges.*

Summary of Discussions for Task 2:

- **Processes to preserve and respect participant privacy**: As participant privacy was pointed out as one of the main concerns in effective data collection, workshop participants deliberated if multiple levels of aggregation can be done on the shared data prior to sharing with the community. Research projects requiring fine-grained data, including personally identifiable information, may be provided data with little to no aggregation, provided appropriate IRB approvals are obtained. Research projects that don't require such fine-grained data may use datasets with a higher aggregation level (to hide personally identifiable information and other sensitive user data). Appropriate mechanisms and processes for sharing data based on need will need to be set up for this purpose.
- **Common archive and standardization**: Workshop participants proposed that ScooterLab data should be published to a common archive, which is peer-reviewed, and all downloads and uses of that data should cite that archive. This will enable standardization of the data usage and will also help the replicability of past studies.
- **Enable partial downloads and data filters**: Workshop participants also observed that not all users may want to download the entire dataset but may want to extract some high-level statistics/aggregated information related to their projects. Thus, it could be helpful to develop appropriate data filters and web interfaces to create such filters and view

their results and make them available to the ScooterLab research community. For extremely large datasets, it could be broken down into multiple smaller datasets and appropriately categorized, making downloading easier for the community.

Attendees:

(Phase 1)

- Wenwen Zhang, Rutgers University
- Junghwan Kim, Harvard
- Nitesh Shah, The University of Tennessee at Knoxville
- Neda Zand, The University of Texas at San Antonio

(Phase 2)

- Lorne Platt, CSULA
- Mauricio Gomez, The University of Texas at San Antonio
- Ray Atkinson, Transportation Systems Analyst at Clackamas Community College
- Louis Merlin, Florida Atlantic University
- Clinton Andrews, Rutgers University

2.6 Theme #4 - Data Analysis and Visualization

This breakout session ideated the most useful set of analysis and visualization tools that ScooterLab should offer to the research community. For accessibility, these analysis and visualization tools will most likely be delivered over a web interface.

Task 1: *List and discuss at least three (more are preferred) different types of search, analysis and visualization tools that would be useful to analyze/visualize ScooterLab data. Discussions should also include potential applications for such tools and relevance to addressing related research problems.*

Summary of Discussions for Task 1:

- **Blended web-accessible dashboard**: Workshop participants noted that it was not only important for the researchers to be able to download entire datasets (containing raw data from the testbed experiments), but they also should be able to filter and download partial data (or datasets). To enable this, a blended web-accessible dashboard comprising of data download, visualization, and analysis tools should be developed and made available to the research community. Access to such a dashboard (and the testbed data) will need to be controlled and appropriately regulated. For example, researchers interested in the data should register, and the level of access can be assigned on a case-by-case basis.

- **Visualization tools**: Workshop participants discussed the need for good visualization tools, as many researchers would like to obtain some high-level statistics and plots from the data, rather than the entire dataset itself. Avoiding downloading the entire dataset and individually computing the statistics and plots themselves would be very time-consuming, so such a visualization tool would be beneficial and time-saving for researchers. Such web-based visualization tools can also be developed by using existing tools/libraries tools such as *Remix* and *ggplot*. Visualization at different temporal (such as hours, days, weeks, months, years) and spatial scales (such as point-level data, segment-level data, and zonal data) would also be very useful. Participants also discussed developing visualization tools that can represent a probabilistic phenomenon, such as heatmaps.
- **API-based access to data**: Workshop participants also discussed the possibility of enabling API-based access to data. This would allow other researchers to write their visualization and analysis tools, which the broader research community can then share and use. For this purpose, a hierarchical structure for the APIs may be helpful for researchers with different needs and skillsets.

***Task 2**: List and discuss at least three (more are preferred) community-wide efforts that will be required to develop and maintain these tools.*

Summary of Discussions for Task 2:

- **Mirror servers**: Workshop participants noted that multiple mirror sites/servers may be needed to improve the availability of the testbed data and resources.
- **Data and resource sharing and replicability**: Testbed website should provide a repository or a tool deposit service for community researchers, which they can use to share trained machine learning models and developed software products with other researchers. This will also improve the replicability of research results and provide additional collaboration opportunities within the research community.
- **Documentation**: Workshop participants agreed that a significant community-wide effort may be required to document all the shared software tools, machine learning models, and datasets. Without good documentation, a researcher will find it difficult to use these tools and resources within their research activities. Good documentation will also prevent duplication of tasks and resources.

  Attendees:

  (Phase 1)

  - Clinton Andrews, Rutgers University
  - Ray Atkinson, Transportation Systems Analyst at Clackamas Community College
  - Louis Merlin, Florida Atlantic University
  - Chris Cherry, University of Tennessee

(Phase 2)

- Junghwan Kim, Harvard
- Lorne Platt, CSULA
- Mauricio Gomez, University of Texas at San Antonio
- Wenwen Zhang, Rutgers
- Neda Zand, University of Texas at San Antonio

2.7 Final Survey Results

Immediately after the workshop, the UTSA team deployed a brief online survey (see Appendix 5) to assess participants' perceptions of the workshop and planned research collaboration. Most of the participants who attended the workshop completed the survey (N=14).

Over three-quarters of respondents indicated ScooterLab, or the data produced from it, would be useful in any of their current or past research projects (79% yes, 21%no). They described useful projects of theirs as follows (edited for brevity):

- "*Optimization of user routing*"
- "*understanding the street-level determinants of e-scooter risk exposure*"
- "*Still developing research based on user experiences (i.e., safety, built environment conditions, and joy) using scooters and other devices.*"
- "*Pedestrian conflicts and safety when sharing space with scooter users have been concerns of many people. I enjoyed learning about the following research during the workshop.*"
- "*Impact of E-Scooters on Pedestrian Safety: A Field Study Using Pedestrian Crowd-Sensing.*"
- "*route choice modeling*"
- "*estimating people's environmental exposures (air pollution) by using the detailed route data from the ScooterLab (e.g., https://doi.org/10.1080/24694452.2020.1756208)*"
- "*Making Micromobility Safer--interested in replicating NJ studies in TX.*"
- "*Scooter users' route choice and Street Configuration*"
- "*The role of street centralities in predicting scooter users. This project will be an improvement of my previous research entitled 'Modelling cyclists' route choice using Strava and OSMnx: A case study of the City of Glasgow' as there is a new software to perform better analysis.*"

- "*Research into segment-level modeling of trip origins and trip destinations.*"
- "*National Micromobility Panel: longitudinal look at e-scooter use and effects on other travel modes. We will get lots of travel behavior data, but we will not have access to person-level routes, only aggregates. A similar study with access to routes would help provide a basis for better understanding mode choice and tradeoffs.*"
- "*Trip data would be useful, but a lot of our application rely on really high ride volume across a large area.*"

86% of the respondents reported that the ScooterLab workshop was helpful in establishing a foundational connection with this research community, with the remainder reporting it as somewhat helpful.

93% reported they were interested in future collaboration with ScooterLab, after attending the workshop—one answered maybe.

To facilitate future ScooterLab collaboration, six participants indicated they would or might need additional resources. Respondents described three specific needs for collaboration, as follows:

- *"Suburban scootershare case studies."*
- *"Data and collaborators."*
- *"A data aggregation portal to identify trip data sources across cities would be very helpful. I know that a number of other researchers could also benefit from this, because data wrangling is a time consuming process of reaching out and communicating with cities."*

Future research topics indicated by survey respondents included:

- *"Better understanding of how people use scooters and make travel decisions. Real actions vs. intentions."*
- *"mainly interested in behavior and safety impacts of e-scooters. How do these provide more access for some populations? How can they be made safer?"*
- *"What type of street-level features may increase e-scooter crash risks and how does it vary by time, space, and different type of users."*
- *"scootershare usage in suburban areas"*
- *"developing geoprivacy protection methods to facilitate data sharing process"*
- *"What is the role of traffic noise in route choice?"*
- *"Scooter route choice. I.e. given multiple routes of approximately equal distance, what are the determinants of which routes scooter drivers select? In specific, does the existence of appropriate infrastructure, such as bike lanes, have an influence?"*
- *"viability of micro-mobilities for utilitarian travel"*

- *"Crash analysis of micro-mobility modes"*
- *"Micromobiliy's role in the 10/20 minute city"*
- *"How does e-scooter use complement or replace other modes of travel? For scooter lab to help answer this question, participants would have to be riding off-campus and preferably the population would include more than college students. We would need a way to survey people (after trips), and access to GPS data but probably not other sensor data."*

In conclusion, the post-workshop survey indicated broad success of the workshop, with participants providing detailed conceptions of their desired collaborations with ScooterLab.

3. Workshop Summary and Next Steps

The 2021 ScooterLab workshop successfully brought together researchers and students from diverse scientific disciplines and technical backgrounds to discuss the various design, deployment, operational, and usage issues related to the planned ScooterLab community research infrastructure. The meeting provided a platform for the scientific community interested in micromobility and micromobility-supported research, to network and learn more about each other's research contributions. It also generated lively discussions on various topics of mutual interest and useful feedback for the PIs (of NSF project 2016717) who are currently engaged in the design and planned deployment of the ScooterLab community research infrastructure/testbed. This discussion and feedback will be extremely critical to the PIs in designing and deploying an open, inclusive, and state-of-the-art infrastructure/testbed which will fuel the next generation of research in Machine Learning & Artificial Intelligence, High Performance Computing, Security and Privacy, Mobility Modeling, Urban Planning & Policy, and Civil & Transportation Engineering.

As a follow-up to this workshop, the PIs will plan smaller and more focused meetings with the participants in the coming months to collect additional feedback and research requirements regarding the planned ScooterLab testbed. The PIs also plan to complete the design and development of the remaining e-scooter prototypes. Prototype details will be shared with the community in a timely fashion to obtain feedback on their design and capabilities. The PIs intend to submit a full proposal to NSF's CISE Community Research Infrastructure (CCRI) program in January 2022 for completing the development and deployment of ScooterLab. The suggestions and feedback from the research community through this workshop will be very important and useful to the PIs in drafting a robust and convincing research and development plan to NSF. Lastly, the PIs also plan to organize similar events and workshops in the future to continue to engage the micromobility research community.

Appendix 1: Workshop Invitation/Call for Participation

Workshop on a Community Testbed to support Micromobility Research
Topics span AI, Machine Learning, Transportation Safety, Security, Privacy
Transportation Planning, and Big Data

The University of Texas at San Antonio (UTSA) received a planning grant from NSF to build and deploy a community research infrastructure in the form of a micromobility (specifically, e-scooter) testbed on UTSA campuses, referred to as ScooterLab. Vehicles in this testbed will be equipped with state-of-the-art sensing capabilities to collect large amounts of highly contextual data, to advance research in the areas of micromobility and transportation systems, urban planning, public policy, user privacy and security, AI/machine learning, high performance computing, and big data systems and algorithms. To create a testbed that holistically serves the interests and needs of diverse sections of the research and academic community, we are organizing a series of workshops and community engagement events to solicit critical feedback from the research/academic community vis-à-vis ScooterLab and to build potential interdisciplinary research partnerships that will leverage the ScooterLab testbed. As part of this series of events, we will be organizing the second virtual workshop primarily geared towards researchers worldwide across these topics.

A summary of the planned event is below:

What is this workshop about?	Planning for ScooterLab – A community testbed to support micromobility research
Who should attend?	Researchers and practitioners in areas such as AI/machine learning, high performance computing, urban planning, transportation engineering, public policy, security, privacy, and Big Data, to name a few. **If data from this testbed will be useful to you in your research, then you should attend!**
When is the workshop?	June 11 or June 18, 2021, depending on responses
How do I attend the workshop?	Zoom link for the workshop will be emailed to the registered participants.
How can I register/RSVP to attend the workshop?	https://scooterlab.utsa.edu/workshop2.php
Where can I find more information about ScooterLab?	https://scooterlab.utsa.edu/index.php

If you have any questions or concerns, please feel free to contact us at: scooterlab@utsa.edu.

We look forward to seeing you at the workshop!
Murtuza Jadliwala, Greg Griffin, Anindya Maiti, and Sushil Prasad.

This workshop is supported by the National Science Foundation award#2016717, CCRI: Planning:ScooterLab: Development of a Programmable and Participatory e-Scooter Testbed to Enable CISE-focused Micromobility Research, Principal Investigator Murtuza Jadliwala, Co-PIs Greg Griffin, Anindya Maiti, and Sushil Prasad.

Appendix 2: Workshop Agenda

Time	Topic
9:00 am – 9:05 am	Welcome and Introductions *Murtuza Jadliwala*
9:05 am – 9:15 am	ScooterLab Overview *Anindya Maiti*
9:15 am – 9:30 am	ScooterLab Progress *Raveen Wijewickrama*
9:30 am – 10:00 am	Lightning Talks *Chaired by Anindya Maiti* "Current and Future E-Scooter Mode Substitution: Measurements and Outcomes" by Dillon Fitch, University of California at Davis "IoRT Cloud Survivability Framework for Autonomous Systems" by Mauricio Gomez, University of Texas at San Antonio "Testbeds for Cybersecurity Experimentation and Test" by Terry Benzel, University of Southern California "Modelling Cyclists' Route Choice Using Strava and OSMnx: A Case Study of The City of Glasgow" by Mohammad Alattar, University of Aberdeen "Micromobility Research Efforts in Nashville, TN", by Will Barbour, Vanderbilt University "What Type of Infrastructures Do E-Scooter Riders Prefer? A Route Choice Model" by Wenwen Zhang, Rutgers University "A Segment-Level Model of Shared Electric Scooter Origins & Destinations" by Louis Merlin, Florida Atlantic University "Making Micromobility Safer" by Clinton Andrews, Rutgers University "The Need to Change Streets to Support the 20 Minute City" by Kevin Krizek, University of Colorado Boulder "Can Scootershare Work in Suburbia?" by Ray Atkinson, Clackamas Community College "The Impacts of Geomasking on Travel Time Estimation Errors" by Junghwan Kim, Harvard University

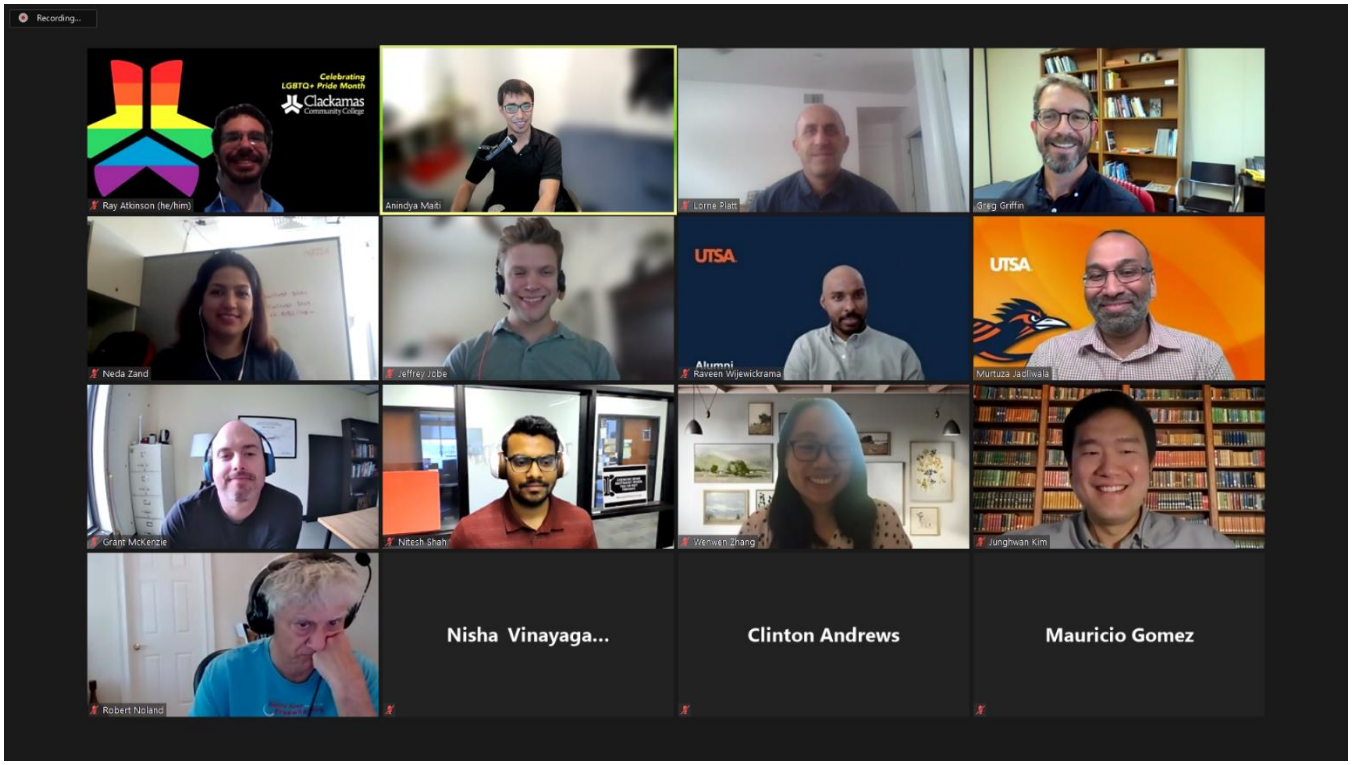
	"Do E-Scooters Fill Mobility Gaps and Promote Equity? A Spatiotemporal Analysis Using the GBFS Data" by Jacob Yan, University of Florida "Extracting Mobility Signatures for Actionable Urban Insight" by Grant McKenzie, McGill University "Micromobility and Smartphone Internet Access in the US" by Greg Griffin, University of Texas at San Antonio "Security and Safety Challenges in Modern Micromobility Systems" by Murtuza Jadliwala, University of Texas at San Antonio	
10:00 am – 10:10 am	Break	
10:10 am – 11:10 am	Breakout Theme #1: Engineering, development, and deployment. *Session Chair: Murtuza Jadliwala*	Breakout Theme #2: Customizable data collection and research enabled. *Session Chair: Anindya Maiti*
11:10 am – 11:30 am	Graduate Student Poster Session *Chaired by Raveen Wijewickrama* "Why do people take e-scooter trips? Big Data and Unsupervised Machine Learning insights on temporal and spatial usage patterns" by Nitesh Shah, The University of Tennessee, Knoxville "Impact of E-Scooters on Pedestrian Safety: A Field Study Using Pedestrian Crowd-Sensing" by Nisha Vinayaga Sureshkanth, The University of Texas at San Antonio "Bike Share System & User Responses to COVID-19" by Jeffrey Jobe, The University of Texas at San Antonio	
11:30 am – 12:30 pm	Breakout Theme #3: Research data publication best practices. *Session Chair: Greg Griffin*	Breakout Theme #4: Data analysis and visualization. *Session Chair: Murtuza Jadliwala/Anindya Maiti*
12:30 pm – 12:45 pm	Final Remarks *Greg Griffin*	

Appendix 3: Workshop Registrants

First name	Last name	Organization
Houssam	Abbas	Oregon State University
Mohammad	Alattar	University of Aberdeen
Clinton	Andrews	Rutgers, The State University of New Jersey
Sameer	Aryal	University of Tennessee Knoxville
Ray	Atkinson	Clackamas Community College
Will	Barbour	Vanderbilt University
Terry	Benzel	University of Southern California
Abhinav	Bhattacharyya	New York University
Jiannan	Cai	The University of Texas at San Antonio
Chris	Cherry	University of Tennessee
Marie-Soleil	Cloutier	INRS
Adam	Cohen	University of California at Berkeley
Justin	Darr	University of California at Davis
Subasish	Das	Texas A&M Transportation Institute
Dillon	Fitch	University of California at Davis
Mauricio	Gomez	The University of Texas at San Antonio
Greg	Griffin	The University of Texas at San Antonio
Mennatullah	Hendawy	TU Berlin
Murtuza	Jadliwala	The University of Texas at San Antonio
Asad Ali	Khan	The University of Texas at San Antonio
Junghwan	Kim	Harvard University
Kevin	Krizek	University of Colorado Boulder
Yingyan	Lin	Rice University
Evangeline	Linkous	University of South Florida
Luyu	Liu	The Ohio State University
Qi	Lu	The University of Texas San Antonio
Grant	McKenzie	McGill University
Louis	Merlin	Florida Atlantic University
Robert	Noland	Rutgers University
Ryanne	Ototivo	University of Colorado - Denver
Kaan	Ozbay	New York University
Lorne	Platt	California State University at Los Angeles
Mohammad	Rahman	Florida International University
Stefan	Robila	Montclair State University
Greg	Rybarczyk	University of Michigan - Flint
Morteza	Safaei Pour	The University of Texas at San Antonio
Nitesh	Shah	The University of Tennessee, Knoxville
Greg	Shannon	CyManII @ UTSA
Travers	Travers	Simon Fraser University

Zihang	Wei	Texas A&M University
Jacob	Yan	University of Florida
Myriam	Zakhem	Southern Methodist University
Neda	Zand	University of Texas at San Antonio
Wenwen	Zhang	Rutgers University
Fumin	Zhang	Georgia Institute of Technology

Appendix 4: Workshop Screenshot



Appendix 5: Final Survey

UTSA ScooterLab Post Workshop Survey

Q1 Please enter your preferred name.

_____

Q2 After attending the workshop, would you be interested in further future collaboration with ScooterLab?

- ○ Yes (1)
- ○ Maybe (2)
- ○ No (3)

Q3 Would ScooterLab, or the data produced from it, be useful (or would have been useful) to you in any of your current or past research projects? If so, please provide details such as a title and brief description of these projects.

- ○ Yes (1) _____
- ○ No (2)

Q4 If participating in future collaboration with ScooterLab, are there any specific research questions you are interested in? If so, please briefly describe.

_____

_____

_____

_____

_____

Q5 If participating in future collaboration with ScooterLab, are any additional resources necessary to facilitate your research? If so, please briefly describe.

- Yes (1) _____
- Maybe (2) _____
- No (3)

Q6 Was the ScooterLab workshop helpful in establishing a foundational connection with this research community?

- Yes (1)
- Somewhat helpful (2)
- No (3)

Q7 If you would like the ScooterLab webpage to include a link to your related project, please paste the URL below.

_____

_____

_____

_____

_____