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Mobility on Demand

A Smart, Sustainable, and Equitable Future

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Mobility on Demand

A Smart, Sustainable, and Equitable Future

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Executive Summary

The market for personal mobility is changing rapidly due to shifting demographics and social trends, as well as technological advances such as smartphones, information processing, and widespread data connectivity. Mobility on Demand (MOD) is an innovative transportation concept evolving around connected travelers, where consumers can access mobility and goods delivery services on demand by dispatching or using public transportation, shared mobility, courier services, urban air mobility, and other innovative and emerging technologies. The U.S. Department of Transportation (DOT) defines MOD as a concept based on the principle that transportation is a commodity where modes have economic values that are distinguishable in terms of cost, journey time, wait time, number of connections, convenience, and other attributes. Modes facilitated through MOD providers can include carsharing, bikesharing, carpooling–vanpooling, ridesourcing, scooter sharing, microtransit, shuttle services, public transportation, and other innovative and emerging transportation solutions. MOD has the potential to

- Embrace the needs of all users (travelers and shippers), public and private facilities, and services across all modes—including motor vehicles, pedestrians, bicycles, public transit, for-hire vehicle services, carpooling/vanpooling, goods delivery, and other transportation services;
- Enable transportation system operators and their partners to monitor, predict, and influence conditions across an entire mobility ecosystem and region;
- Receive data inputs from multiple sources and provide response strategies geared to various operational objectives;
- Incorporate public-sector objectives and interactions related to transportation system performance; and
- Improve transportation system efficiency and increase the accessibility and mobility of all travelers.

On January 13, 2019, the U.S. DOT and the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine cohosted a workshop on Mobility on Demand—A Smart, Sustainable, and Equitable Future at the 98th Annual Meeting of the Transportation Research Board in Washington, D.C. The workshop was sponsored by the following standing committees and subcommittees:

- Emerging and Innovative Public Transport and Technologies Committee (AP020);
- Shared-Use Mobility and Public Transit Subcommittee [AP020(1)];
- Emerging Ridesharing Solutions Joint Subcommittee [AP020(2)];
- Automated Transit Systems Committee (AP040);
- Transportation Demand Management Committee (ABE50); and
- Regional Transportation Systems Management and Operations (AHB10).

Organization of this workshop was made possible by the standing committee and subcommittee sponsors and the organizing committee members: Susan Shaheen, Transportation Sustainability Research Center (TSRC), University of California (UC) Berkeley; Gustave Cordahi, Booz Allen Hamilton; Bob Sheehan, Intelligent Transportation Systems Joint Program

Office (ITS-JPO), U.S. DOT; Gwo-Wei Torng and Faith Hall, Federal Transit Administration (FTA), U.S. DOT; and Jeffrey Chernick, RideAmigos. The organizing committee would like to acknowledge all of the efforts to support the workshop by Adam Cohen and Prachi Vakharia.

The workshop facilitated a dialogue among over 150 participants from public-sector organizations, private companies, nonprofit research groups, and educational institutions. Government, industry, and academic thought leaders presented and participated in panel discussions with the audience about the pilot projects, public–private partnerships, research, and next steps, emphasizing the future of multimodal MOD. In the second half of the workshop, attendees participated in interactive breakout sessions and reported back on next steps for preparing for the transition to autonomy and developing public policy, such as pricing to optimize sustainability and ensure equitable outcomes. The workshop emphasized the role of public transit, shared mobility, and automation shaping the future of mobility. The workshop also highlighted key opportunities for public policies related to equity, pricing, rights-of-way management, public transit automation, and shared automated vehicle deployments.

The workshop addressed several key goals:

- Presenting on the latest findings of MOD demonstration projects;
- Enhancing public transit industry preparedness for enabling mobility solutions and technologies (both public and private);
- Advancing adoption of mobility management into existing transportation operations through a mobility marketplace approach;
- Highlighting the role of parking and land use;
- Reviewing FTA's MOD Sandbox Demonstration and TRB's Preparing for Automated Vehicles and Shared Mobility Forum; and
- Developing a research agenda to support an equitable and sustainable transition to shared automated vehicles, including pricing strategies for curb access and other rights-of-way management policies and practices.

The workshop focused on many of the new trends in MOD. The role of MOD and vehicle automation were discussed in a variety of contexts and how these innovations are and will continue to change the way people travel. The need for equity and not leaving anyone behind was highlighted throughout the panel and breakout sessions as discussions highlighted how it is important to be as inclusive as possible, ensuring access to individuals lacking digital access, those living in lower-density communities, households of all socioeconomic backgrounds, and people with disabilities. Key insights and discussion points from the workshop include the following:

1. Key performance measures for MOD and shared automated vehicles (AVs) are safety, affordability, reliability, and availability to all. Measuring these metrics requires a greater understanding and response to individual and societal goals, such as protecting traveler safety; understanding traveler needs and preferences; ensuring comfortable and convenient travel; advancing education, health, and safety; ensuring environmental sustainability; and more broadly, getting people to where they want to go.
2. Improving data sharing, data accessibility, and data integration are key to the success of MOD and shared AVs. Moreover, there is a need for a platform that can integrate data seamlessly and provide the user with easy access and a simple payment method for all the

transportation methods used in one origin–destination trip.

3. Emerging lessons learned suggest that data sharing and integration; forming public–private partnerships; defining and ensuring equitable outcomes; and preparing for the transition to automated public transportation, shared automated vehicles, and other automated applications represents a notable opportunity and challenge.
4. Innovation is key to aligning funding with transformative changes in the transportation network, recognizing diverse traveler needs, improving understanding of MOD, and maximizing the opportunities of automation.

This workshop synopsis covers findings and discussions from the event and summarizes the key topics explored throughout the day. The workshop commenced with introductions from the day's facilitators: Susan Shaheen of TSRC and the Department of Civil and Environmental Engineering at UC Berkeley; Jeffrey Chernick of RideAmigos; and Robert Sheehan of the ITS-JPO of the U.S. DOT.

Following participant introductions, the workshop included three expert panel sessions. Key points made by each panel are summarized below. Next, findings are summarized from the interactive breakout sessions. The breakouts were organized into four topic areas:

1. Automation and Public Transportation;
2. Shared Automated Vehicles;
3. Rights-of-Way Management and Pricing to Optimize Sustainability; and
4. Accessible and Equitable Outcomes.

Finally, closing thoughts and key takeaways are presented from the workshop. The workshop agenda is provided as Appendix A, and copies of the slide decks are provided as Appendix B.

Panel Sessions

SESSION 1: WORKSHOP OVERVIEW AND PARTICIPANT INTRODUCTIONS

The workshop started with an overview by Susan Shaheen and Jeffrey Chernick. Chernick provided a brief history of the annual workshop series since 2012. Shaheen set the stage for the day by presenting an overview of the agenda focusing on MOD in the morning and pivoting to automation in the afternoon. This was followed by brief participant introductions. Robert Sheehan of FHWA's ITS-JPO provided a brief introduction welcoming workshop participants. Representatives from the FTA participated on the workshop organizing committee.

SESSION 2: FROM TECHNOLOGY TO POLICY: LESSONS LEARNED FROM MOBILITY ON DEMAND PILOT PROJECTS

The second session of the morning, moderated by Gustave Cordahi of Booz Allen Hamilton, consisted of an overview of lessons learned from MOD deployments across the country. This included six expert panelists: Yi-Chang Chiu, Metropia; Jeff Ericson, Ruby Ride; Jonathan Steketee, Livermore Amador Valley Transit Authority; Elliot Martin of the TSRC at UC Berkeley; and Sharon Feigon of the Shared-Use Mobility Center (SUMC).

Cordahi opened the panel providing background on the projects, panel participants, and partnerships represented in the session. Cordahi provided an introduction to the FTA's MOD Sandbox demonstration projects, the MOD Innovation and Knowledge Accelerator, other MOD deployments and perspectives represented on the panel. FTA is conducting research on new service options in combination with available technologies that allow for greater individual mobility. FTA's MOD Sandbox Demonstration Program provides a venue through which integrated MOD concepts and solutions—supported through local partnerships—are demonstrated in real-world settings. FTA seeks to fund project teams to innovate, explore partnerships, develop new business models, integrate public transit and MOD solutions, and investigate new, enabling technical capabilities such as: integrated payment systems, decision support, and incentives for traveler choices. Importantly, the MOD Sandbox also provides FTA the opportunity to measure project impacts and assess how existing FTA policies and regulations may support or impede these new service transportation models through evaluation of all project efforts. FTA's Innovation and Knowledge Accelerator initiative creates a structure through which MOD Sandbox participants and others interested in implementing shared mobility programs can exchange ideas, discuss lessons learned, and offer mutual support. FTA's On-Ramp program provides an opportunity for public transit agencies with promising MOD concepts to receive expert assistance to build those concepts into workable projects.

Elliot Martin of the Transportation Sustainability Center as UC Berkeley presented on the independent evaluation for the MOD Sandbox Demonstration program. The MOD Sandbox aims to examine issues and explore opportunities and challenges for public transportation as they relate to technology-enabled mobility services, including ways that public transit can learn from, build on, and interface with innovative transportation modes from a user, business model, technology, and policy perspective. The objectives of the sandbox include:

1. Enhancing transit industry preparedness for MOD;
2. Assisting the transit industry to develop the ability to integrate MOD practices with existing transit services;
3. Validating the technical and institutional feasibility of innovative MOD business models, and documenting MOD best practices that may emerge from the demonstrations;
4. Measuring the impacts of MOD on travelers and transportation systems; and
5. Examining relevant public-sector and federal requirements, regulations, and policies that may support or impede transit sector adoption of MOD.

For Fiscal Year 2016, FTA announced 11 MOD Sandbox grantees (Figure 1).

Martin provided a brief overview of the MOD Sandbox grantees and the independent evaluation process. Martin said the evaluation is performing three types of surveys depending on the particular MOD project and evaluation plan: (1) retrospective surveys (users surveyed once at least 6 months after the demonstration launch); (2) before-and-after surveys (surveying users twice at the beginning of the demonstration and later in the deployment; and (3) recent trip surveys (short two- to three-question surveys given after users take trips at a specified frequency). Martin briefed that there are four surveys ongoing: Bay Area Rapid Transit (BART), Dallas Area Rapid Transit, Valley Metro, and Tri-County Metropolitan Transportation District (TriMet). Additional surveys for the other seven MOD Sandbox sites will launch throughout 2019. For more information on the MOD program, please see https://rosap.ntl.bts.gov/view /dot/34258 and https://www.transit.dot.gov/research-innovation/mobility-demand-mod-sandbox-program.

Yi-Chang Chiu of Metropia provided an overview of the Pima County MOD Sandbox project with Pima County Regional Transportation Authority (RTA). The project officially launched in December 2018. The AMORE (Adaptive Mobility with Reliability and Efficiency) pilot program allows selected participants to schedule free door-to-door "transit hailing" service with RubyRide through a smartphone app. Funded by the FTA MOD Sandbox, AMORE's goal

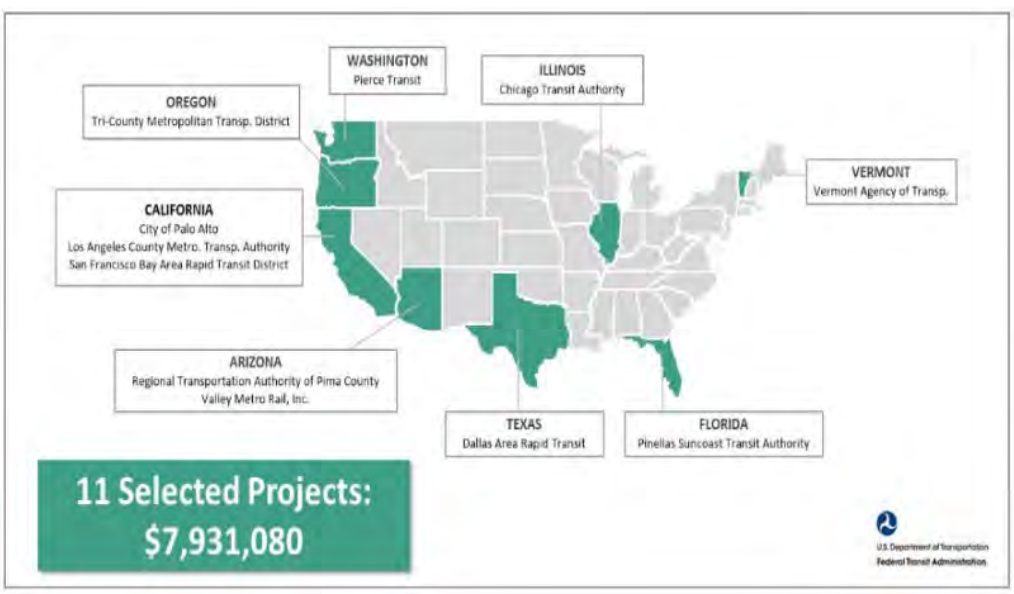


FIGURE 1 MOD Sandbox Grantees (FY16).

is to increase affordable transportation options throughout the region. Jeff Ericson from RubyRide discussed the challenges of data sharing while protecting individual user privacy. He said this is one of the main challenges with public–private collaboration.

Jonathan Steketee from the Livermore Amador Valley Transit Authority started by talking about the declining ridership and increasing operational costs that caused the agency to explore new partnership opportunities with ridesourcing that ultimately evolved into the GoDublin! program. Jonathan provided an overview of the service, a brief history of the pilot and soft launch, as well as the critical importance of having an independent third-party evaluation. Key findings from the independent evaluation that were presented included that most trips were weekday peak and midday trips; most trips were 1 to 3 mi and 7 to 8 min of waiting and 8 to 9 min of traveling; and first-mile/last-mile connections between low-density residential neighborhoods and BART were among some of the most popular origin-and-destination pairs. Finally, Jonathan noted that GoDublin average subsides per trip were lower with GoDublin! than fixed route service.

Sharon Feigon of the SUMC served as a commentator on the panel. She emphasized highlighted the importance of integrating MOD with public transportation to provide flexible multimodal options. Feigon discussed their center's role in the MOD Innovation Knowledge Accelerator and working with stakeholders to support MOD on-ramp efforts. Feigon expressed optimism and progress toward a multimodal future. She concluded by recognizing the challenges associated with public–private partnerships and the importance of including all stakeholders in MOD deployments.

SESSION 3: THE FUTURE OF MOBILITY ON DEMAND—PART 1

In the third session, experts in this panel spoke about future MOD and multimodal integration. Many issues were covered, such as multimodal measures, fare integration, mobility marketplace, and the role of public–private partnerships.

Moderator Bob Sheehan of the ITS-JPO opened by introducing and defining MOD as an innovative transportation concept evolving around connected travelers, where consumers can access mobility and goods delivery services on demand by dispatching or using public transportation, shared mobility, courier services, urban air mobility, and other innovative and emerging technologies. Sheehan emphasized that MOD a concept is based on the principle that transportation is a commodity where modes have economic values that are distinguishable in terms of cost, journey time, wait time, number of connections, convenience, and other attributes. Sheehan discussed early lessons learned for the MOD program including: (1) the importance of partnerships and data agreements; (2) the need to identify viable pricing and business models; and (3) the critical importance of ensuring equity and complete trip accessibility for all users. Sheehan introduced Shari Schaftlein of the FHWA Office of Planning who spoke of the importance of incorporating MOD into long-range planning processes and performance measures. She discussed the Mobility Innovation Research and Development working group that shares this expertise within the U.S. DOT. She discussed the growing role of multimodal micromobility design, curb space, and rights-of-way management for a growing number of low-speed and active transportation modes. She also highlighted the importance of monitoring equity outcomes for MOD.

Chris Pangilinan of Transit Center spoke about how to develop performance indicators for MOD. He emphasized the need for agencies to develop core traveler-centric performance

metrics (e.g., time, budget, reliability, availability, and safety). Emphasizing "safety, affordability, reliability, and availability to all," Pangilinan said that measuring these metrics requires a greater understanding and response to individual and societal goals, such as: (1) protecting traveler safety; (2) understanding traveler needs and preferences; (3) ensuring comfortable and convenient travel; (4) advancing education, health, and safety; ensuring environmental sustainability; and (5) more broadly, getting people to where they want to go. In addition to traveler-centric metrics, Pangilinan also discussed three different tiers of performance indicators including: (1) Tier 1: system-centric metrics; (2) Tier 2: regional-centric metrics; and (3) Tier 3: nation-centric metrics.

Tham Nguyen of LA Metro's Office of Extraordinary Innovation spoke about the importance of public agencies being open to innovation on a continual basis. She said Los Angeles wants to reimagine an innovative mobility future. Nguyen emphasized the importance of multimodal transportation investments. LA Metro adopted the Metro Vision 2028 Strategic Plan with the goal of doubling non-single occupant vehicle modes over the next decade. The strategic plan establishes a goal of a 10-min walk or roll to high-quality mobility options for all users. LA Metro is also considering pricing mechanisms to address travel demand. Nguyen discussed the agency's unsolicited proposal process that establishes broad goals and then asks the private sector to submit concepts to help LA Metro achieve these goals. LA Metro has received 122 unsolicited proposals to-date, including 16 for regional mega-projects. Nguyen discussed two MOD pilots including: a microtransit pilot and the MOD Sandbox first-and-last-mile connectivity pilot. Both pilots are launching in Q1 2019. She concluded by emphasizing the importance of fostering collaboration with internal and external mobility stakeholders.

Adam McGavock discussed Moovel's mission and how it aligns with macro trends driving the future of MOD. McGavovk said "Moovel's mission is to transform cities by providing the most convenient and sustainable mobility solutions with public transportation at its core." McGavock said it is forecast that there will be 8.9 billion smartphone subscriptions globally by 2024, and more than 80% of the world's population will live in cities by 2030. McGavock then transitioned from demographic trends to discussing technological trends impacting the future of MOD, namely the convergence of sharing, electrification, connectivity, and automation. McGavock posed two key questions for participants:

1. How do public agencies keep pace with technology?
2. How can we improve the way that agencies and vendors work together?

McGavock concluded by emphasizing the importance of shared urban mobility and the role of data sharing to guide the entire industry to the next level.

SESSION 4: THE FUTURE OF MOBILITY ON DEMAND—PART 2

In the afternoon, experts highlighted the role of automation in the future of MOD. Moderator Adam Cohen of TSRC at UC Berkeley opened the session introducing the panel. Following his remarks were presentations by Annie Chang and Tim Weisenberger of SAE International, Gregory Winfree, Texas A&M Transportation Institute, presenting on behalf of TRB's Forum on Preparing for Automated Vehicles and Shared Mobility, and Rob Antoniak of Valley Metro.

Chang and Weisenberger discussed SAE International's role in automation and mobility standards. Chang discussed the recent release of J3163, Taxonomy and Definitions for Terms

Related to Shared Mobility and Enabling Technologies that provides standard terms and recommended practice for the use of shared mobility nomenclature. For more information, please see https://www.sae.org/standards/content/j3163_201809/. Weisenberger discussed J3016 Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems, the standard that established five levels of vehicle automation ranging from no automation (Level 0) to full automation (Level 5). For more information, please see https://www.sae.org/standards/content/j3016_201401/.

Next, Winfree discussed TRB's Forum on Preparing for Automated Vehicles and Shared Mobility. Winfree explained that the purpose of the forum is to bring together public, private, and research organizations to share perspectives on critical issues surrounding the deployment of automated vehicles and shared mobility and to support fact-based research needed to deploy these technologies in a manner and timeframe that informs policy to meet long-term goals. Key long-term goals discussed include: increasing safety, reducing congestion, enhancing accessibility, increasing environmental and energy sustainability, and encouraging economy development and equitable outcomes. As such, the forum has five focus areas: (1) impacts on safety; (2) social, environmental, and economic impacts; (3) data considerations; (4) transportation system impacts; and (5) cross-cutting issues. To do this, the forum is engaging a broad stakeholder community, sharing information and perspectives, identifying research needs and priorities, and facilitating research.

Antoniak of Valley Metro talked about Valley Metro's partnership with Waymo. Valley Metro began using Waymo's automated vehicle technology as part of a 2-year pilot program for first-and-last-mile connectivity that began in September 2018. The pilot began with a control group of employees who use Waymo vehicles to connect them from a bus or light-rail stop to their final destinations. Through a data sharing agreement, Waymo and Valley Metro will analyze information about the riders' experiences and adapt accordingly. The program anticipates expanding to the general public as part of a second phase later in 2019. Antoniak highlighted three key lessons learned, (1) be creative with available resources (e.g., leveraging funds from different sources); (2) be patient (building trust with partners and the public takes time); and (3) partner with the private sector (with understanding and flexibility).

Breakout Sessions

After Session 4, the workshop attendees organized into one of four breakout sessions and discussed one of four topics: (1) Automation and Public Transportation; (2) Shared Automated Vehicles (SAVs); (3) Rights-of-Way Management and Pricing to Optimize Sustainability; and (4) Accessibility and Equity Outcomes. Breakouts were conducted at each table by facilitators and notetakers and summarized by four breakout moderators (one for each discussion topic). Facilitators at each table followed a standard protocol intended to probe key questions applicable to MOD for these topics. The protocol asked participants to spend 75 min (approximately 25 min per topic area) discussing the following key questions:

1. What policies are needed to support the transition to an automated vehicle future for your table's focus area?
2. What are some possible solutions for addressing (your table's focus area) from the public and private-sector perspectives?
3. What role can research play in advancing challenges/solutions in the context of your table's focus area?

After a lively exchange of ideas in the breakout sessions, lead moderators of each breakout reported back the key ideas that came out of their respective discussions. Special thanks go to the following individuals for their role as facilitators and notetakers during the breakout session: Bob Sheehan, ITS-JPO; Allen Greenberg, FHWA; Marlene Connor, Marlene Connor Associates; Carolina Burnier, Noblis; Jean Ruestman, Michigan DOT; Amy Jacobi, Noblis; Amir Tafreshian, University of Michigan; Adam Davidson, World Resource Institute; Emily Ryou of Allstate/Arity; and Adam Stocker of TSRC, UC Berkeley.

AUTOMATION AND PUBLIC TRANSPORTATION

The first breakout session, automation and public transportation, was summarized by Marlene Connor of Marlene Connor and Associates and Amy Jacobi of Noblis.

Policy challenges and needs identified include:

- Labor and workforce impacts. At present, it is unclear if automated transit systems will replace existing jobs; change the role of drivers (e.g., passenger support/rider concierge); or create opportunities for new jobs (e.g., maintenance, high-tech jobs). Labor and workforce impacts could be real or perceived (i.e., public perception).
  - 49 U.S.C. § 5333(b) (formerly Section 13(c) of the Urban Mass Transportation Act) specifies that these protective arrangements must provide for the preservation of rights and benefits of employees under existing collective bargaining agreements, the continuation of collective bargaining rights, the protection of individual employees against a worsening of their positions in relation to their employment, assurances of employment to employees of acquired transit systems, priority of reemployment, and paid training or retraining programs.
- New metrics are needed to measure new types of automated transit services.

- Dedicated and prioritized rights-of-way are needed for automated transit systems.
- Policies that protect the safety of users and prevent crime and terrorism are needed on automated transit systems.
- Standardized rules and practices are needed across public transit agencies as automated vehicles are deployed in fleets.

Key solutions discussed include:

- Financial resources. More money is needed to expand public transit access for all.
- High occupancy vehicle (HOV)–automated transit lanes. Dedicated lanes for minimum passenger loads (e.g., four to six or more persons) could encourage public transit use.
- Education and outreach. Customer familiarization in advance of AV deployments is key to encourage adoption and acceptance. Pilots with college students is one outreach mechanism that could help encourage mainstreaming.
- Encouraging sustainable Adoption. Policies that encourage, incentivize, or require AV fleet ownership over private ownership. Disincentives to prevent and/or reduce zero occupant vehicles are needed.
- Safety. Policies that protect consumer safety in an automated transit vehicle are needed (e.g., late-night security, cameras).
- Preparing for the transformation. Institutional guidance can help prepare public agencies (and labor) for the transformation of assets from human driven to driverless transit systems.

Research needs identified include:

- New performance metrics. New performance metrics are needed to address an ever-changing transportation ecosystem, including automated transit services.
- Labor and workforce development. Research that identifies new labor roles and retraining programs for displaced workers is needed to prepare the workforce for automation.
- Life-cycle costs. There is a need to accurately quantify the life-cycle costs of automated transit systems (e.g., propulsion, infrastructure, support, etc.).
- Insurance and liability. More research is needed to understand the potential liability and insurance challenges with automated transit systems.
- Coordination with AVs. There is a need (though artificial intelligence, machine learning, or other mechanisms) to research and teach automated vehicle systems “manners” for interacting with one another (e.g., SAVs yield to automated transit vehicles).
- Operating policies. There is a need to identify an array of cross-cutting operating policies in a driverless transit future (e.g., passenger safety, homeland security–counter-terrorism).

SHARED AUTOMATED VEHICLES

The second breakout session, preparing for SAVs, was summarized by Carolina Burnier of Noblis and Adam Stocker of TSRC. Policy challenges and needs identified include:

- Safety. Including the safe operations of automated vehicles, pedestrian safety, and safety of passengers sharing a ride.

- Fleet management regulations. Ensuring equitable access for all users, including people with disabilities, low-income, unbanked, and other users.
- Congestion pricing. Temporal and occupancy-based pricing to optimize sustainable outcomes including reducing vehicle miles traveled and congestion and increasing average vehicle occupancy.

Key solutions discussed include:

- Funding. Additional funding and funding flexibility for SAV pilots.
- Workforce development. Programs to prepare for labor training/retraining and job placement in an automated vehicle future.
- Ride quality. Improving rider experience.
- First- and last-mile connections. Fostering partnerships to leverage SAVs for connectivity to public transportation.

Research needs identified include:

- Built environment. Understanding the impacts of SAVs on land use.
- Travel behavior. Understanding the social and behavioral impacts of vehicle automation.
- Economic impacts. Understanding the potential impacts of automation on value of time, labor, household expendable income, and macro-economic trends.
- Vehicle-to-vehicle infrastructure. Continuing research on cellular and dedicated short-range communications opportunities, challenges, and best practices.
- Multimodal planning. Methods for incorporating SAVs into land use and transportation modeling and long-range planning.
- Institutional readiness. Best practices to prepare public agencies for SAVs.

RIGHTS-OF-WAY MANAGEMENT AND PRICING TO OPTIMIZE SUSTAINABILITY

The third breakout session, rights-of-way management and pricing to optimize sustainability, was summarized by Allen Greenberg of FHWA and Adam Davidson of the World Resource Institute.

Policy challenges and needs identified include:

- Curb space management. Managing a finite amount of rights-of-way for an increasing number of modal needs and users (e.g., loading zones, last-mile delivery).
- Potential impacts of for-hire services. Are ridesourcing impacts an indicator for SAV?
- Pricing. Pricing rights-of-way access to prioritize sustainable outcomes, multimodality, and shared uses.

Key solutions discussed include:

- A variety of pricing mechanisms and structures were discussed as potential solutions to encourage higher occupancies and discourage congestion during peak periods.
- The breakout session also discussed potential strategies to manage the transition to

automation within the public rights-of-way.

- Pricing and its potential to support equitable outcomes was also discussed (e.g., pricing based on environmental footprints, funding for users with special needs, etc.)
- HOV infrastructure could be converted for AV and/or SAV use.

Research needs identified include:

- Pricing and Equity. There is a lack of research on implementation best practices for employing pricing. There is also a concern that pricing could have disparate impacts on low-income communities.
- HOV–High Occupancy Toll (HOT) Lane Conversion. More research is needed to understand if the travel behavior and environmental impacts of HOV–HOT lane conversions, such as the impacts on average vehicle occupancy (e.g., does improved lane performance result in increased occupancy or does it result in an increase in single occupant vehicles).
- Transitional Policies (i.e., HOV–SAV lane conversions). More research is needed to understand if HOV lanes could be converted to AV or SAV lanes and the potential impacts of such a conversion on average vehicle occupancy, pricing, users, and environmental outcomes.
- Test Corridors and Curb Environments. There is a need to develop test corridors and curb space management with ridesourcing–transportation network companies and SAVs through pilot programs.
- Modeling and Scenario Analysis. There is a need to model the potential impacts of emerging and innovative services on curb space, as well as the impacts of pricing on travel behavior.

ACCESSIBLE AND EQUITABLE OUTCOMES

The fourth breakout session, accessible and equitable outcomes, was summarized by Jean Ruestman of the Michigan DOT and Emily Ryou of Allstate/Arity.

Policy challenges and needs identified include:

- Defining equity. There is not a universally agreed upon definition of equity and all of its facets; legislative and regulatory definitions narrowly focus on protected classes [inclusive of race, national origin, Americans with Disabilities Act (ADA) etc.] but often exclude unbanked, low-income, and digitally impoverished households. Additionally, there is no consensus about the acceptability of universal design–accessibility (everyone can access all modes) versus universal mobility (everyone has access to a mode of transportation that can provide equivalent level of service).
- Equity versus business optimization. Equity outcomes can sometimes conflict with service provider goals of optimizing operations and business potential.
- ADA and AVs. There are numerous questions about ADA access in an AV future. Some key questions include
  - What should equitable service requirements be required for private companies as well as private individuals providing mobility services?
  - Should all vehicles be ADA compliant?
  - Should privately owned vehicles placed into a fleet service also be ADA compliant?

  - Will attendants or concierge services be required for older adults and people with disabilities?
- Temporal and spatial equity. Should there be standards for minimum levels of geographic and time-of-day service?
- Cross-cutting collaboration. More collaboration is needed to connect services that overcome equity issues (e.g., job training and placement, economic development, affordable housing, transportation). A comprehensive planning and policy process is needed to support equitable outcomes.
- Occupancy, pricing, and government regulation. There is another equity issue of prioritizing and incentivizing higher-occupancy modes. Pricing lower-occupancy modes and subsidizing higher-occupancy ones (e.g., feebates) is one example of how government regulation can help to support equitable outcomes.
- High fares. High (and increasing) public transit fares are having a disparate impact on those who need transit the most.

Key solutions discussed include:

- Prioritizing higher occupancy modes. Higher occupancy modes should be prioritized through pricing, curb space management, and other policies.
- Subsidies. Financial aid can help reduce the cost of services to end users with a variety of special needs.
- Data sharing. Compulsory data sharing could help public agencies audit service providers and aid in regulating equitable service provisions.
- Civil rights. Protected classes should be expanded to include a broader set of policy goals in the transportation context. Policies could also clarify applicability of civil rights to private and quasipublic service providers.
- Expanded definitions of equity. Expanding the definitions of equity (beyond vehicle accessibility) can help advance equitable outcomes for all.

Research needs identified include the following.

- There is a need to provide broader definitions of equity with performance metrics, guidance, and best practices for public agencies and service providers to monitor and enhance equitable outcomes.
- Researching international best practices and policy examples may be able to help enhance equitable outcomes in the United States.
- More research is needed to understand how the financial sector is addressing equity in light of future banking trends.
- There is a need to understand capabilities and gaps for MOD to serve emergency management functions (i.e., to prevent evacuation issues that occurred in Hurricane Katrina).
- More research is needed to guide public policy and prevent anti-trust issues with MOD providers (e.g., curb space or service provider monopolies) (e.g., equity among modes and service providers).
- Pilots and research are needed on rural MOD and AV applications to understand opportunities, challenges, best practices, and lessons learned.

Closing Thoughts and Key Takeaways

Cohen and Chernick reunited workshop participants in the closing plenary session for a final workshop summary and recap of the breakout sessions. MOD is changing rapidly and automation will contribute to fundamental changes in the marketplace, business models, societal impacts, and user needs.

KEY INSIGHTS

Key insights and discussion points from the workshop are listed below:

- Key performance measures for MOD are safety, affordability, reliability, and availability for all travelers and modes. Measuring these metrics requires a greater understanding and response to individual and societal goals, such as protecting traveler safety; understanding traveler needs and preferences; ensuring comfortable and convenient travel; advancing education, health, and safety; ensuring environmental sustainability; and more broadly, getting people to where they want to go.
- Traveler-centric metrics are the foundation of understanding MOD and meeting traveler needs. Additional tiers of metrics include system-, regional-, and nation-centric metrics. Understanding these different levels can help public agencies understand and develop appropriate metrics for different levels of government and uses.
- There are a lot of related cross-cutting research questions and gaps in knowledge with public transit automation and SAVs.

Key research gaps identified include:

- Metrics to understand the impacts of automation on public transportation. Research metrics are needed to guide to research on public transit automation and SAVs.
- Opportunities and challenges of artificial intelligence and machine learning. More research is needed on the opportunities and challenges of machine learning and artificial intelligence to understand the equity implications and potential outcomes on public agencies and society.
- Life-cycle cost estimation. There is a need to understand the life-cycle costs of automation to guide public agencies in procurement and capital investment decisions of innovative and emerging transportation technologies, including vehicle automation.
- Safety and security. There is a need to identify and advance an array of operating policies in a driverless transit future (e.g., passenger safety, homeland security–counter-terrorism).
- Impacts of automation on society. Greater research and understanding is needed on the impacts of automation (inclusive of public transit and SAVs) on the built environment, travel behavior, the economy, planning, and institutional readiness.
- Pricing. More research is needed on best practices for implementing a variety of pricing policies (e.g., cordons, time of day, occupancy, road tolls).
- Occupancy. More research is needed to understand the impacts of HOV–HOT lane

conversions and the potential role conversions can play to enabling physical AV infrastructure.

- Pilot testing. More pilots (and funding) are needed to test and evaluate policies, AV deployments, and rights-of-way management.
- Planning and modeling guidance. More research and guidance is needed to incorporate MOD AVs into modeling and scenario planning.
- Public policy. Research is needed in the areas of public policy and equity to ensure MOD is serving is meeting the needs of all users. A few key topics include:
    1. Expanding traditional definitions of equity;
    2. Overcoming technology and banking access challenges;
    3. Policies to encourage higher occupancies;
    4. Practices and policies to manage the rights-of-way today and prepare for a transition to AV future;
    5. Understanding of the impacts of MOD and AVs on the built environment, travel behavior, economy, planning, and institutional readiness; and
    6. Preparing public transportation for automation including workforce development, operating policies, life-cycle costs, and performance metrics.

The interactive breakout sessions provided an opportunity for the audience to get directly involved with the moderators after listening to the four sessions. A vibrant discussion ensued on policy challenges and needs; potential solutions; and research needs for maximizing opportunities and overcoming challenges for expanding MOD and preparing for automation. Many participants expressed the need to improve collective understanding of the impacts of automation (both public transit and SAVs), proactively advance public policy, and reverse and prevent the historic and new social inequities. In summary, the workshop facilitated a much-needed dialogue among MOD and AV experts and practitioners from diverse backgrounds and informed the audience about developments, challenges, and the future for MOD and automated transportation services.

APPENDIX A
WORKSHOP AGENDA

Mobility on Demand

A Smart, Sustainable, and Equitable Future

Sunday, January 13, 2019
9:00 a.m. to 4:30 p.m.
Walter E. Washington Convention Center
Washington, D.C.

The market for personal mobility is changing rapidly due to shifting social and cultural trends, as well as technological advances, such as smartphones, information processing, widespread data connectivity, and vehicle automation. MOD represents a sustainable vision for future mobility—energized by the constantly evolving world of innovation—that results in a safe, carefree, and reliable network of mobility options that are available to all travelers. This workshop highlights FTA MOD Sandbox, other MOD and shared AV initiatives, FTA's Strategic Transit Automation Research (STAR) program, and U.S. DOT's comprehensive effort to explore the challenges and approaches to advancing MOD.

In the afternoon, the workshop culminates in an interactive breakout session focused on the transition toward shared vehicle automation, including supportive policies. Participants will be asked to develop a research agenda to guide this transition through one of four breakout groups. We will conclude the workshop with a final summary session and closing remarks.

Key goals of the workshop include:

- Presenting on the latest findings of MOD demonstration projects;
- Enhancing public transit industry preparedness for enabling mobility solutions and technologies (both public and private);
- Advancing adoption of mobility management into existing transportation operations through a mobility marketplace approach;
- Highlighting the role of parking and land use;
- Reviewing the FTA's STAR and MOD programs and TRB's Preparing for Automated Vehicles and Shared Mobility Forum; and
- Developing a research agenda to support an equitable and sustainable transition to SAVs, including pricing strategies for curb access and other rights-of-way.

Organizers: Susan Shaheen, TSRC, UC Berkeley; Gustave Cordahi, Booz Allen Hamilton; Bob Sheehan, ITS-JPO, U.S. DOT; Gwo-Wei Torng and Faith Hall, FTA, U.S. DOT; and Jeffrey Chernick, RideAmigos.

Sponsors: TRB Emerging and Innovative Public Transport and Technologies Committee (AP020); Shared-Use Mobility and Public Transit Subcommittee [AP020(1)]; Emerging Ridesharing Solutions Joint Subcommittee [AP020(2)]; Automated Transit Systems Committee

(AP040); the Transportation Demand Management Committee (ABE50); and Regional Transportation Systems Management and Operations (AHB10).

Session 1: 9:00 a.m. to 9:30 a.m. (1/2 hour)

Workshop Overview & Participant Introductions

Susan Shaheen, *UC Berkeley*, Jeffrey Chernick, *RideAmigos*; Robert Sheehan, *ITS-JPO*

Session 2: 9:30 a.m. to 10:45 a.m. (1 hour and 15 minutes)

From Technology to Policy: Lessons Learned from MOD Pilot Projects

Gustave Cordahi, *Moderator*
Sharon Feigon, *SUMC, Commentator*

Pima County, AZ: AMORE
Yi-Chang Chiu, *RTA of Pima County*; Jeff Ericson, *Ruby Ride*

Livermore Amador Valley Transit Authority, CA: GoDublin
Jonathan Steketee, *LAVTA*

MOD Sandbox Independent Evaluation: Data Challenges, Findings, and Lessons Learned
Elliot Martin, *TSRC, UC Berkeley*

BREAK: 10:45 a.m. to 11:00 a.m.

Session 3: 11:00 a.m. to Noon (1 hour)

Future of Mobility on Demand—Part 1

MOD: What Are We Learning and What's Next?
Bob Sheehan, *ITS-JPO*; Shari Schaftlein, *FHWA Office of Planning*

Multimodal Mobility Measures
Chris Pangilian, *Transit Center*

Multimodal Integration
Tham Nguyen, *LA Metro*

Mobility Marketplace and Connected Traveler and Public–Private Partnerships: Focusing on Mobile Devices
Adam McGavock, *Moovel*

LUNCH BREAK: Noon to 1:30 p.m.

Session 4: 1:30 p.m. to 2:30 p.m. (1 hour)

The Future of Mobility on Demand—Part 2

Adam Cohen, *TSRC, UC Berkeley, Moderator*
Annie Chang and Tim Weisenberger, *SAE International*

TRB Forum on Preparing for Automated Vehicles and Shared Mobility
Gregory Winfree, *Texas A&M, Forum co-chair*; Rob Antoniak, *Valley Metro*

2:30 p.m. to 3:45 p.m. (1 hour and 15 minutes)

Preparing for a SAV Future of 2030

Breakout Session Protocol
Robert Sheehan and Allen Greenberg, *FHWA*

Advancements in technology, such as automated driving systems, are rapidly transforming the transportation system. We need to begin preparing for this transition today, particularly the public transit industry. Pricing of curb space and other rights-of-way will likely play a notable role in a 2030 SAV future. With the growth of flexible routing, one-way, and on-demand mobility solutions, public transportation systems of the future could operate very differently than they do today. This interactive breakout focuses on the world of public transportation automation (e.g., low-speed shuttles, shared AVs) and the policies needed to support this transition. Participants will be asked to create a vision, identify challenges to implementation, and outline a research agenda to help prepare for this SAV transition.

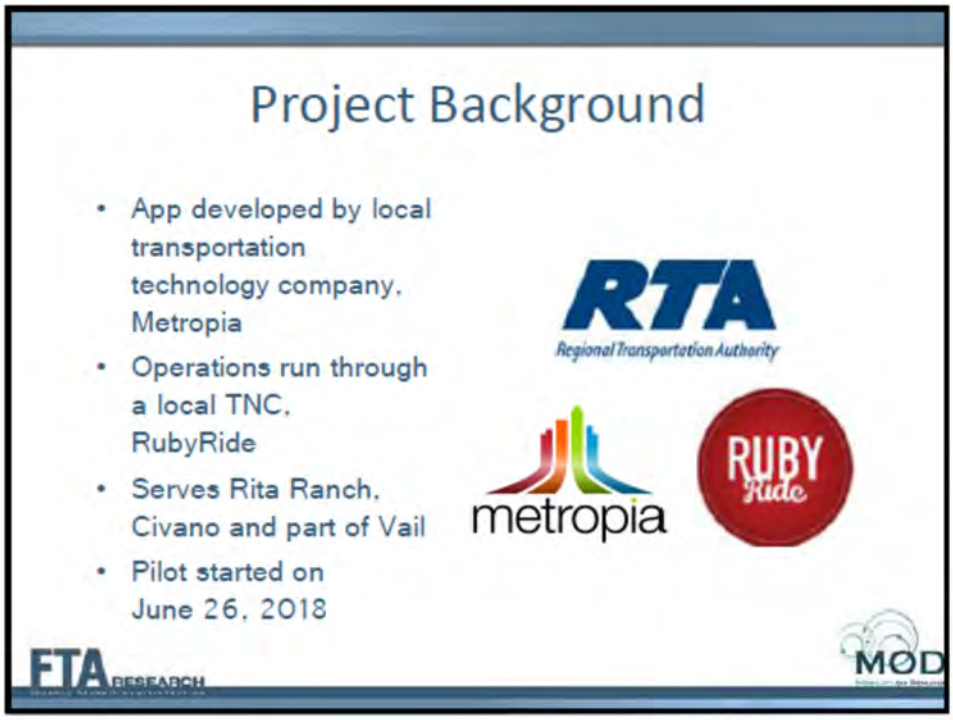
To do this, participants will be divided into four groups. Two groups will focus on SAV systems including: public transit shuttles and shared, automated conventional vehicles. The other two will focus on policies including road–curb access and pricing to optimize sustainability, accessibility, and equity outcomes. Each of the four groups will be assigned two moderators—one to lead the discussion and one to take notes. Each group will be asked to envision a public transportation system for 2030, identify the challenges to implementing their vision and/or strategy, and the research needed to prepare for this transition. This shared automated future could include first-/last-mile connections, mobility hubs, fixed or flexible route services, public and/or private solutions, and innovative modes that do not exist today. All groups will appoint a spokesperson to represent each group's vision for automated public transit and the policies needed to support the transition to 2030, along with the challenges and research needs.

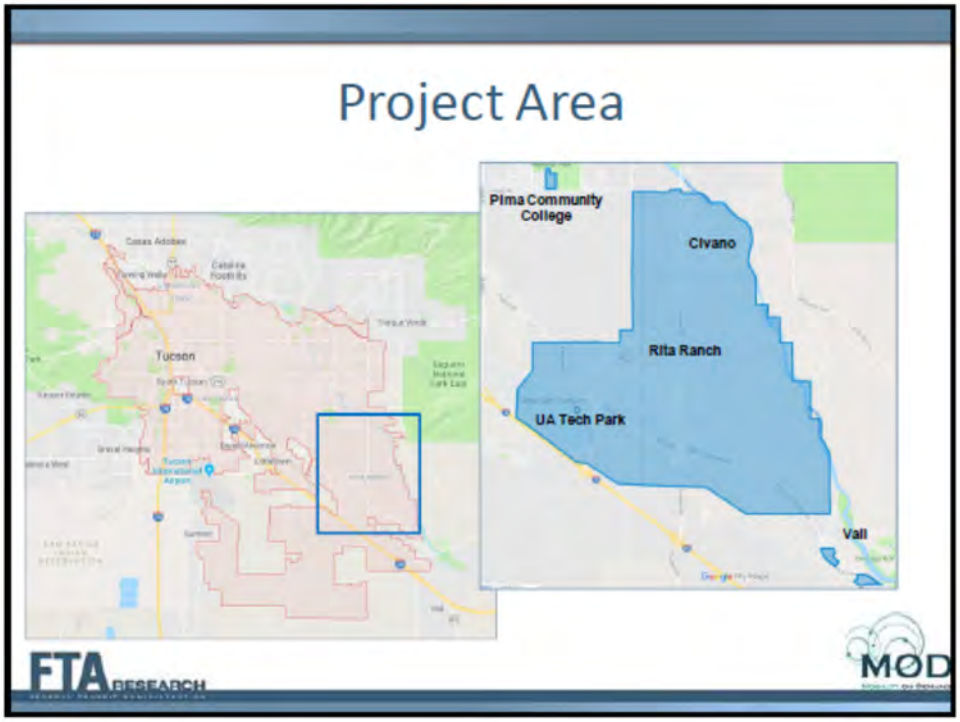
BREAK: 3:45 P.M. TO 4:00 P.M. (15 minutes)

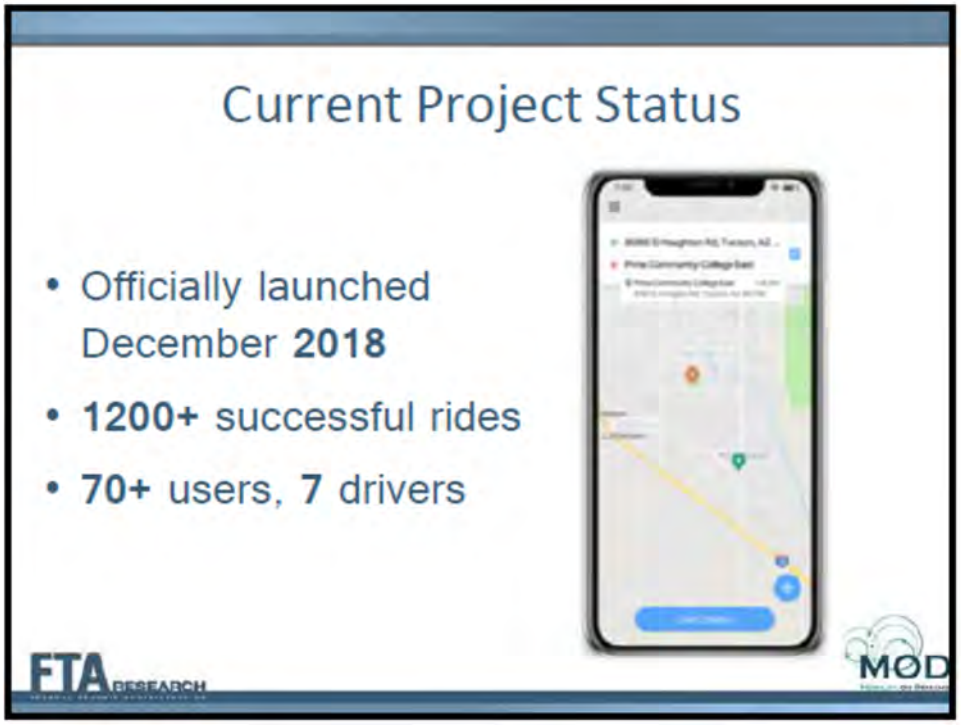
4:00 p.m. to 4:30 p.m. (1/2 hour)
Rapporteurs Report Back and Final Wrap Up
Four Rapporteurs from each breakout group.
Adam Cohen, *TSRC, UC Berkeley*; Jeffrey Chernick, *RideAmigos*

APPENDIX B

Slide Presentations




Project Area
Tucson
Pima Community College
Civano
Rita Ranch
UA Tech Park
Vail
FTA RESEARCH
MOD

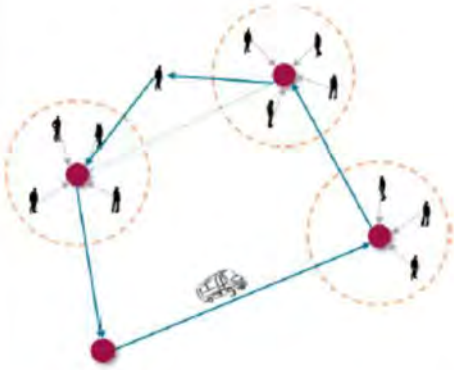

Current Project Status
• Officially launched December 2018
• 1200+ successful rides
• 70+ users, 7 drivers
FTA RESEARCH
MOD

What makes **AMORE** unique?

- Limited Service Area
- Paid Drivers
- Community Based
- Transit-Hailing

FTA RESEARCH 5 MOD

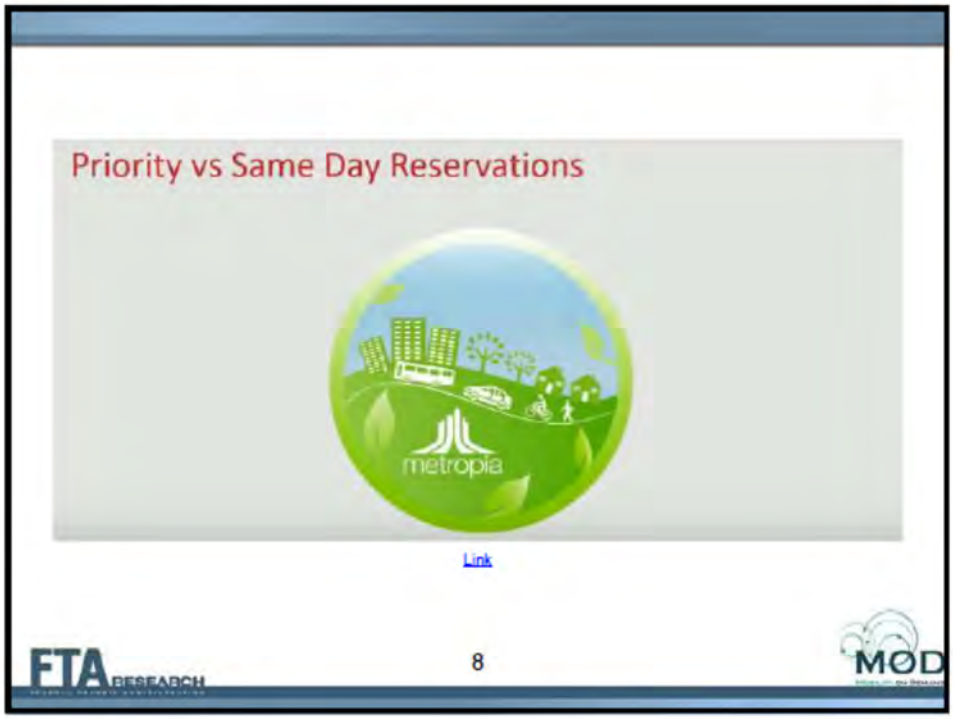
Transit-Hailing



- Priority (pre-scheduled) and Standard (Same Day) reservations
- Multiple pickups and drop-offs to maximize efficiency
- Dynamically determine the meet-up locations and balance system's travel time and fleet utilization
- Maximum fleet efficiency and increase service level
- Demand responsive stops and routes
- Connect to other mobility options
- Integrated transit payment (MaaS) – in planning

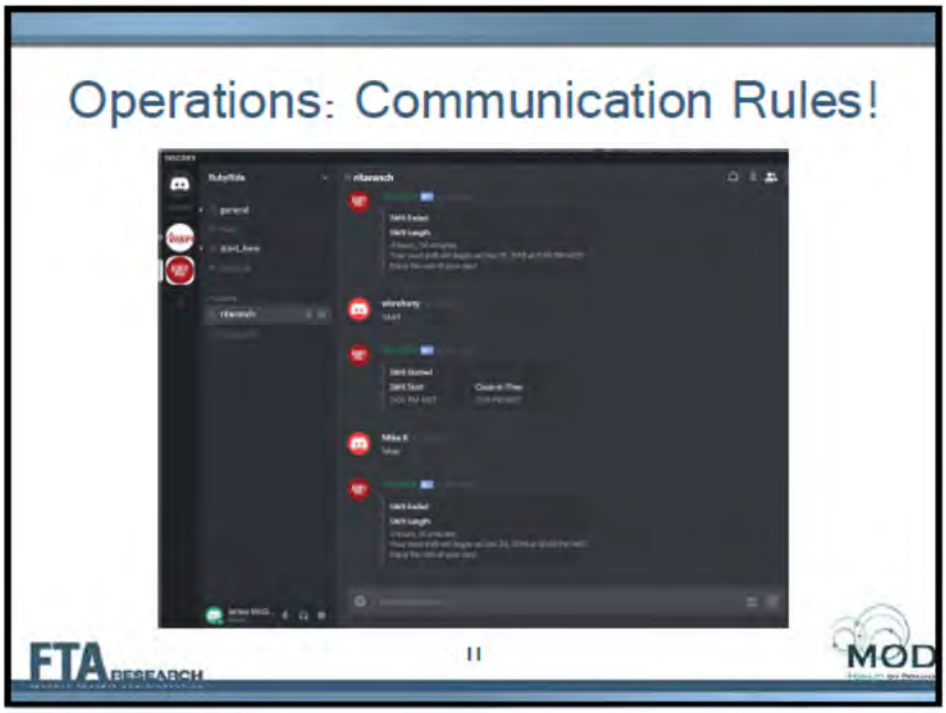
FTA RESEARCH 6 MOD

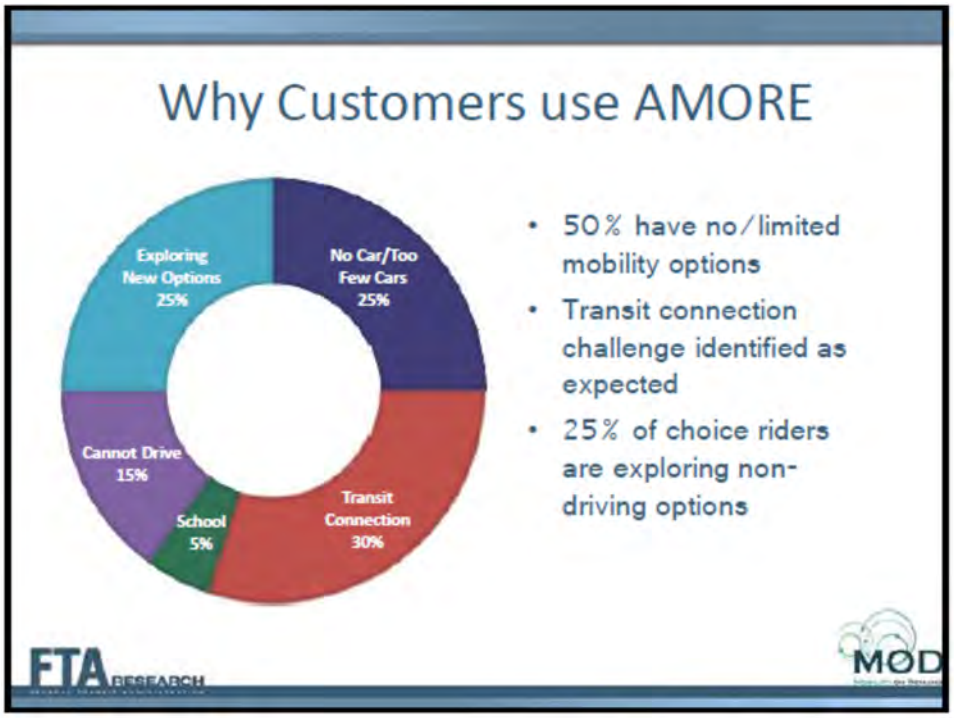

AMORE App Overview
Your Community,
Your Ride
Link
7


Priority vs Same Day Reservations
metropia
Link
8


AMORE in Action
9
FTA RESEARCH
MOD


What We've Learned
metropia
RTA
Regional Transportation Authority
RUBY Ride
10
FTA RESEARCH
MOD


Operations: Communication Rules!
FTA RESEARCH
MOD


Why Customers use AMORE
Exploring New Options 25%
No Car/Too Few Cars 25%
Cannot Drive 15%
School 5%
Transit Connection 30%
• 50% have no/limited mobility options
• Transit connection challenge identified as expected
• 25% of choice riders are exploring non-driving options
FTA RESEARCH
MOD


Where Customers Travel
TRIP PURPOSES
Non-medical Appointment
Grocery Shopping
Social Outings
Running Errands
School
Work
0
10
20
30
40
50
60
70
%
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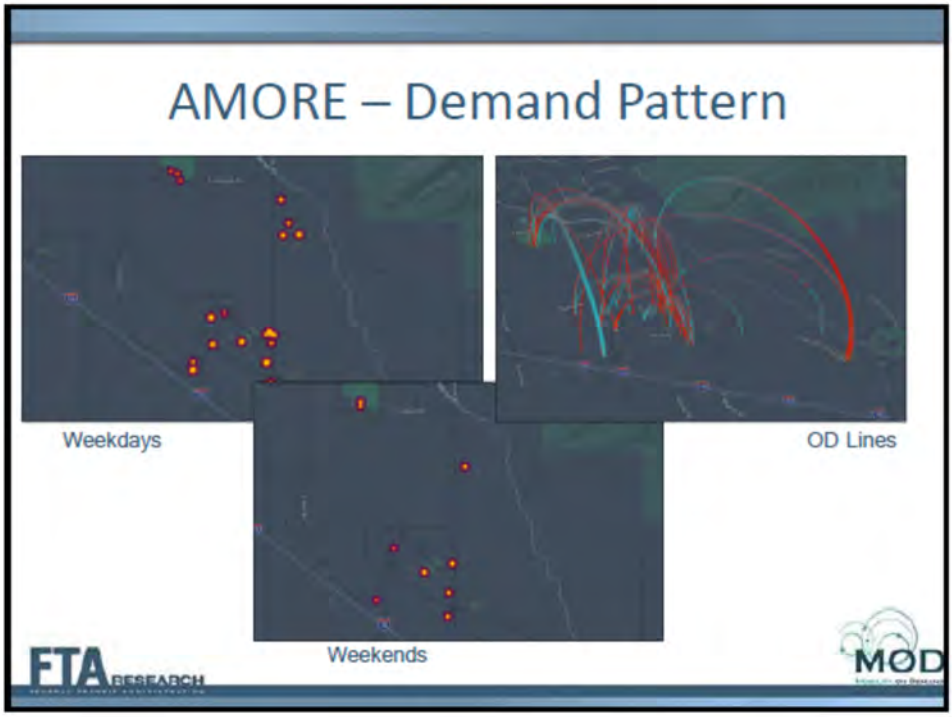
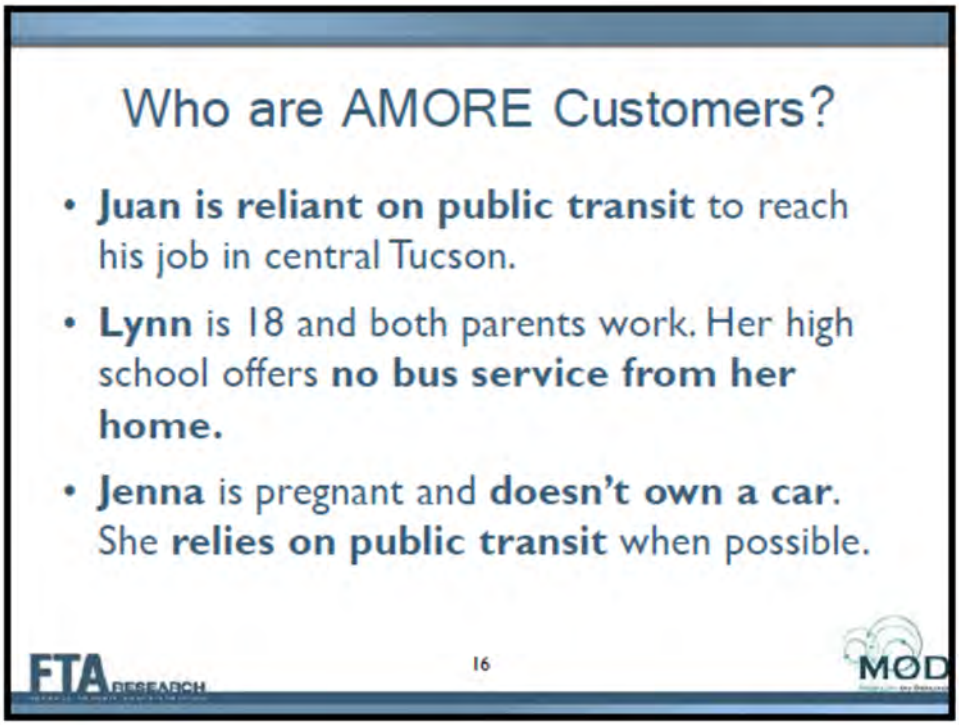
MOD


Major Origin-Destinations
Pima Community College
Bus Stops
Sun Express Park and Ride
Commercial Centers
FTA RESEARCH
MOD


AMORE – Demand Pattern
Weekdays
OD Lines
Weekends
FTA RESEARCH
MOD


Who are AMORE Customers?
• Juan is reliant on public transit to reach his job in central Tucson.
• Lynn is 18 and both parents work. Her high school offers no bus service from her home.
• Jenna is pregnant and doesn't own a car. She relies on public transit when possible.
FTA RESEARCH
16
MOD

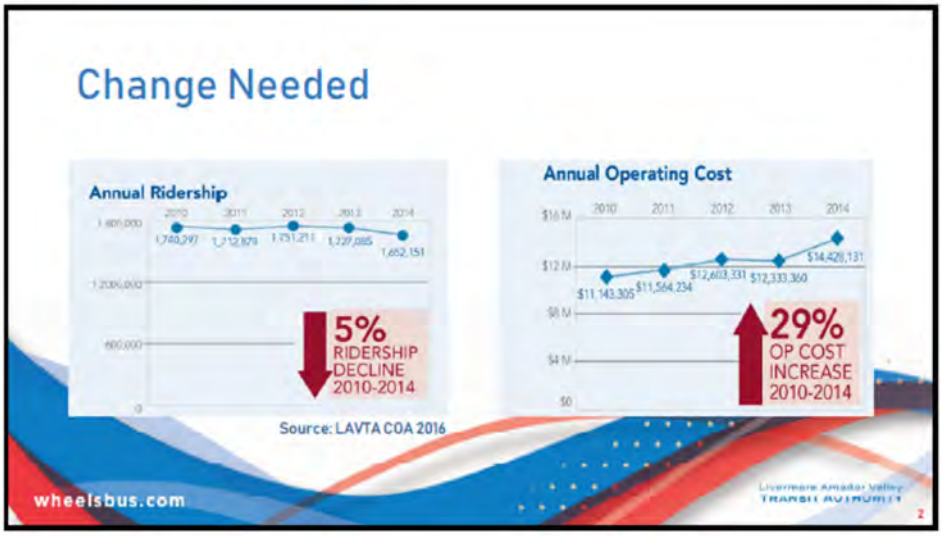

Where We're Headed
metropia
RTA
Regional Transportation Authority
RUBY Ride
FTA RESEARCH
17
MOD

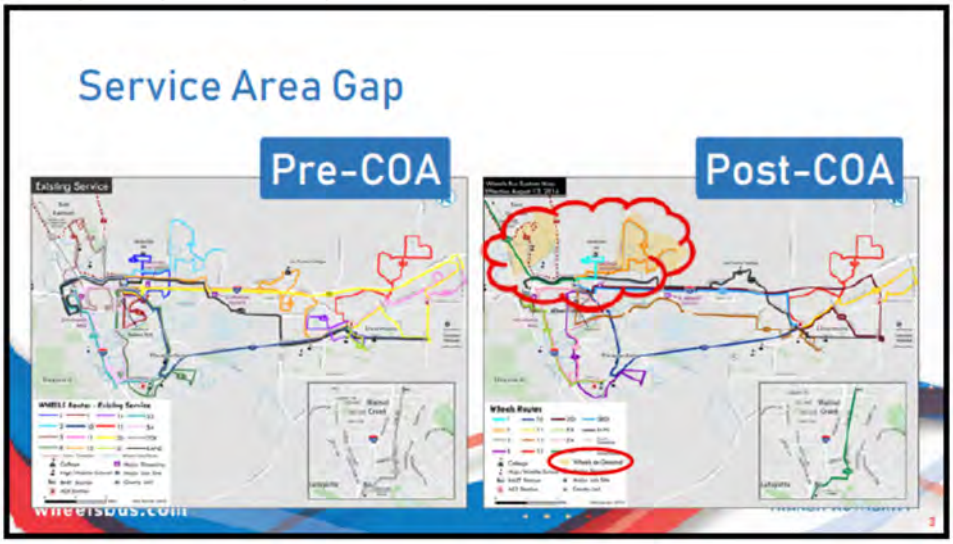

Outreach
Road Runner: New ride service in Civano, Vail, Rita Ranch links areas to buses
Media engagement
Direct Mailers
Amore
Who says there's no such thing as a FREE RIDE?
SIGN UP NOW
SIGN UP NOW
AMORE Tucson
Your Community. Your Ride
Social engagement, Click-To-Install campaigns
FTA RESEARCH
MOD


Next Up
• Iterate App and Backend
• Incentive/Gamification Trials
• Community Building
– Marketing and Outreach
– Focus on Identified Use Cases
• Explore further MaaS offerings
– Introducing DUO carpooling in Spring
FTA RESEARCH
MOD


For More Information
Website: www.amoretucson.com
RTA
– James McGinnis (jmcginnis@pagregion.com)
– Katharine Mitchell (kmitchell@pagregion.com)
Metropia
– Yi-Chang Chiu (yc.chiu@metropia.com)
– Chris Colemon (chris.colemon@metropia.com)
– Ali Arian (ali.arian@metropia.com)
– Jeff Lin (jeff.lin@metropia.com)
Ruby Ride
– Jeffrey Ericson (jeff@rubyride.co)
FTA RESEARCH
MOD


GoDublin!
LAVTA's TNC Partnership
Jonathan Steketee
Customer Service & Contract Compliance Manager| LAVTA
Email: jsteketee@lavta.org Office: (925)-455-7562
@wheelsbus
wheelsbus.com


Change Needed
Annual Ridership
2010
2011
2012
2013
2014
1,740,297
1,712,879
1,651,211
1,227,085
1,652,151
5%
RIDERSHIP
DECLINE
2010-2014
Source: LAVTA COA 2016
Annual Operating Cost
2010
2011
2012
2013
2014
$11,143,305
$11,564,234
$12,603,331
$12,333,360
$14,428,131
29%
OP COST
INCREASE
2010-2014
wheelsbus.com


Service Area Gap
Pre-COA
Post-COA
Existing Service
Wheels Routes
wheelsbus.com


Program Structure
GO DUBLIN!
UBER
lyft
DESOTO
INTRODUCING GoDublin RIDESHARE!
We'll pay half your fare (up to $5) when you ride with these services in Dublin!
wheelsbus.com
Livermore Amador Valley TRANSIT AUTHORITY

Results: Program Exceeded Expectations

Measure	Pre-COA Dublin Route 3	COA Wheels-on-Demand Goal (limited service span)	GoDublin! Result (24/7/365)
Annual O&M Cost	$224,000	~$61,000	~$34,000
Avg. Daily Ridership	42	120	34
Avg. Subsidy per Trip	$26.13	$4–$10	$2.35

wheelsbus.com

Livermore Amador Valley TRANSIT AUTHORITY

5

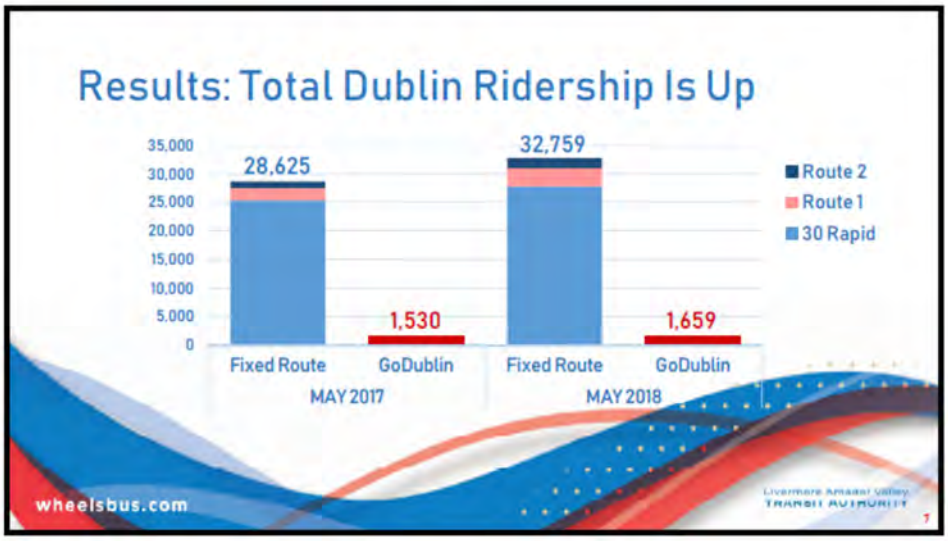
Ridership Summary

Time of Day	Most trips were weekday peak and midday
Distance	1–2 miles per fetch, 2–3 miles per fare
Travel Time	7–8 minutes waiting, 8–9 minutes traveling
O/D Frequencies	FM/LM connections between low-density residential neighborhoods and BART
Fares	GoDublin avg fares paid were higher than FR fare

wheelsbus.com

Livermore Amador Valley TRANSIT AUTHORITY

6

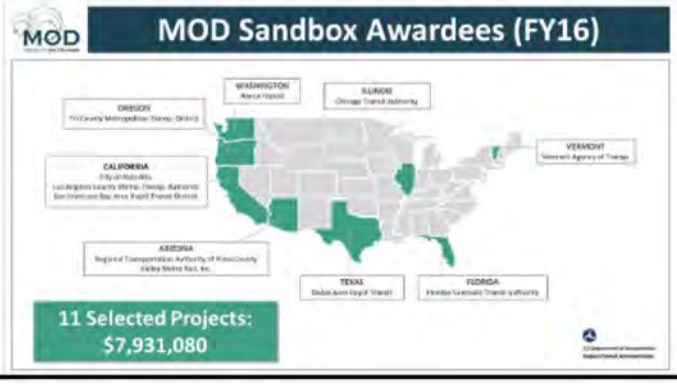

Results: Total Dublin Ridership Is Up
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
28,625
1,530
32,759
1,659
Fixed Route
GoDublin
Fixed Route
GoDublin
MAY 2017
MAY 2018
Route 2
Route 1
30 Rapid
wheelsbus.com

MOD Demonstration Projects Overview

Project Sponsor	Succinct Description
Pinellas Suncoast Transit Authority	On-demand paratransit to provide improved door-to-door service.
Chicago Transit Authority	Incorporates local bike-sharing company Divvy into CTA's transit trip planning app
Tri-County Metropolitan Transportation District	Builds an improved trip-planning platform including shared mobility options and advance routing information.
Dallas Area Rapid Transit	Integrates ride-sharing services and information into DART's GoPass ticketing app.
Vermont Agency of Transportation	Statewide transit trip planner incorporating flex-route, hail-a-ride, and other non-fixed-route services into mobility apps.
Pierce County Public Transportation Benefit Area Corporation	Limited Access Connections project connects service across two transit systems – local and regional – and a ride-share companies to provide better FMLM within the region.

MOD Sandbox Program Background

- The MOD Sandbox Demonstration Program demonstrates the experimental integration of MOD concepts with public transit agency systems.



Evaluation Plans

MOD Demonstration Projects Overview

Project Sponsor	Succinct Description
Regional Transportation Authority of Pima County	Integrates fixed route, subscription based ride-sharing and social carpooling services into a platform to address first mile/last mile issues.
Valley Metro Rail, Inc.	Smart phone mobility platform that integrates mobile ticketing and multimodal trip planning, including ride-hailing, bike sharing, and car-sharing companies.
City of Palo Alto	Commuter planning project incorporating trip reduction software, a multi-modal trip planning app, and workplace parking rebates.
Los Angeles County Metropolitan Transportation Authority	Mobility on demand partnership with VIA. Led by LA Metro, the project includes a companion initiative in Seattle, WA.
San Francisco Bay Area Rapid Transit	Integrated carpool-to-transit program

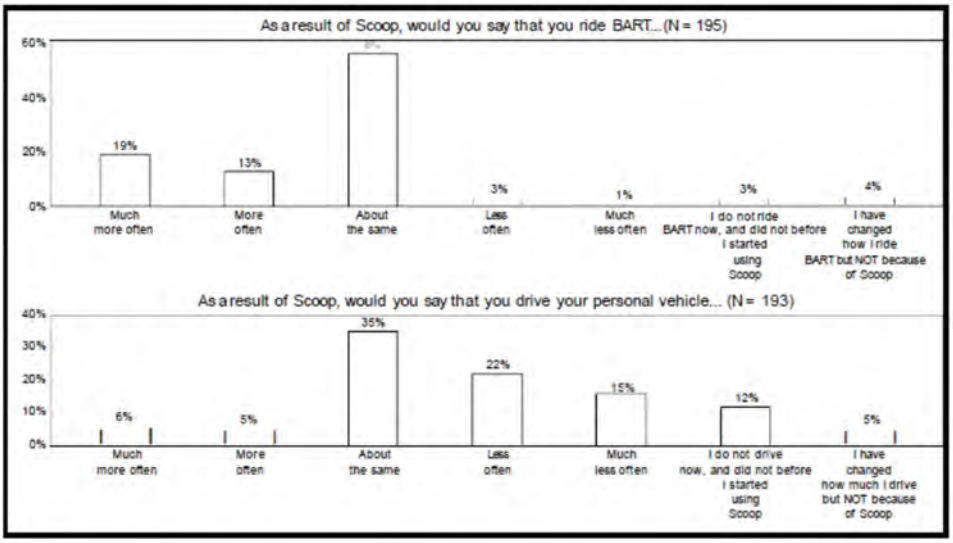
Data Sources: Surveys

- **Retrospective:** Users are surveyed once, at least 6 months after demonstration launch
  - Captures behavioral impacts as a result of the project based on a one-time engagement with respondents.
- **Before-After:** Users are surveyed twice. First at the beginning of the demonstration and then again later in the deployment.
  - Survey are slightly shorter. Users do not have to recall what they did prior to the project.
- **Recent Trip:** Sort 2-3 question survey given after users take trips at some specified frequency
  - Provides high-resolution mode shift, ideally tied to a specific trip

Selected Survey Results

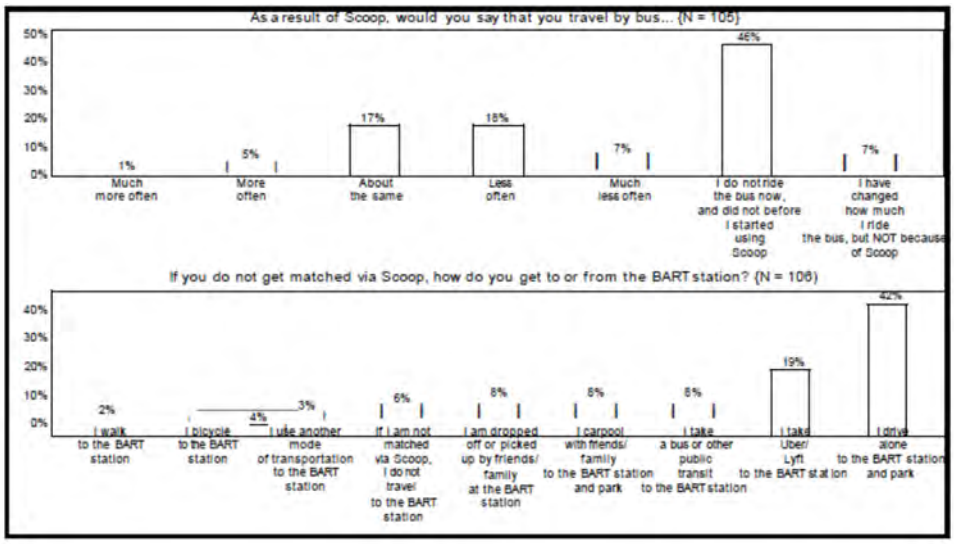
- Present Status
  - BART (n = 197)
  - DART (n = 25)*
  - TriMet (n = 186)
  - Valley Metro (Before survey n = 400+ ; After survey n = ~200)*
- BART:
  - Survey deployed to users of the Scoop platform to access BART stations.
  - Surveys were deployed about quarterly to evaluate how Scoop had impacted travel behavior, parking, and cost.
- TriMet:
  - Survey was deployed to evaluate how Tri-Met transit riders respond to a new trip planning platform produced by the Tri-Met MOD Sandbox project.

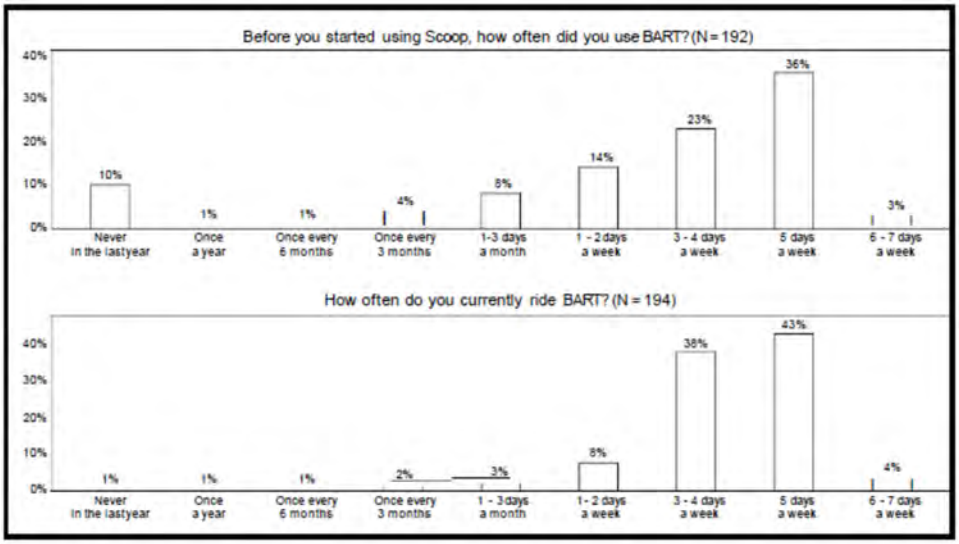
* Survey analysis not presented here



Selected Results from BART Survey

- **Demographics:**
  - Considerably more men and Asians (with Caucasians coming in second) use the service, users are also often in their 30s, highly educated with high incomes.
  - Very few single households, a majority of respondents were in households with 3 or more people
- **Usage of Scoop:**
  - Scoop taken fairly frequently by respondents, about 60% of respondents reported using Scoop at least 3 times a week
  - Top 4 reasons given for using Scoop included:
    1. Obtaining a parking permit
    2. Serve as a alternative to driving
    3. Speed and
    4. Cost





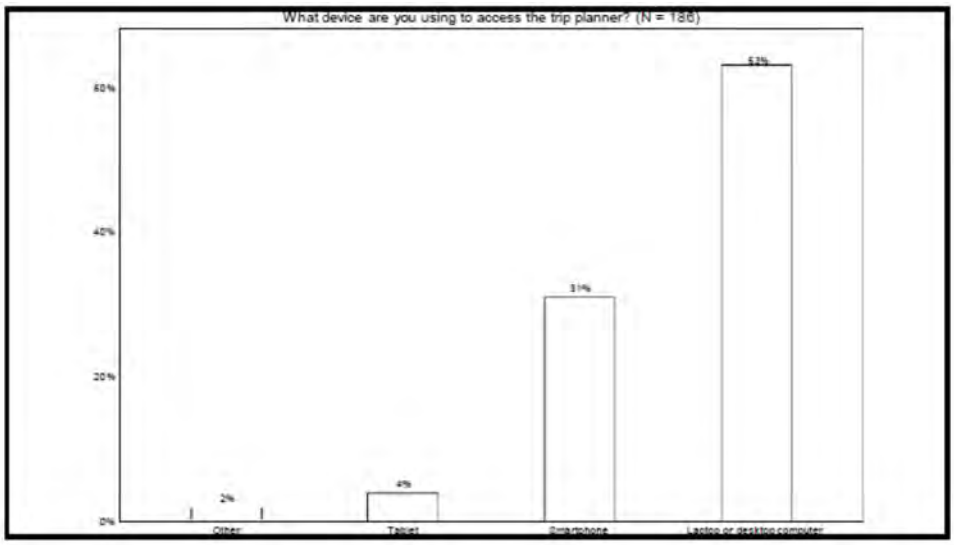
Some Concluding Remarks on BART Results to Date

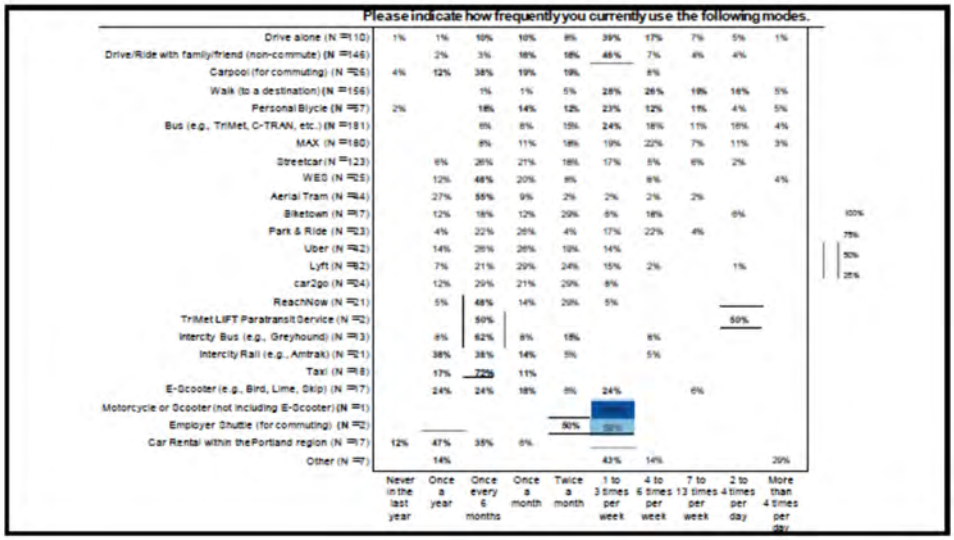
- Preliminary survey analysis suggests that the carpooling program with Scoop was making it easier for users to get to BART.
- Results suggest that the use of Scoop increased the propensity of users to use BART
- The use of Scoop was substituting for a fair share of driving alone to BART, and was reducing overall travel by personal vehicle.
- Among other insights, further analysis will yield information about impacts on parking, enforcement, as well as estimates of impacts that the mode shift is having on key travel metrics.

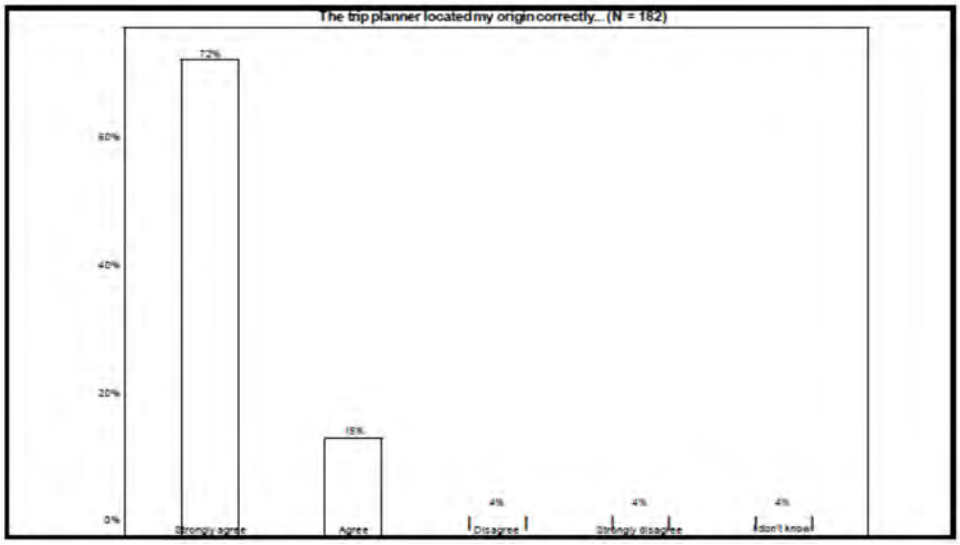
Selected Results from Tri-Met Survey

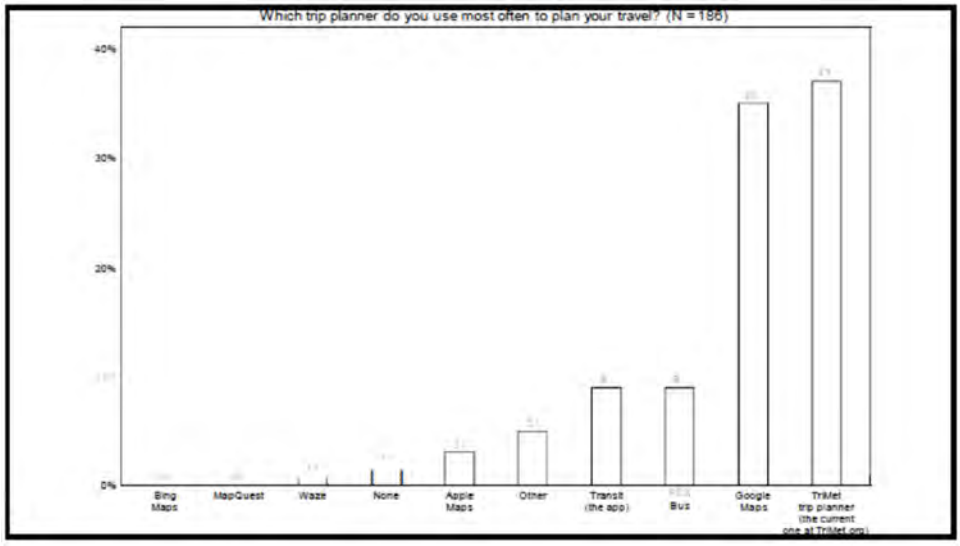
- **Demographics:**
  - Respondents slightly balanced towards female (47%) versus male (44%) with the remainder spanning transgender or prefer not answer.
  - About 75% of testers were Caucasian with Hispanic/Latino and Asian users representing the next largest ethnic groups.
  - At least 65% had at least a bachelor's degree.
  - Rather normal distribution of income with the mode of $50K to $75K in annual income.
  - The plurality of respondents lived in single family homes (37%), but residence type was well distributed across different building types.

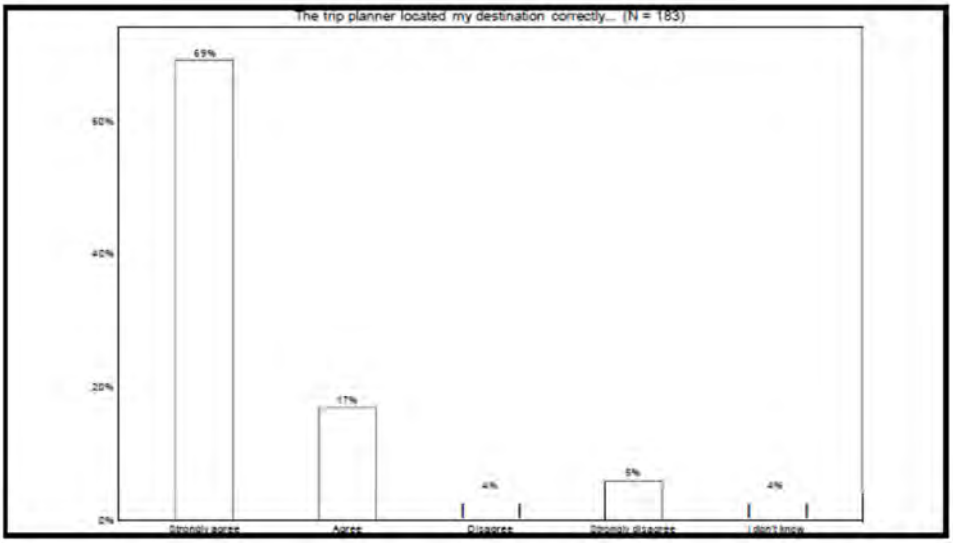
TRIMET

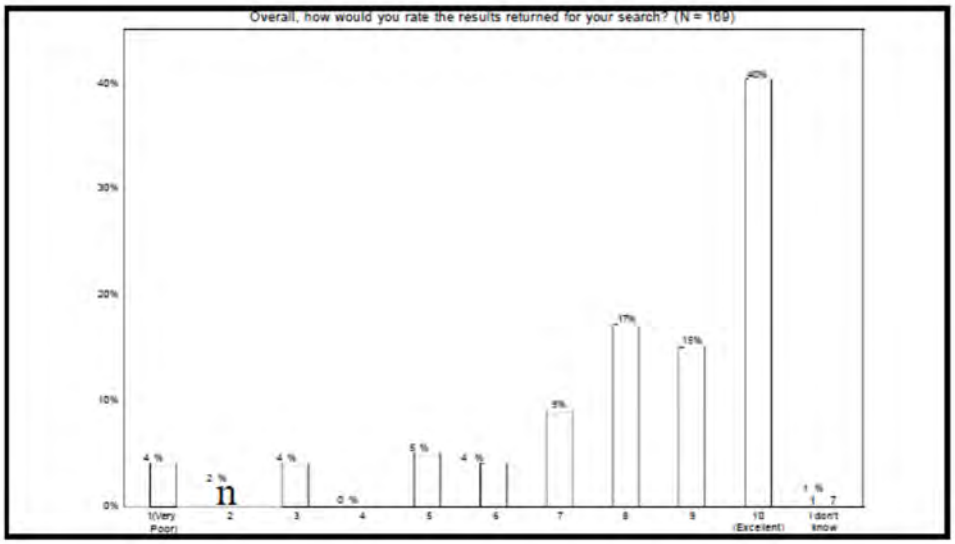





The trip planner located my origin correctly... (N = 182)
72%
60%
40%
20%
15%
4%
4%
4%
0%
Strongly agree
Agree
Disagree
Strongly disagree
don't know

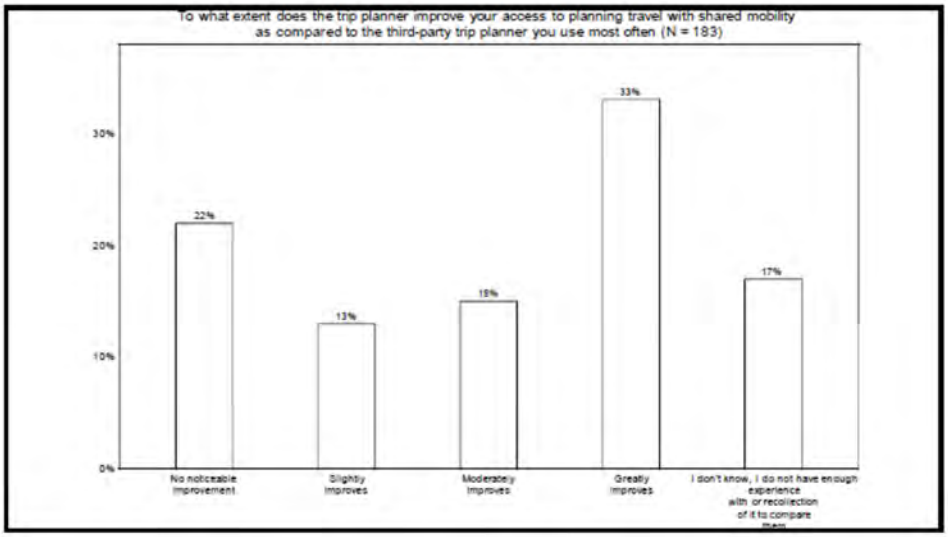

Which trip planner do you use most often to plan your travel? (N = 186)
40%
30%
20%
0%
Bing Maps
MapQuest
Waze
None
Apple Maps
Other
Transit (the app)
Bus
Google Maps
TriMet trip planner (the current one at TriMet.org)


The trip planner located my destination correctly... (N = 183)
69%
60%
40%
20%
17%
4%
6%
4%
0%
Strongly agree
Agree
Disagree
Strongly disagree
I don't know



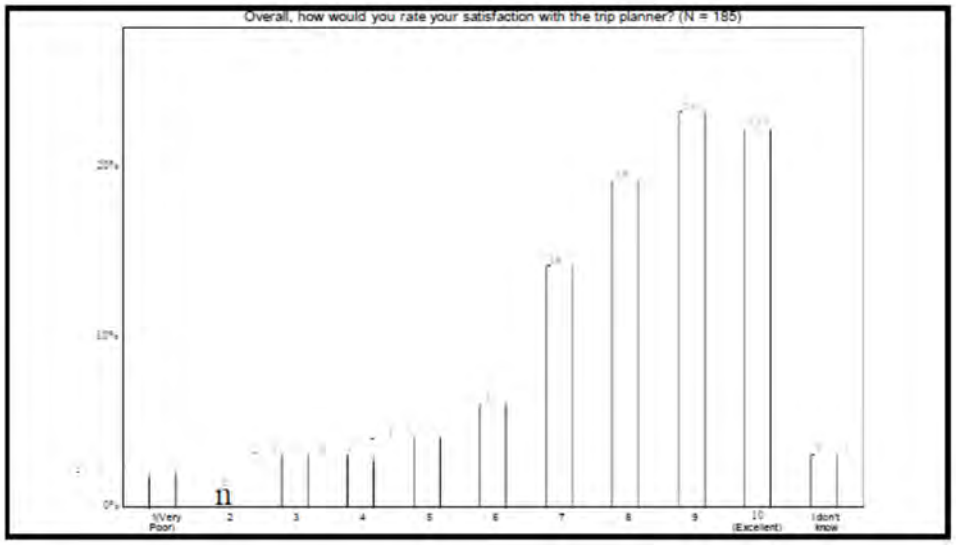
Some Concluding Remarks on Tri-Met Results to Date

- Overall, on balance, respondents appeared to like the new trip-planner developed and deployed by Tri-Met.
- They reported finding the shared mobility information, real-time information, and the changes to the design interface to be generally useful.
  - Map interface and information richness were considered to be the most improved.
- Further analysis of results and comments are being used to evaluate how the trip planner may further address user needs.



Data Sources: Activity Data

- Activity data consists of events related to the system.
- Examples include trip records with
  - date/time,
  - origin/destination,
  - distance traveled,
  - wait/travel time, etc.
- Activity data is useful for evaluating direct measurements of system use as well as the distribution of that use.
- Activity data also tells us about the scale of the system use and deployment, which we cannot see very well in surveys.
- The data is important component of the behavioral analysis conducted for the MOD Sandbox projects.



Data Sources: Agency Data

- Agency data consists of statistics that are standard to the agency and measured within the organization
- Examples include ridership, parking, and other measured costs of systems as they relate to the project
- Agency data is useful to evaluate whether there are high-level changes occurring as a result of the project.
- For a number of projects, the scale of deployment is not large enough to move agency statistics.
- For others, the impacts may be perceptible, and so they are of interest.

Data Sources: Expert Interviews

- IE team will conduct at least three interviews per project near the end of each demonstration
  - Interviewees could be staff and project partners who have knowledge about the project, and can provide insights/lessons learned
- Questions for key stakeholders and experts are designed to gauge their involvement and experience with the project, as well as their opinions about the successes and difficulties related to project implementation and operations
- The interviews will provide insights into unique challenges faced, ultimately culminating in a series of lessons learned and recommendations for improving longer-term operation of the system

Concluding Remarks and Early Lessons Learned

- The MOD projects are exciting and ambitious undertakings to improve public transit systems.
- Results are starting to show the fruits of these ambitions within several of these projects.
- Such projects are inherently challenging with unknown hurdles, barriers, and adaptations required along the way.
- The discovery of these challenges should be considered beneficial to the public learning on how to best advance innovations in the context of our changing technology.

TransitCenter

Performance Indicators for Mobility on Demand

Chris Pangilinan

January 13, 2019

Core Indicators (Traveler Centric)	Tier 1 Indicators (System Centric)	Tier 2 Indicators (Region Centric)	Tier 3 (Nation Centric)
Measures performance for individual travelers	Measures the performance of the mobility system with focus on the effectiveness of MOD on service planning and delivery, as well as operational efficiency	Measures the impact of MOD from a regional perspective	Measures the impact of MOD from the national perspective
Performance categories/dimensions: • Time • Budget • Reliability • Availability • Safety	Performance categories/dimensions: • Capacity • Utilization • Effectiveness • Efficiency • Access • Safety • Accessibility	Performance categories/dimensions: • Economic • Social • Financial • Labor • Land use • Mobility • Accessibility • Environmental • Safety / Public Health	Performance categories/dimensions: • Economic • Social • Financial • Labor • Land use • Mobility • Accessibility • Environmental • Safety / Public Health
Trip stages: • Pre-trip (planning) • Trip (operations) • Post-trip (feedback/experience)	Trip stages: • Pre-trip (planning) • Trip (operations) • Post-trip (feedback/experience)	Impact stages: • Local (county/city/municipality) • Regional (MPO level)	Impact stages: • National
Performance indicators: • Travel time • Waiting time • Price of trip • Incidence of crime	Performance indicators: • Travel time • Waiting time • Availability • Number of options • Number of connections • Number of persons served • Number of linked trips • Availability of multi-dimensional connections (schedule, location, O/D, spontaneity, etc.) • Cost to provide service • Public subsidy of trip • Incidence of fatality or serious injury • Percent of services that are accessible	Performance indicators: • Alignment with opportunity maps • Effective service area/coverage • New access (route/area) • Economic development • Impact on accessibility • Reduction of trip times • Budget spent on transportation • Incidence of fatalities or serious injuries • Difference between opportunities reached by those of different physical abilities	Performance indicators: • Alignment with national goals • Increased access to opportunity by median American • Reduced transportation and living costs • Economic development • Impact on accessibility • Amount spent on transportation that increases access • Incidence of fatalities or serious injuries
Future indicators • Spontaneity • Number of options available • Number of connections available			

	Category of Performance Indicator	Trip Stage	Traveler Question	Performance Indicator	Unit of Measurement	Indicator description	Data Required	Justification
3	Time	Pre-Trip	How long does it take to plan my trip? How easy is it for me to plan and book my trip?	Trip planning and booking experience	Survey rating	Traveler satisfaction with trip planning and booking process.	Booking time, availability and accuracy of real-time information, survey of travelers	Determines how efficient trip planning is and whether travelers can do it during their trip.
4	Time	Trip	How long do I have to wait until my trip begins if requested immediately?	Wait time	Minutes, seconds	Amount of time between end of trip planning and beginning of trip	Reservation date and time, actual departure date and time	This determines the amount of time for the mobility system to meet the demand of a traveler.
5	Time	Trip	How long will my trip take until I am at my destination?	Travel time	Minutes, seconds	Amount of time walking to access and "in-vehicle"	Actual departure and arrival date and time, origin, destination, pickup point, drop off point.	Determines how long the operations portion of the trip phase will take
6	Time	Trip	How long does my connection take before my next leg of my trip begins?	Connecting time	Minutes, seconds	Difference between alighting from first vehicle/mode and getting back on the trip on second vehicle/mode	Actual wait time(s) at connection points	Determines how much of the trip phase will be taken up by connecting between two services in the same trip.
7	Time	Trip	How long will my total journey time be?	Total journey time	Minutes, seconds	Wait time plus trip time plus connecting time	Reservation date and time, actual arrival date and time	Determines the total time the trip phase took.
8	Budget	Pre-Trip	Are trip options offered at a reasonable price as determined reasonable by the traveler?	Trip prices	Dollars, cents	Price of each trip available	Trip planning inputs, prices of offered trips before booking, traveler survey	Determines the price of the trip provided by the mobility system

3 | Volume 1: Performance Indicators | 14 December 2018 | TransitCenter

	Category of Performance Indicator	Trip Stage	Traveler Question	Performance Indicator	Unit of Measurement	Indicator description	Data Required	Justification
C8	Budget	Pre-Trip	Are trip options offered at a reasonable price as determined reasonable by the traveler?	Trip prices	Dollars, cents	Price of each trip available	Trip planning inputs, prices of offered trips before booking, traveler survey	Determines the price of the trip provided by the mobility system
C13	Reliability	Pre-Trip	Can I plan on my preferred trip options being available every day?	Option availability	Percentage, cluster analysis	Percent of times when planning a trip that there is at least one trip option available that fits within traveler time, cost, and mode preferences	Trip planning inputs, trip options offered before booking	Determines whether the service will be physically available at the cost determined reasonable by the traveler.
C14	Reliability	Pre-Trip	Will the same trip options always be available to me for recurring trips?	Option reliability	Percentage	Percent of recurring trips that offer the same menu of trip options	Trip planning inputs, trip options offered before booking, actual itinerary of booked trip	Determines whether the same selection of trip options will be available.
C15	Reliability	Post-Trip	Did my trip cost me as much as I was told it would?	Travel cost prediction accuracy	Percentage / dollars, cents	Percent and absolute difference between predictions and actual trip cost	Price of booked trip before booking, actual price paid of booked trip	Determines the reliability of the trip cost estimate.

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	Category of Performance Indicator	Trip Stage	Traveler Question	Performance Indicator	Unit of Measurement	Indicator description	Data Required	Justification
C18	Availability	Pre-Trip	How many trips were not taken, had to be deferred, or had to be taken in a way that was not preferred?	Trip deferments, cluster analysis	Number of trips deferred/ 100 trips	Number of trips planned but not taken, deferred, or taken in a way outside of traveler preferences	Trip planning inputs, actual departure and arrival date and arrival time, actual price paid of booked trip, actual itinerary of booked trip, survey	Determines how many trips the traveler planned, but did not take.
C19	Availability	Trip	Are there redundancies along my trip in case something happens?	Connection redundancy	Number of trip branches available in real-time per trip taken	Number of trip "branches" providing a similar travel time and cost available in real-time to travelers	Number of comparable trip options immediately available to traveler while they are on their trip	Determines whether the traveler can change to a different service midway through their trip to reach their destination.
C20	Safety	Trip	Do I feel safe on my trip?	Safety perception (personal security)	Survey rating	Level of safety felt during all parts of a trip	Survey results	Determines travelers' perception of safety on their trip.
C21	Safety	Trip	Am I actually safe on my trip?	Crime rate, crash rate, injury rate	Number of reported crimes, crashes, and severe injuries per 100,000 trips	Crime rate, crash rate, injury rate	Number of reported crimes, number of crashes, number of severe injuries	Determines whether the traveler is actually safe on their trip.

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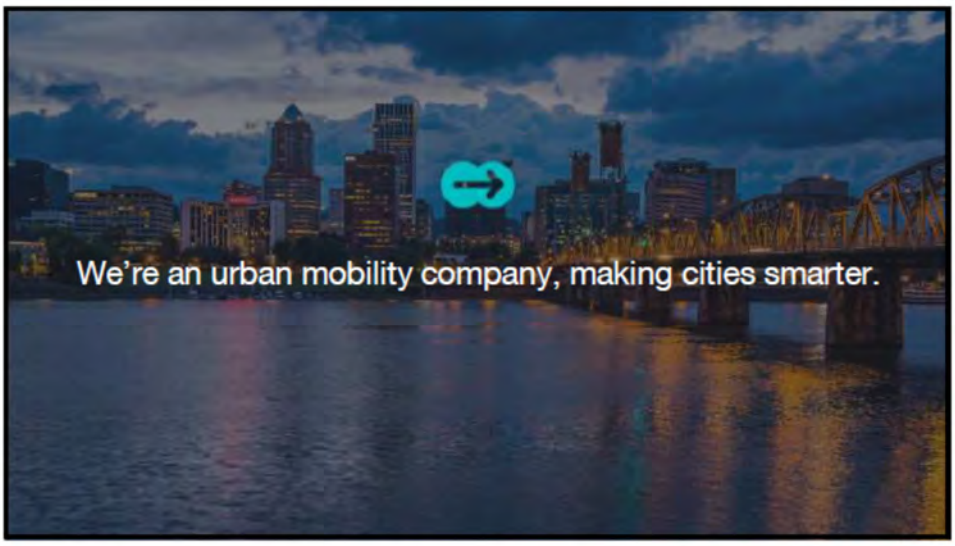
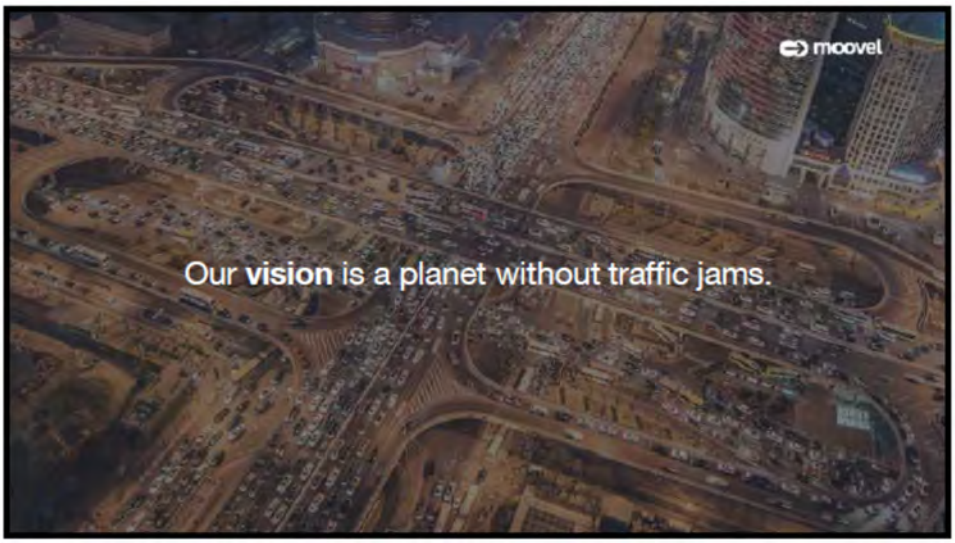
The Future of Mobility on Demand
2019 Transportation Research Board Annual Meeting
Future of Mobility on Demand Workshop
January 13, 2019


We're an urban mobility company, making cities smarter.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Our vision is a planet without traffic jams.


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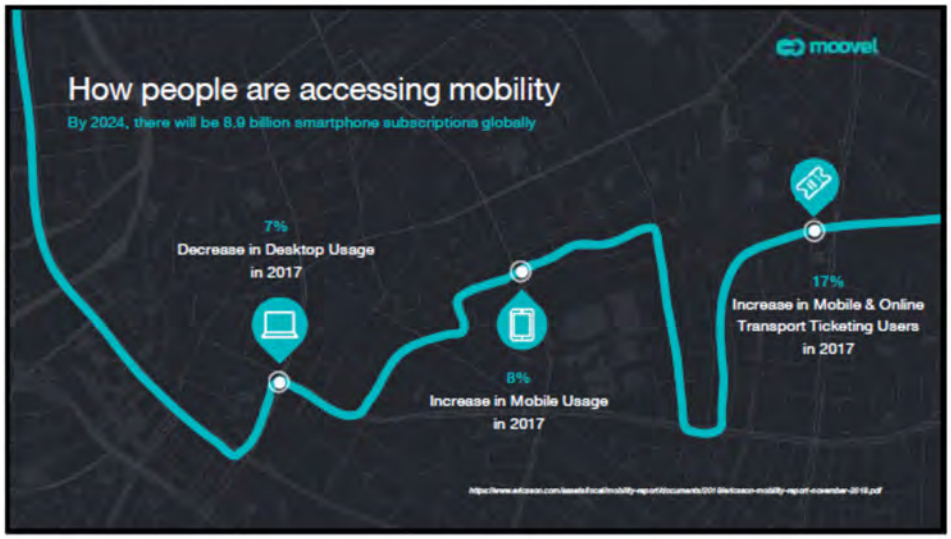
Our **mission** is to transform cities by providing the most convenient and sustainable mobility solutions.


80.4%
of the world's population is estimated to live in urban areas by 2030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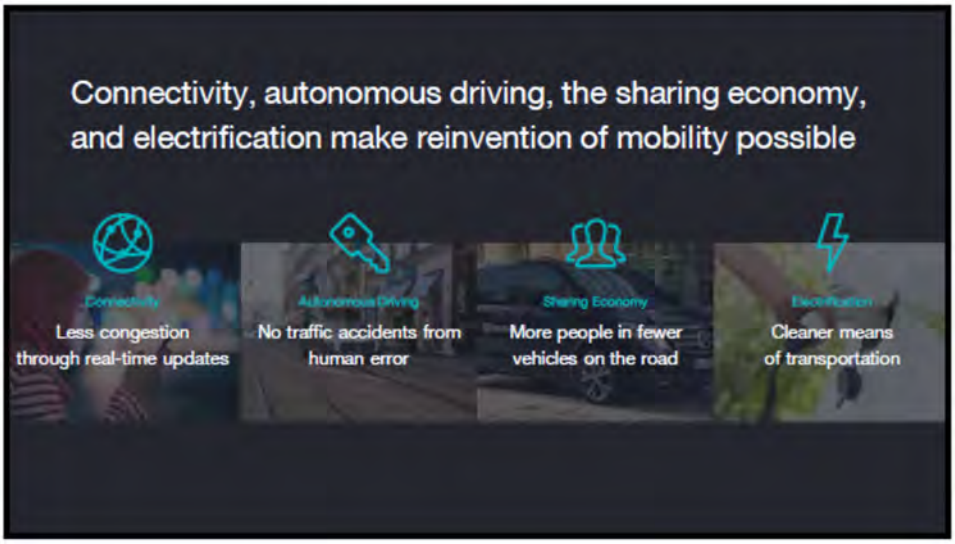
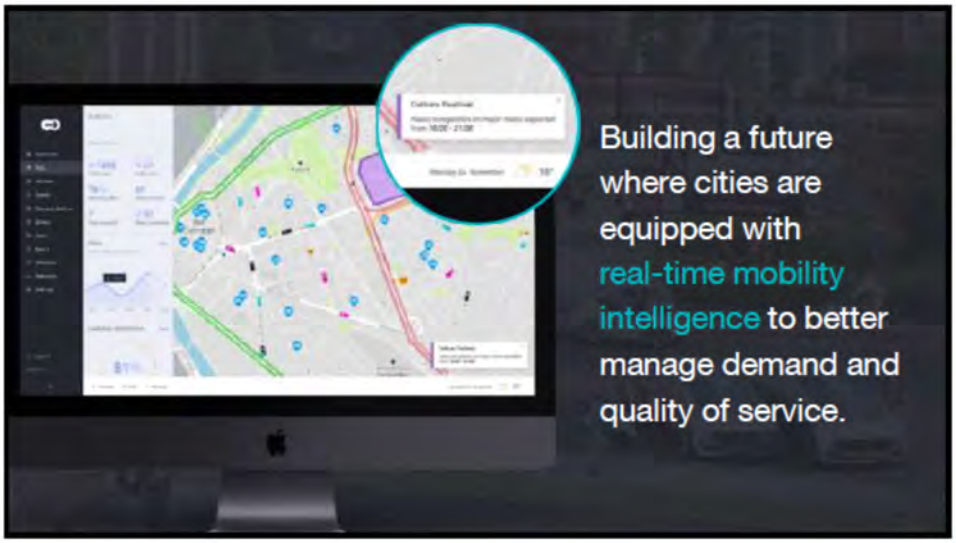
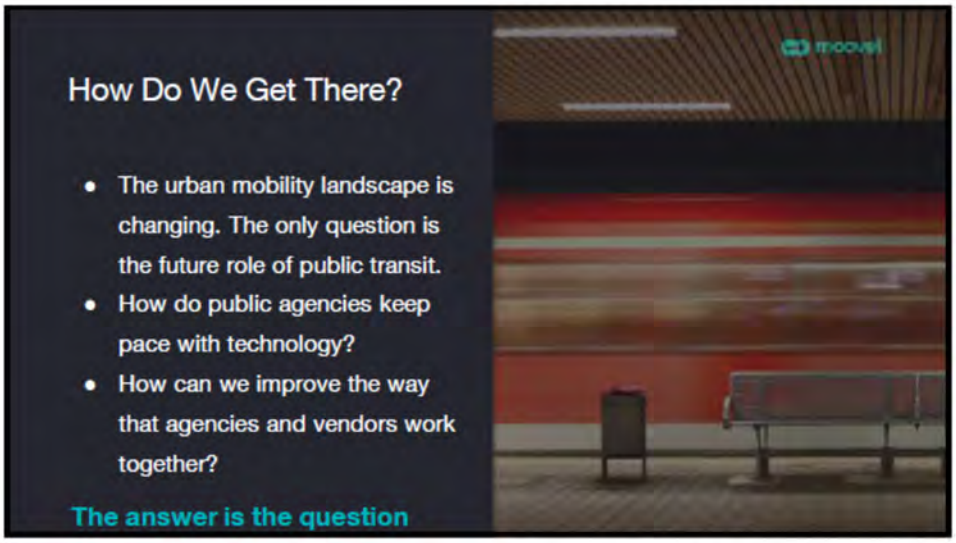
How people are accessing mobility
By 2024, there will be 8.9 billion smartphone subscriptions globally
7%
Decrease in Desktop Usage in 2017
8%
Increase in Mobile Usage in 2017
17%
Increase in Mobile & Online Transport Ticketing Users in 2017

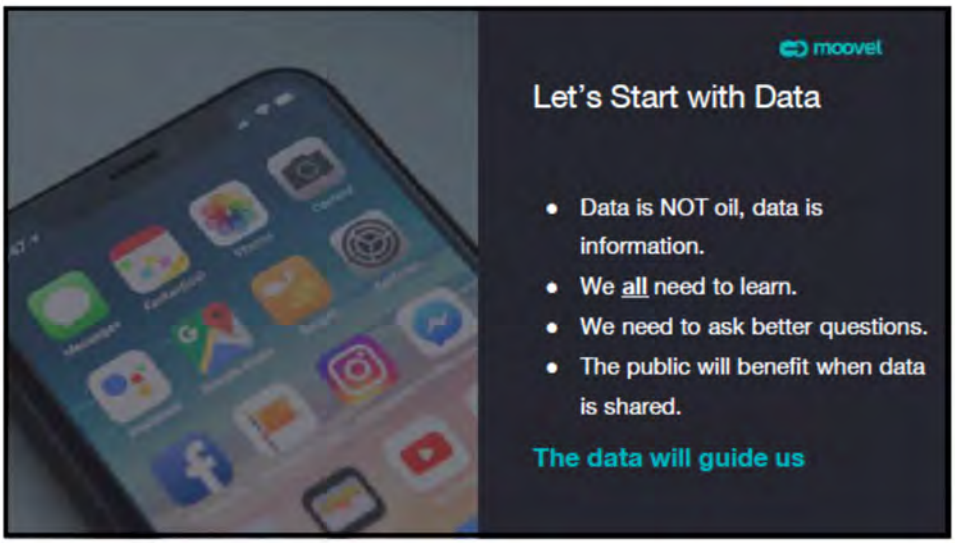

moovel
Shaping the future of urban mobility
98% of 18- to 24-year-olds live in a house with at least one smartphone
Closed Loop Payment
Contactless Ticketing and Fare Validation
Dynamic Content
First & Last Mile Challenges


moovel
Mobility convergence
Transit agencies and cities are evaluating ways to provide greater mobility within their community.
User
Seamless access to a whole range of mobility services
Booking & payment included
Transit Agencies
Operational efficiencies
Route optimization
New markets needs
Focus on Customer Experience
Cities
Insights into different mobility patterns
Insights for city planning purposes
moovel
Dynamic data showing how people move in cities
Insights into different mobility patterns


Connectivity, autonomous driving, the sharing economy, and electrification make reinvention of mobility possible
Connectivity
Less congestion through real-time updates
Autonomous Driving
No traffic accidents from human error
Sharing Economy
More people in fewer vehicles on the road
Electrification
Cleaner means of transportation


Building a future where cities are equipped with real-time mobility intelligence to better manage demand and quality of service.


How Do We Get There?
The urban mobility landscape is changing. The only question is the future role of public transit.
How do public agencies keep pace with technology?
How can we improve the way that agencies and vendors work together?
The answer is the question
moovel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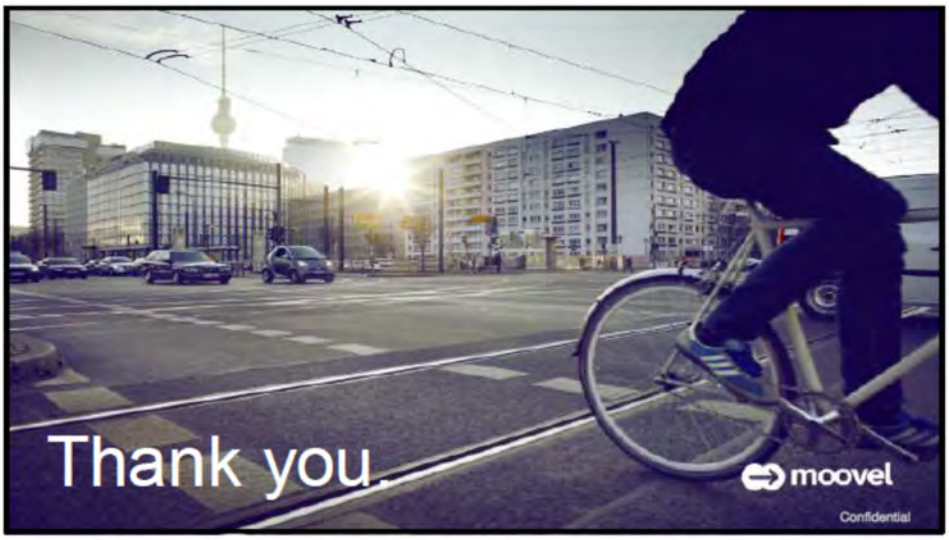
Let's Start with Data
Data is NOT oil, data is information.
We all need to learn.
We need to ask better questions.
The public will benefit when data is shared.
The data will guide us


Thank you
moovel
Confidential

Mobility on Demand: A Smart, Sustainable, and Equitable Future, Part 1

Los Angeles County
Metropolitan Transportation Authority

2019 TRB Workshop
January 13, 2019

Metro

Metro Vision 2028 Strategic Plan
Outcomes by 2028

Double the % usage of transportation modes other than driving alone, including transit, walk, bike, shared-ride and carpool modes

10-minute walk or roll to high-quality mobility options

15-minute maximum wait, any time of day

30% faster bus speeds

Options to bypass congestion

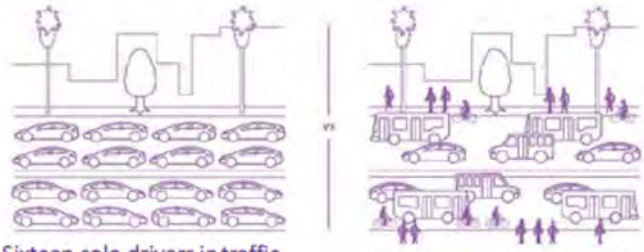
Office of Extraordinary Innovation

- Incubator, facilitator, and implementer of innovative ideas within LA Metro
- Partnership and collaboration across departments and with external partners
- 2 primary tools:
  - Strategic planning – metro.net/vision2028
  - Unsolicited Proposals

Metro

Root Cause

We use transportation system capacity inefficiently.



Sixteen solo drivers in traffic congestion

Many more people moving smoothly when we make better use of street space

Metro

Unsolicited Proposals

- To date, OEI has received **122** proposals
- Engaged over **150** internal subject matter experts
- Received **16** proposals for megaprojects or major financing initiatives

Metro

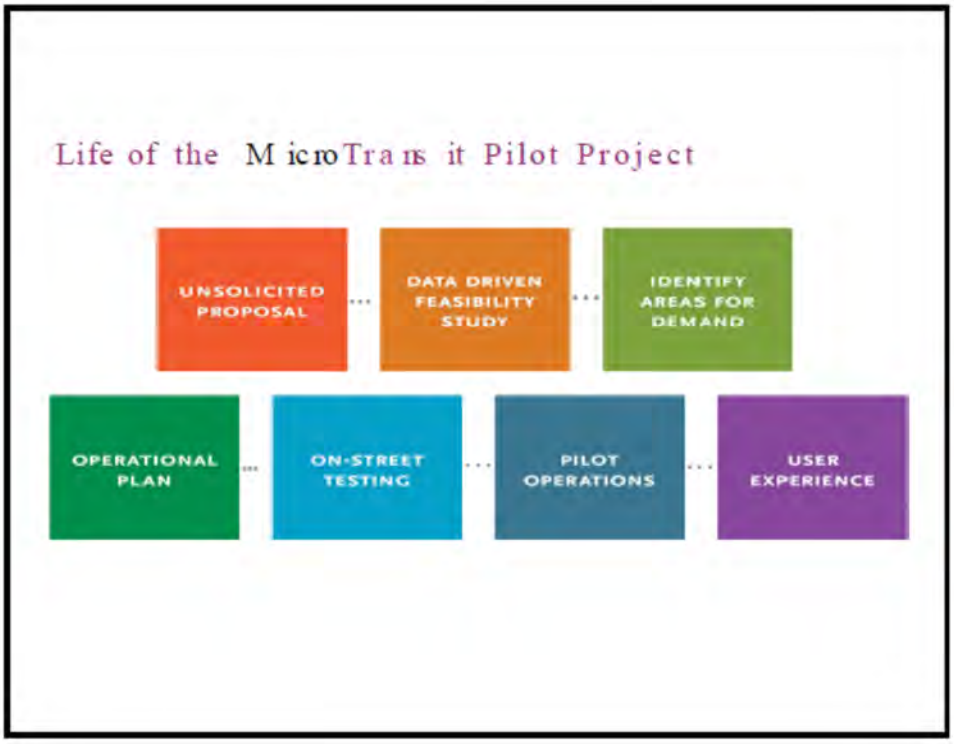
MicroTransit Pilot Project

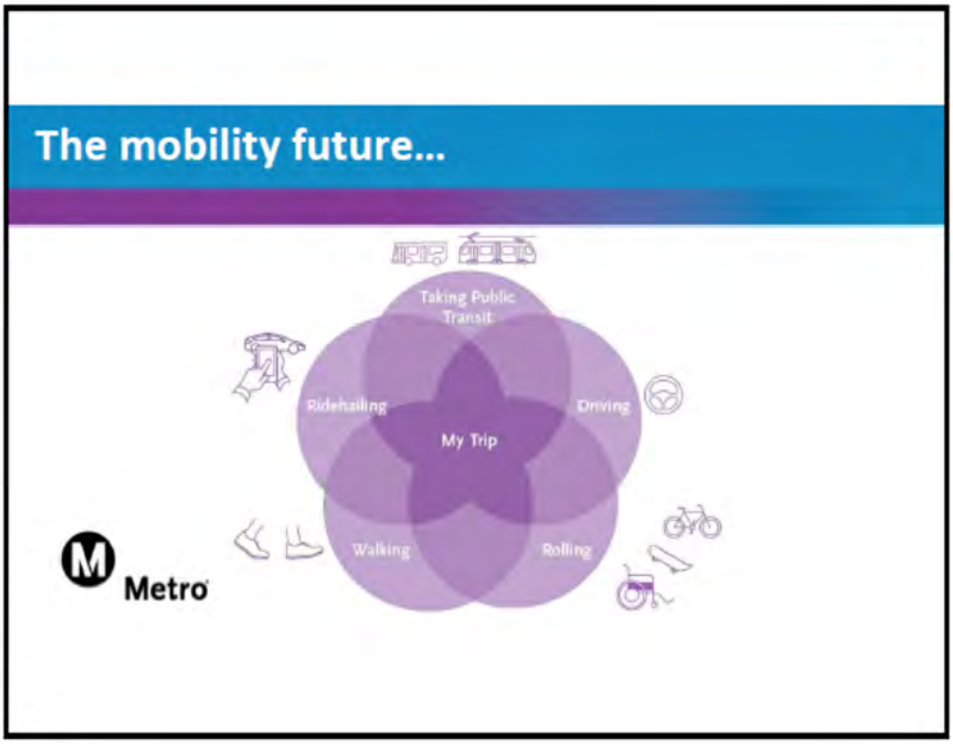
- Adds to Metro's portfolio of services
- Customer-focused
- On-demand service
- Dynamic routing
- Serves short trips under 20 minutes
- Uses smaller vehicles than traditional transit vehicles

Metro

New Mobility Pilots

on Demand	MicroTransit Pilot
LAUNCH: 1/28/19	LAUNCH: 2019
Serving first and last mile rides to/from Metro stations	Serving all trip types
One year of operation with option for one additional year	Up to three years of operations in pilot phase
Three zones focused around Metro stations	Number and types of zones to be determined
Testing a business model using independent contractors	Testing a business model using Metro operators
Mixed fleet of driver-owned vehicles, inspected and approved by Via	Mixed fleet of vehicles to be leased by private sector
Lite TAP integration for pilot period	TAP Integration anticipated
Rides are requested using Via's app or Via's call center	Rides are requested using an app and call center


Life of the MicroTransit Pilot Project
UNSOLICITED PROPOSAL
DATA DRIVEN FEASIBILITY STUDY
IDENTIFY AREAS FOR DEMAND
OPERATIONAL PLAN
ON-STREET TESTING
PILOT OPERATIONS
USER EXPERIENCE

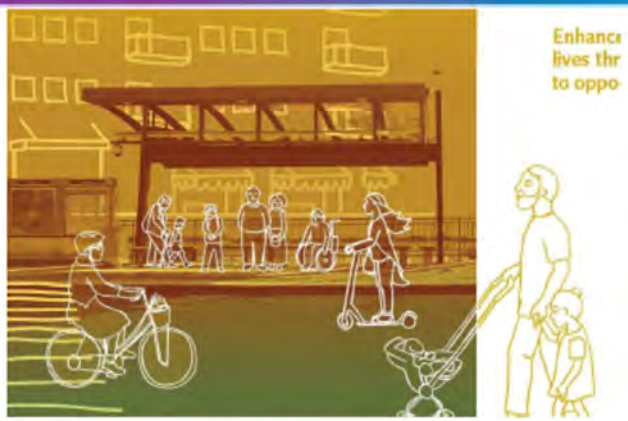

The mobility future...
Taking Public Transit
Ridehailing
Driving
My Trip
Walking
Rolling
Metro

Mobility on Demand (FTA Grant)

Can Metro and Transportation Network Companies partner to provide seamless, integrated, complete trips for all?

- Subsidized first-last mile trips from rapid transit stations
- Options for customers who are unbanked, in wheelchairs, and without smart phones
- Metro ands first-last mile solutions and shared rides

...where our community thrives



Metro

Thank You

metro.net/oei

Tham Nguyen,
Interim Deputy Executive Officer
Office of Extraordinary Innovation
NguyenTha@metro.net or (213) 922-2606

Metro

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TRB 2019 ANNUAL MEETING - JANUARY 13-17

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Forum on Preparing for Automated Vehicles & Shared Mobility

(est. 2018)

GREGORY WINFREE, TEXAS A&M TRANSPORTATION INSTITUTE

Forum on Preparing for Automated Vehicles & Shared Mobility

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- Bring together public, private, and research organizations to share perspectives on critical issues surrounding the deployment of automated vehicles and shared mobility. Focus on the discussion, identification, and facilitation of fact-based research needed to deploy these technologies in a manner and timeframe that informs policy to meet long-term goals.
  - The long-term goals include increasing safety, reducing congestion, enhancing accessibility, increasing environmental and energy sustainability, and encouraging economic development and equity.

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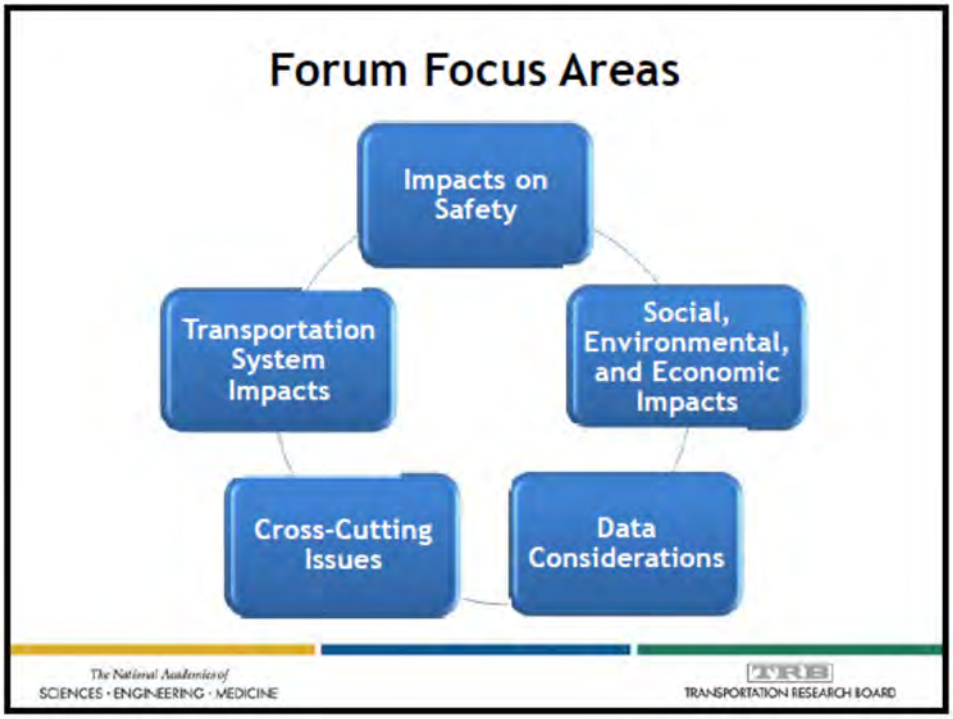
Forum Focus Areas
Impacts on Safety
Social, Environmental, and Economic Impacts
Data Considerations
Cross-Cutting Issues
Transportation System Impacts
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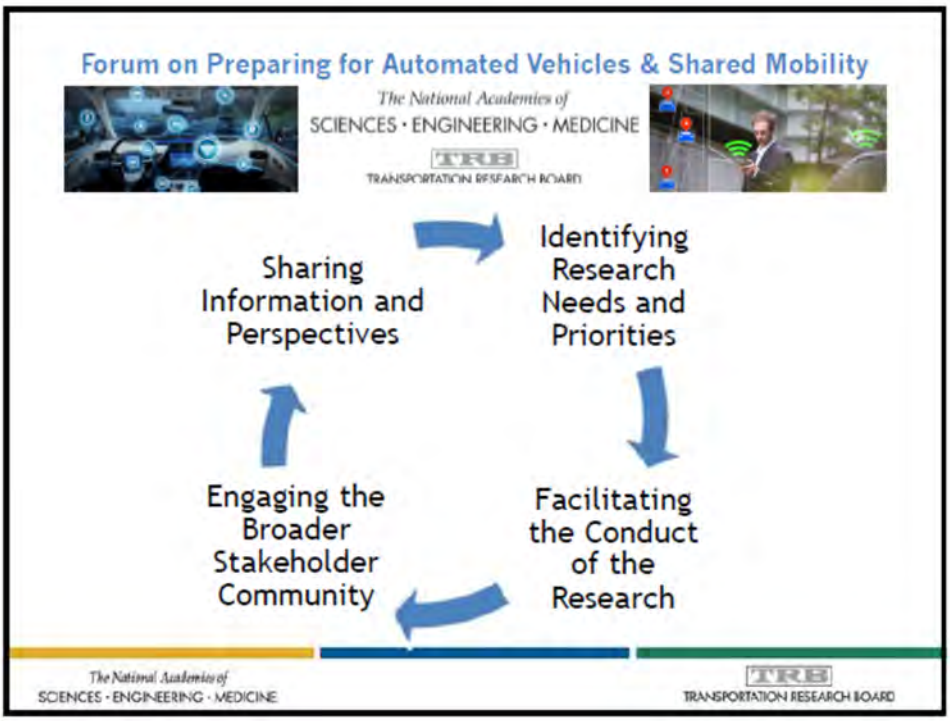
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Identifying Research Needs and Priorities
Facilitating the Conduct of the Research
Engaging the Broader Stakeholder Community
Sharing Information and Perspectives
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Participating Federal, State, and Local Agencies

- U.S. Department of Transportation
- U.S. Department of Energy
- Transport Canada
- State Transportation Agencies
  - Caltrans and California DMV
  - Florida DOT
  - Michigan DOT
  - Ohio DOT
  - Virginia DOT
  - Washington State Transportation Commission
  - Washington State DOT
- Local Transportation Agencies
  - New York City DOT
  - Maricopa County DOT

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- Southwest Research Institute
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- University of Arizona
- University of Michigan and American Center for Mobility

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Producing Products

- TRB e-Circular "Preparing for Automated Vehicles & Shared Mobility
  - Makes the case for long-term strategic research effort
  - Available on TRB website
  - Updated annually
- Directory of Information Resources
  - Key resources that directly address mission of the Forum
  - Direct links to more than 60 reports published 2017 to date
  - Continuously updated

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Identifying Critical Research Needs

- Produced list of more than 100 critical research needs
  - Provided to U.S. DOT, TRB & other research organizations for possible funding
  - Updating annually
- Ranked top 10 critical research issues
  - Many subsequently selected for funding by NCHRP
  - In 2019, preparing white papers on each to include: description of issue, links to information already available, research completed/underway/planned, and remaining research gaps

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Addressing the BIG Questions

- What is the vision(s) for a "fully evolved" future?
- What are the potential impacts on government & private sector?
- What are the financing, funding, and economic implications?
- What is the importance and role of connectivity?

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Addressing the BIG Questions

- Forum working groups established for each
- TRB Annual Meeting Session 1679
  - Wednesday, January 16th, 8:00 am - 9:45 am, Convention Center Salon A
- Forum Workshops during 2019
- Forum summary reports on each:
  - Why the issue is of critical importance
  - Current status - what we know now, and what we don't know
  - Future scenarios and implications
  - Questions and issues that need to be addressed to achieve positive outcomes

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Forum on Preparing for Automated Vehicles & Shared Mobility
The National Academies of
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TRANSPORTATION RESEARCH BOARD
Forum Website:
https://trb.org/AVSMForum
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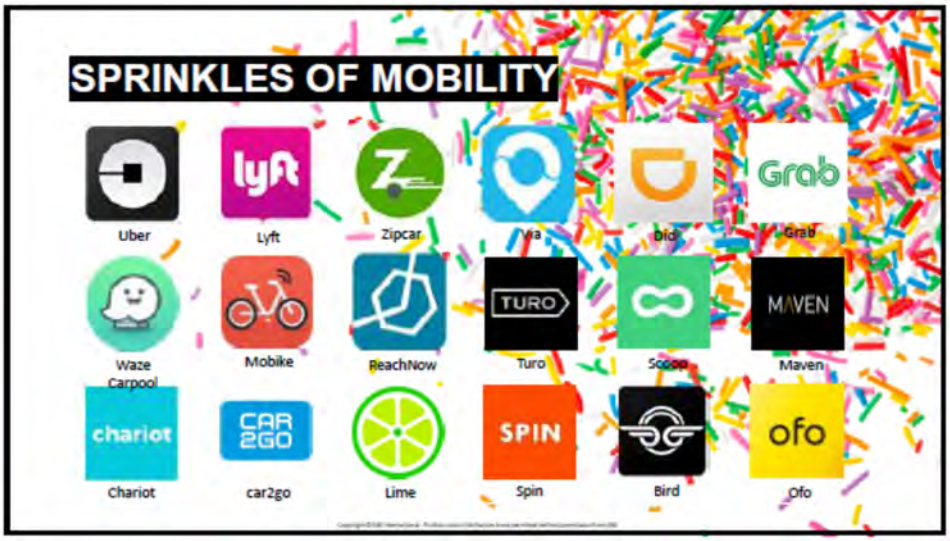
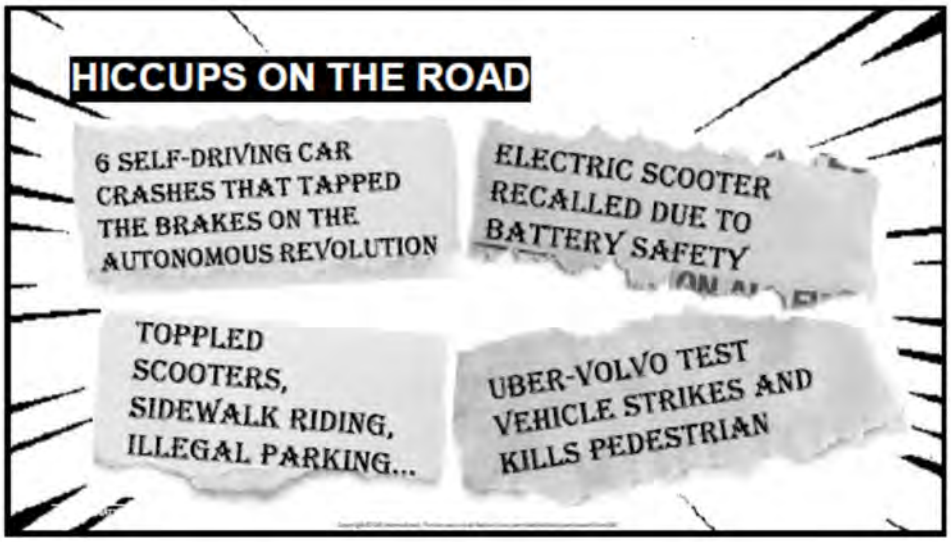
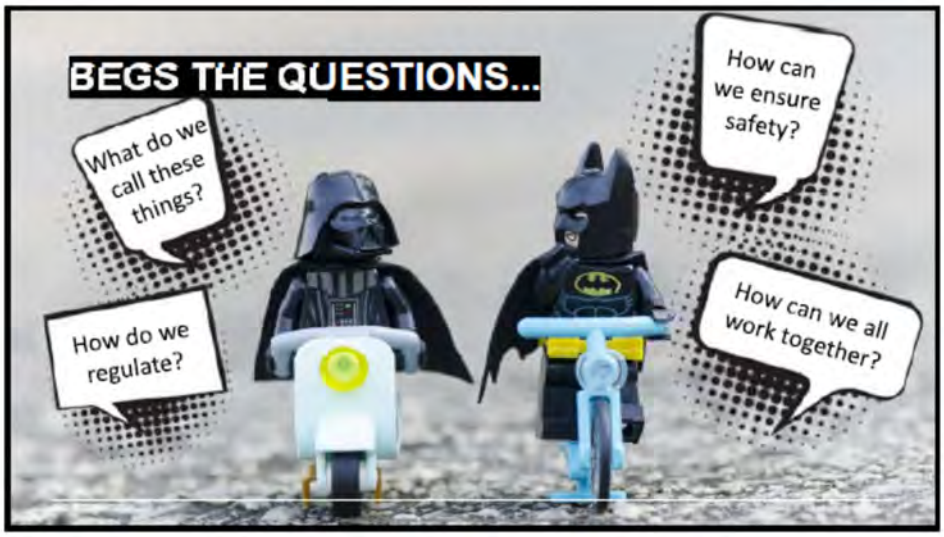
SAE INTERNATIONAL
EMERGING STANDARDS FOR EMERGING MOBILITY
TRB 98th Annual Meeting
Mobility on Demand: A Smart, Sustainable, and Equitable Future
January 13, 2019
Annie Chang (annie.chang@sae.org)
Tim Weisenberger (tim.weisenberger@sae.org)

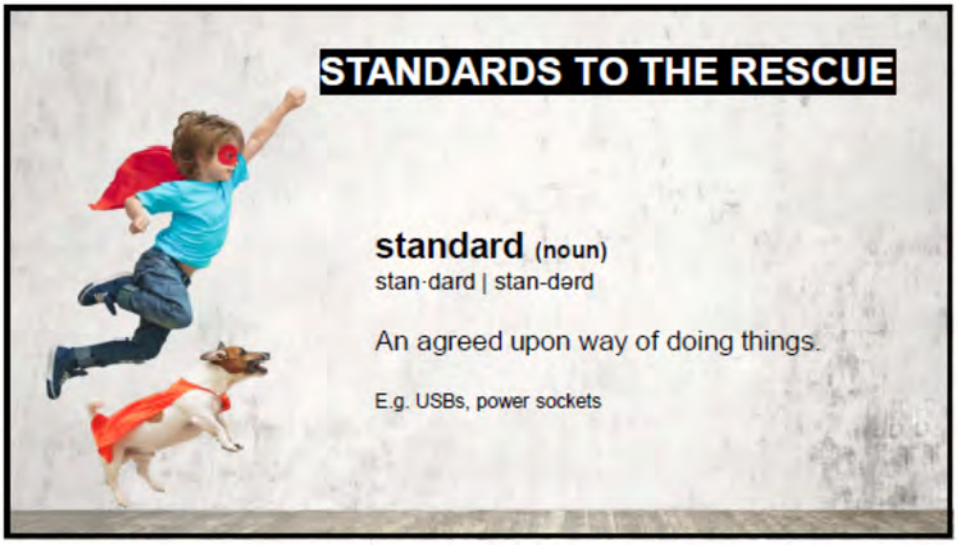

HELLO
my name is
ANNIE CHANG
Emerging Mobility Standards
SAE International

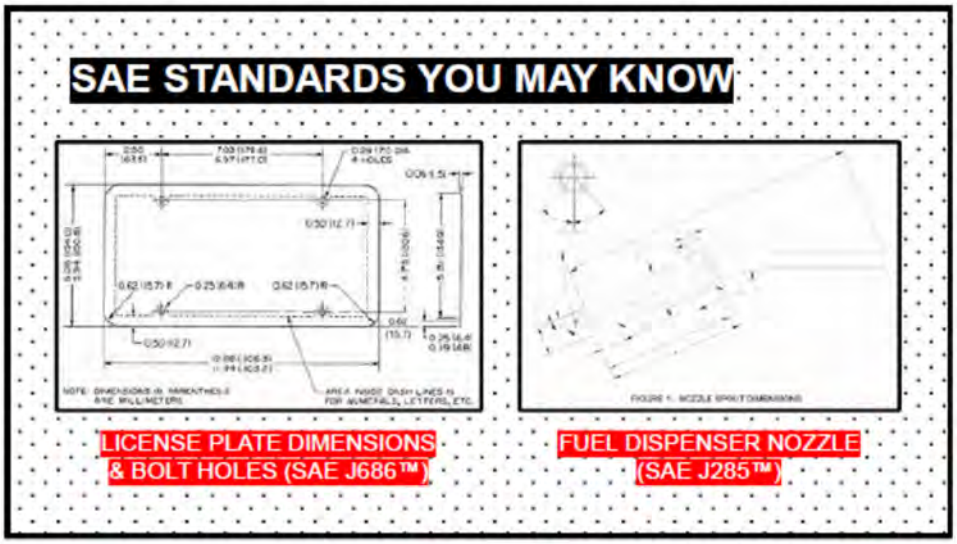

HELLO
my name is
TIM WEISENBERGER
Emerging Technologies Standards
SAE International

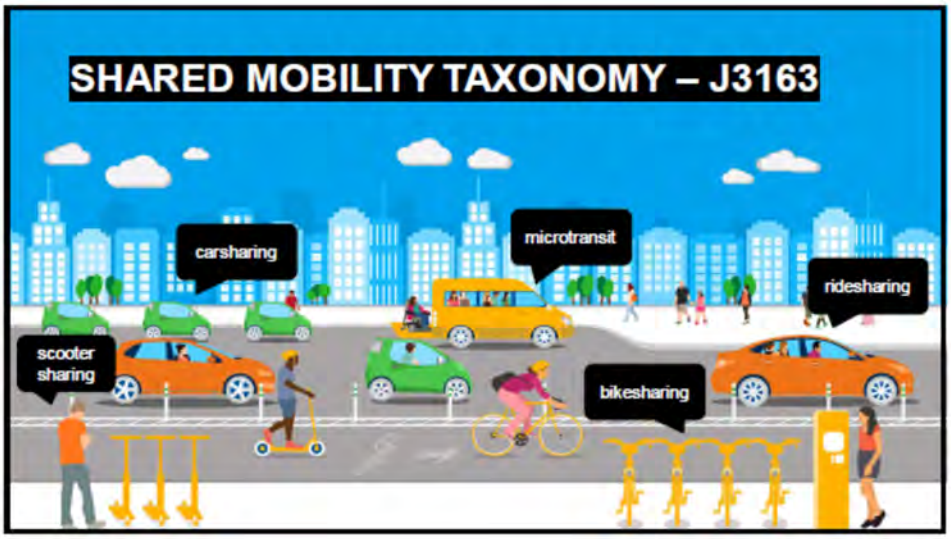

SPRINKLES OF MOBILITY
Uber
Lyft
Zipcar
Via
Didi
Grab
Waze Carpool
Mobike
ReachNow
Turo
Scooot
Maven
Chariot
car2go
Lime
Spin
Bird
Ofo

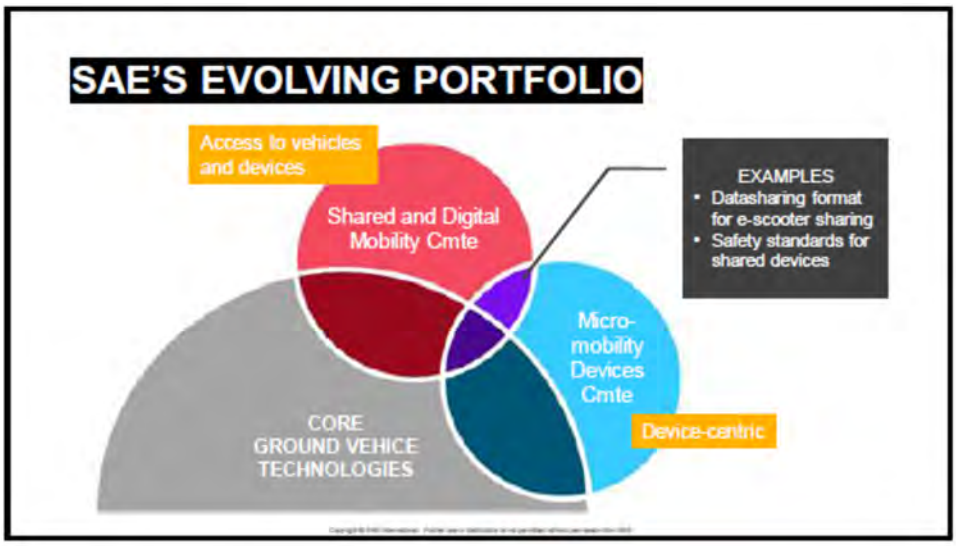

HICCUPS ON THE ROAD
6 SELF-DRIVING CAR CRASHES THAT TAPPED THE BRAKES ON THE AUTONOMOUS REVOLUTION
ELECTRIC SCOOTER RECALLED DUE TO BATTERY SAFETY
TOPPLED SCOOTERS, SIDEWALK RIDING, ILLEGAL PARKING...
UBER-VOLVO TEST VEHICLE STRIKES AND KILLS PEDESTRIAN

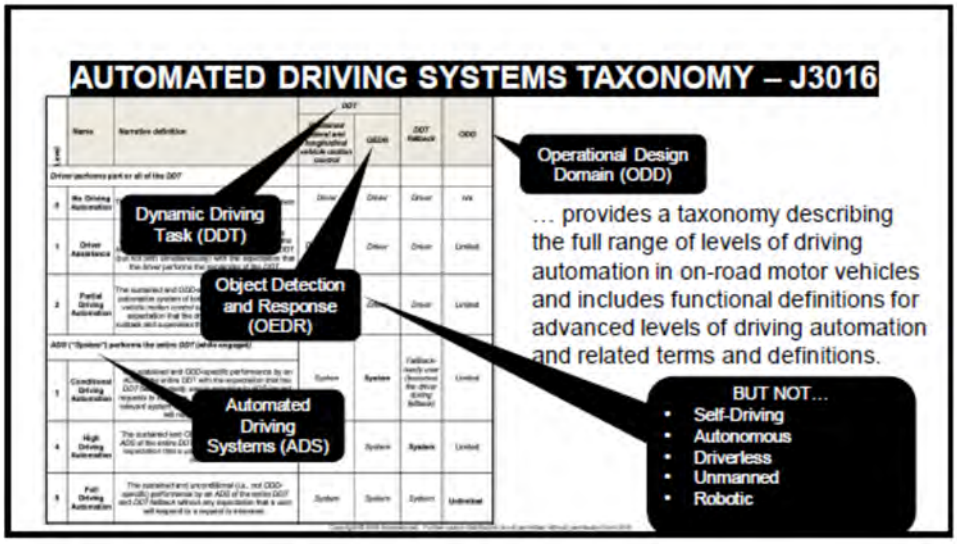

BEGS THE QUESTIONS...
What do we call these things?
How do we regulate?
How can we ensure safety?
How can we all work together?

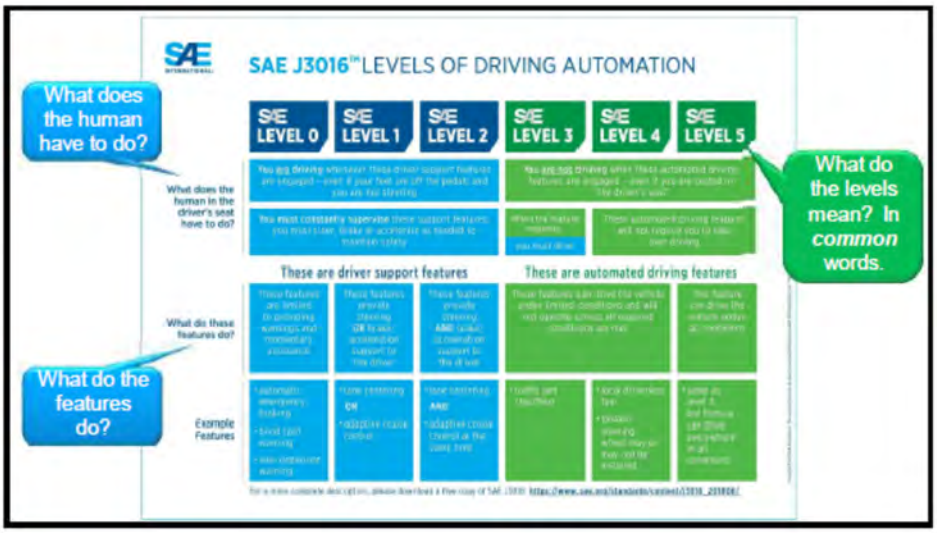

STANDARDS TO THE RESCUE
standard (noun)
stan·dard | stan-dərd
An agreed upon way of doing things.
E.g. USBs, power sockets

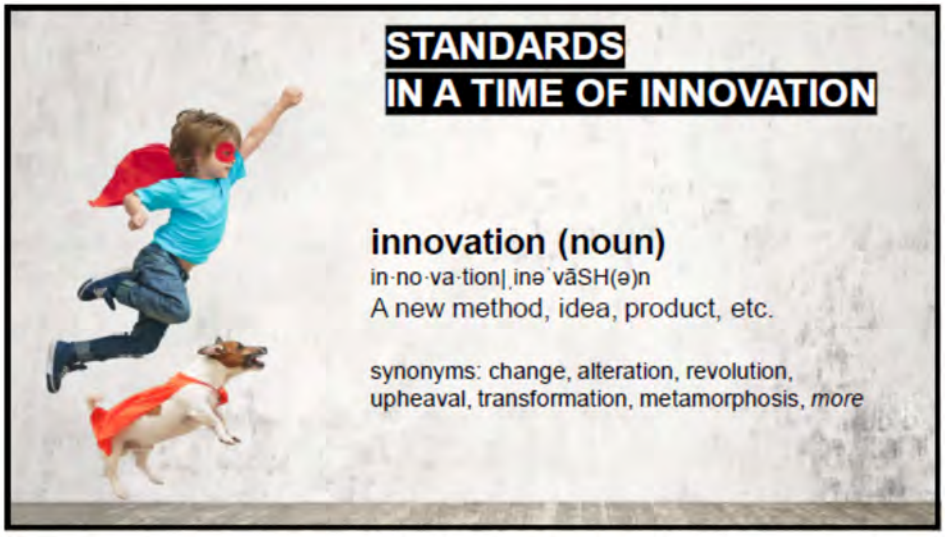

SAE STANDARDS YOU MAY KNOW
LICENSE PLATE DIMENSIONS & BOLT HOLES (SAE J686™)
FUEL DISPENSER NOZZLE (SAE J285™)

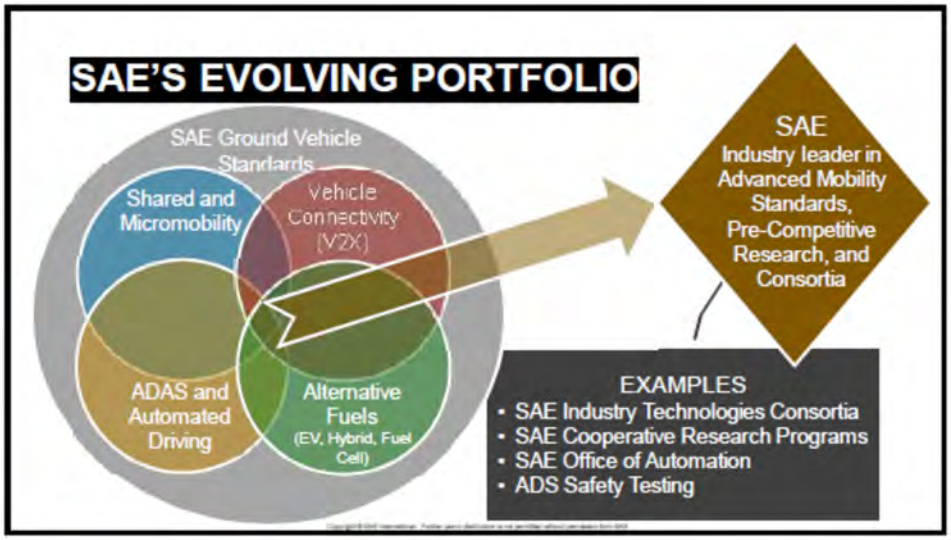

SHARED MOBILITY TAXONOMY – J3163
carsharing
microtransit
ridesharing
scooter sharing
bikesharing


SAE'S EVOLVING PORTFOLIO
Access to vehicles and devices
Shared and Digital Mobility Cmte
EXAMPLES
• Datasharing format for e-scooter sharing
• Safety standards for shared devices
Micro-mobility Devices Cmte
Device-centric
CORE GROUND VEHICLE TECHNOLOGIES


AUTOMATED DRIVING SYSTEMS TAXONOMY – J3016
Dynamic Driving Task (DDT)
Object Detection and Response (OEDR)
Automated Driving Systems (ADS)
Operational Design Domain (ODD)
… provides a taxonomy describing the full range of levels of driving automation in on-road motor vehicles and includes functional definitions for advanced levels of driving automation and related terms and definitions.
BUT NOT…
• Self-Driving
• Autonomous
• Driverless
• Unmanned
• Robotic


SAE J3016™ LEVELS OF DRIVING AUTOMATION
SAE LEVEL 0
SAE LEVEL 1
SAE LEVEL 2
SAE LEVEL 3
SAE LEVEL 4
SAE LEVEL 5
What does the human have to do?
What do the levels mean? In common words.
What does the human in the driver's seat have to do?
These are driver support features
These are automated driving features
What do these features do?
What do the features do?
Example Features


STANDARDS
IN A TIME OF INNOVATION
innovation (noun)
in·no·va·tion|ˌinəˈvāSH(ə)n
A new method, idea, product, etc.
synonyms: change, alteration, revolution, upheaval, transformation, metamorphosis, more


SAE'S EVOLVING PORTFOLIO
SAE Ground Vehicle Standards
Shared and Micromobility
Vehicle Connectivity (V2X)
ADAS and Automated Driving
Alternative Fuels (EV, Hybrid, Fuel Cell)
SAE
Industry leader in Advanced Mobility Standards, Pre-Competitive Research, and Consortia
EXAMPLES
• SAE Industry Technologies Consortia
• SAE Cooperative Research Programs
• SAE Office of Automation
• ADS Safety Testing


THANK YOU
Annie Chang
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Tim Weisenberger
Manager, Technologies
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Waymo…

What do they mean to us?

Connecting communities. Enhancing lives.
Rob Antoniak, Chief Operating Officer

VALLEY METRO

FTA Mobility on Demand Sandbox

DEMONSTRATION PROGRAM TO EXPLORE MOD MODELS

- **EMPOWERS** transit agencies to explore innovative business models and partnerships to deliver high-quality, seamless and equitable mobility options
- **INFORMS** the USDOT and communities on how to approach MOD and structure future MOD policies, and support FTA grantees

MOD
MOBILITY ON DEMAND

PASS 2 GO
PILOT

Autonomous Vehicle Demo

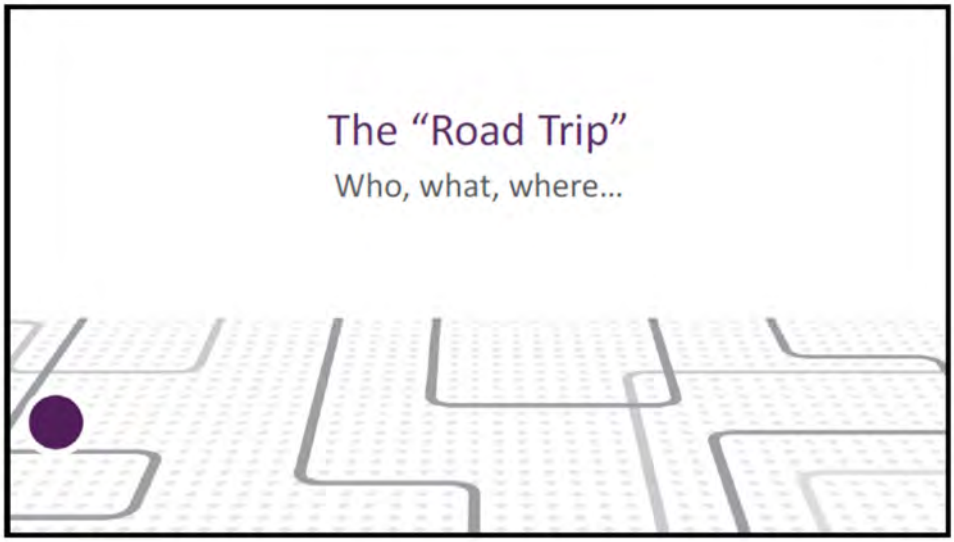
$250K EXTRA AWARDED FOR "DEMO"
- + $80K local = $330K Total Budget

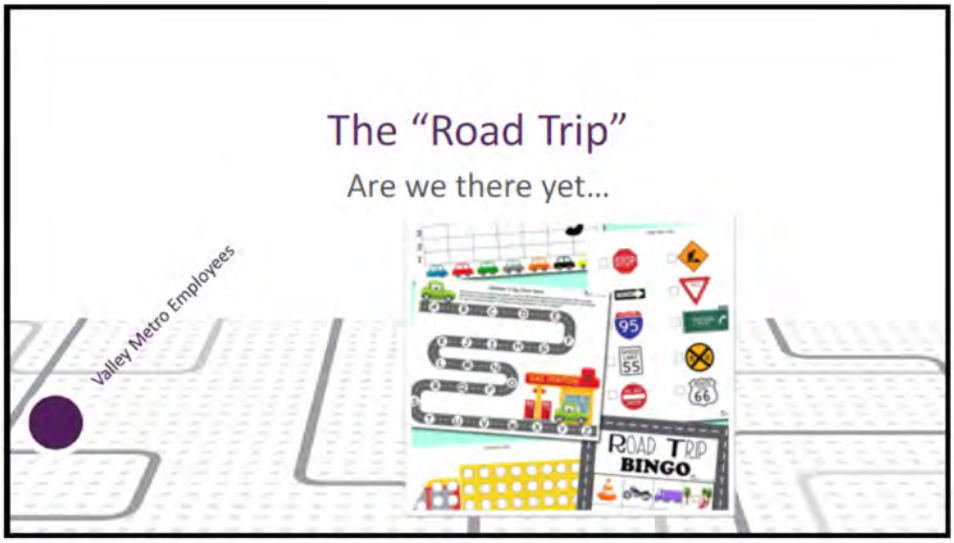
FIRST/LAST MILE CONNECTOR OR LOCAL CIRCULATOR

DATA COLLECTION ON LESSONS LEARNED REGARDING:
- Implementation
- Operations and maintenance,
- Policies and regulations,
- Human factors and user satisfaction
- Other aspects of automated first mile / last mile.

VALLEY METRO | WAYMO

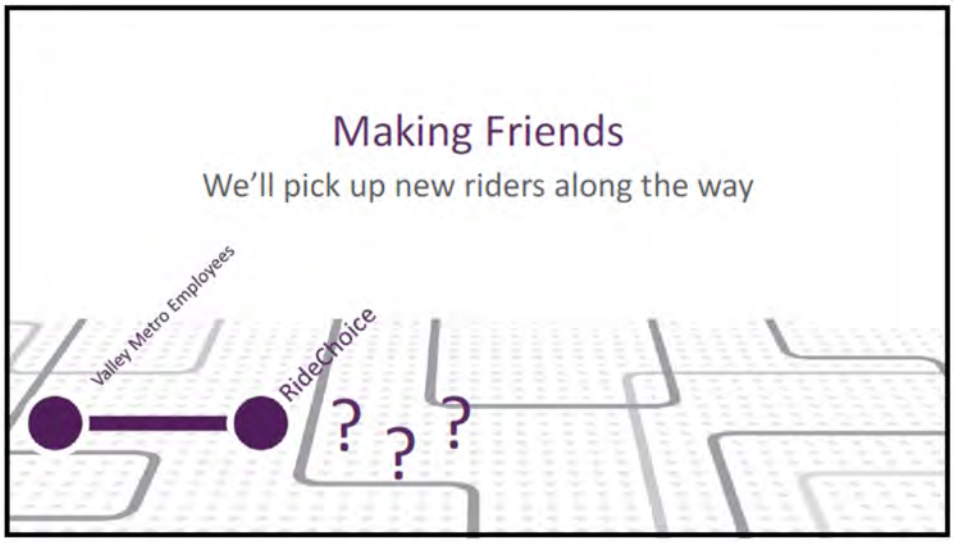

VALLEY METRO
• https://www.youtube.com/watch?v=rKyvHnUz3bs

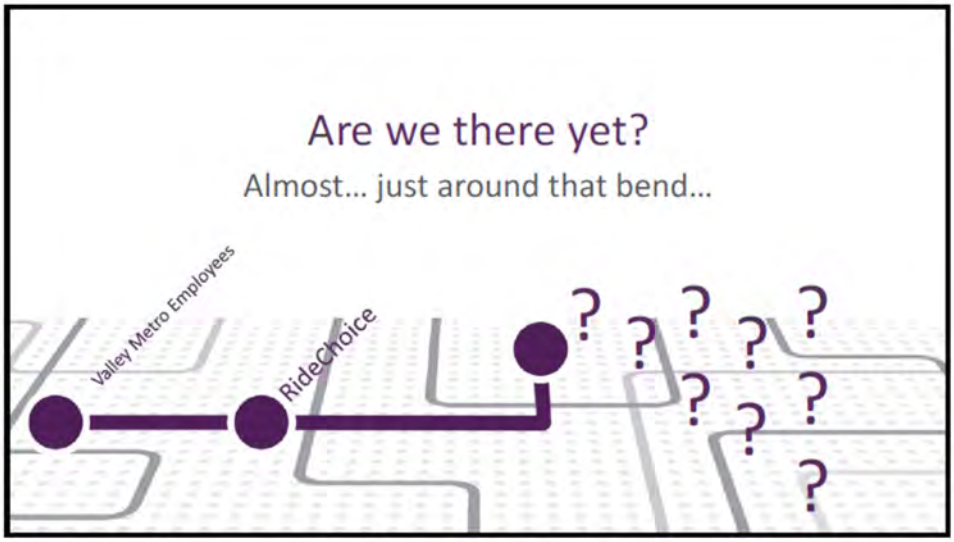

The "Road Trip"
Who, what, where…


The "Road Trip"
Are we there yet…
Valley Metro Employees
ROAD TRIP
BINGO


First Destination
What have we learned?
Valley Metro Employees
Lessons Learned
First/Last Mile
Customer Experience
ROAD TRIP
BINGO


WAYMO


Making Friends
We'll pick up new riders along the way
Valley Metro Employees
RideChoice

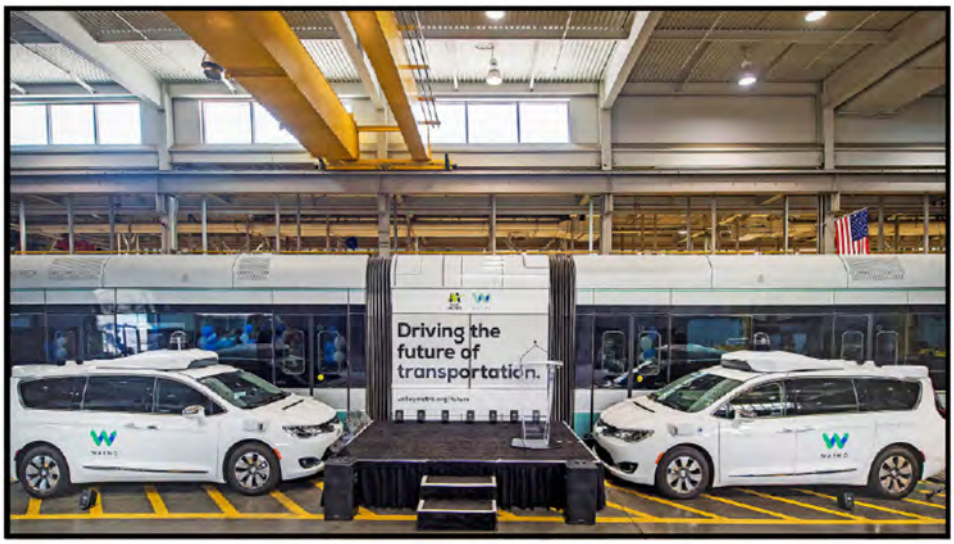

Are we there yet?
Almost… just around that bend…
Valley Metro Employees
RideChoice


Project Timeline
• July 31, 2018 – Announcement
• September 1, 2018 – Phase I
• September 1, 2018 – March 31, 2019
• Identify any barriers to entry and Phase II prep
• April, 2019 – Phase II anticipated launch
• Through July, 2020 – Additional phases
Driving the
future of
VALLEY METRO
WAYMO

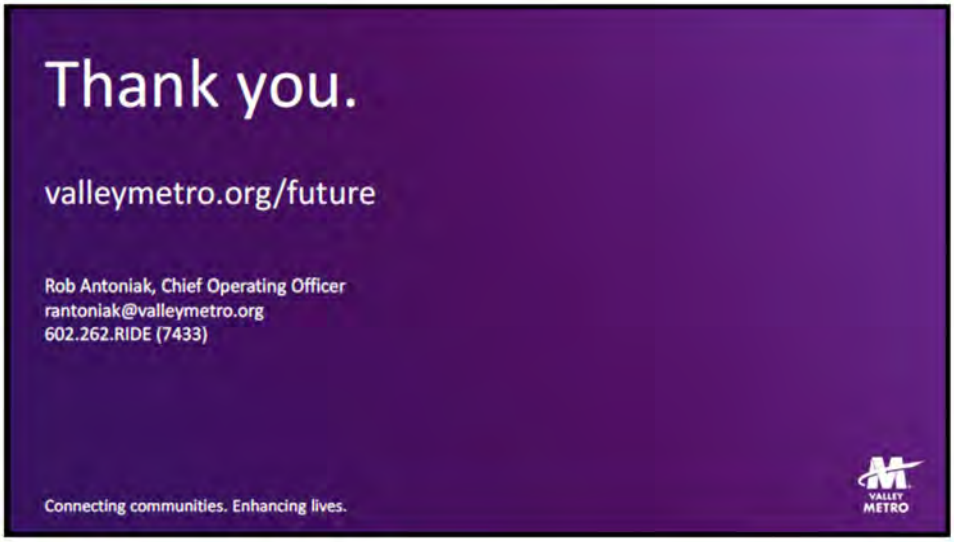
Lessons Learned

BE CREATIVE, PATIENT & UNDERSTANDING

- Be creative with available resources
  + local funds
  + budget neutral
  + FTA MOD Sandbox funds
  = **Innovation, Pilot & Goal!**
- Building trust takes time… persevere
- Meet business at their door… seek to understand




VALLEY METRO
WAYMO
Driving the future of transportation.


Thank you.
valleymetro.org/future
Rob Antoniak, Chief Operating Officer
rantoniak@valleymetro.org
602.262.RIDE (7433)
Connecting communities. Enhancing lives.
VALLEY METRO

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, non-governmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. C. D. Mote, Jr., is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the **National Academies of Sciences, Engineering, and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The National Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.national-academies.org**.

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Learn more about the Transportation Research Board at **www.TRB.org**.

TRANSPORTATION RESEARCH BOARD
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