Mobility on Demand Marketplace Concept of Operations Blueprint

www.its.dot.gov/index.htm

Final Report – July 2020

FHWA-JPO-20-822

MOD

MOBILITY ON DEMAND

U.S. Department of Transportation

Produced by ICF
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology, Intelligent Transportation Systems Joint Program Office

Notice

Cover image: U.S. Department of Transportation

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-20-822		

4. Title and Subtitle	5. Report Date
Mobility on Demand Marketplace Concept of Operations Blueprint	July 2020
	6. Performing Organization Code
7. Author(s) Fariel Bouattoura (MINDHOP), Joe Zingalli (MINDHOP), Les Brown (ICF), Deepak Gopalakrishna (ICF), Radha Neelakantan (ICF)	8. Performing Organization Report No.
9. Performing Organization Name and Address ICF 9300 Lee Highway Fairfax, VA 22031 Mindhop, Inc. 719 Bedford Road Bedford Corners, NY 10549	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH6116D00052-693JJ318F000330
12. Sponsoring Agency Name and Address U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology ITS Joint Program Office 1200 New Jersey Avenue, SE Washington, DC 20590	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

Robert Sheehan, ITS JPO Task Manager

16. Abstract

A Mobility on Demand (MOD) Marketplace is a digital platform that integrates multimodal supply for personal mobility and goods delivery services into a trusted venue for consumers to plan, reserve, and purchase services that meet their current needs. By streamlining multimodal travel choice for users, an effective MOD Marketplace supports the achievement of the USDOT MOD vision, which seeks to leverage innovative technologies and public-private partnerships to provide safe, reliable, seamless, and equitable mobility and goods delivery for all users. This Concept of Operations (ConOps) document frames the overall MOD Marketplace and defines a blueprint for a prototype technical system and the course for future projects based on a thorough assessment of system users' needs and use case scenarios. The document also provides understanding of the institutional, operational, technical, and policy opportunities and constraints when considering a MOD Marketplace system deployment. This document will be useful for all transportation and information technology professionals involved in the planning, design and implementation of a MOD Marketplace technical system or MOD program.

17. Keywords	18. Distribution Statement
Mobility on demand, MOD, shared mobility, Integrated Payment, Multimodal Trip Planner	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
		128	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

Table of Contents

List of Tables

List of Figures

1 Scope

1.1 Background

Innovations in transportation are rapidly changing how people navigate our streets. These emerging mobility services and technologies include ridesourcing services, bikeshare services, autonomous vehicles, and more. At the same time, public and private transportation providers are working together to create more integrated multimodal mobility services. These trends are changing the way people travel and goods are delivered, disrupting traditional trip chains and creating more flexible, user-centric transportation allowing for mode shifts based on convenience, accessibility, reliability, cost, and trip duration.

1.2 Intended Audience

This Concept of Operations (ConOps) document is designed for project managers, system owners, operators, maintainers, and anyone else who is planning to implement a Mobility on Demand (MOD) Marketplace platform.

This guide is intended for all transportation professionals who will be involved in the planning, design and implementation of a MOD Marketplace and will need to understand the various sub-systems required for a successful MOD Marketplace implementation.

1.3 Mobility on Demand

The MOD program is a joint U.S. Department of Transportation (USDOT) initiative led by the Intelligent Transportation Systems (ITS) Joint Program Office (JPO), Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) to provide helpful information, best practices, tools, and customized technical support to state and local agencies for contemporary and emerging travel management services.

USDOT's concept of **MOD is a vision for "an integrated multimodal network of safe, carefree, and reliable transportation options that are available to all."** MOD is built on four guiding principles: user-centric, technology-enabled, partnership-driven, and mode-agnostic. A traveler-centric system promotes choice in personal mobility and increases access to modes and destinations. By being technology-enabled, the system can leverage emerging technologies and innovations to enable integration of mobility options. The partnership-driven nature of MOD emphasizes collaboration and transformation between traditional and non-traditional partners. Lastly, MOD's mode-agnostic foundation encourages an integrated, multimodal approach based on local needs and goals. This vision of MOD merges the supply of mobility provided by public agencies, private providers, and even individuals with the demand for improved personal mobility and movement of goods.

To help achieve this vision, this document explores the concept of a MOD Marketplace technical platform that connects users (people and goods) with service providers (public and private) in an efficient and productive manner. This platform encompasses the MOD Marketplace supply side and demand side to provide the data necessary to feed into a multimodal transportation operations management decision support system (DSS).

1.4 MOD Ecosystem

The MOD Ecosystem describes the dynamic between stakeholders, enablers, and mobility integration platforms such as the MOD Marketplace that can facilitate and/or influence the supply and demand sides of MOD. The supply side is comprised of the professionals, operators, carriers and devices that provide transportation service (e.g., public and private mobility services, goods delivery services, transportation facilities, and information services). The demand side consists of the users of transportation services (e.g., all travelers, couriers, consumers, and modal demand).

1.5 MOD Marketplace

The MOD Marketplace concept consists of a digital platform where supply and demand of transportation and goods delivery services can be integrated into a trusted venue for consumers to potentially plan, reserve, and purchase services. Transportation agencies, as well as private mobility providers (see details in section 4.3 - MOD Marketplace Stakeholders) are now both providers of transportation services to consumers.

The MOD Ecosystem is in constant influx as new suppliers and business models frequently enter the market. In addition, digital connectivity enables travelers, goods delivery, and transportation systems to be fully connected, not just to the Internet itself, but also to each other, creating a platform where supply and demand for services are exchanged.

With the proliferation of new mobility offerings and changes in customer preferences for transportation, there is a high level of interest in the MOD Ecosystem from both transportation agencies and the private sector. Some of the current marketplace observations include:

- Both public and private sector companies are increasingly acknowledging changing demand and are adjusting their business models and forming partnerships to capture the emerging market and participate in the MOD program. New business models and partnerships shaping the MOD Ecosystem could be challenging for the private sector. Many transit and public agencies have operated their services without necessity of coordination with other providers. Thus, participation in the MOD program may require changes not only in the way agencies schedule and operate their services, but also in the role of each agency in the overall transportation network and MOD supply and demand chain.
- The MOD Ecosystem is benefitting from strategic funding and private sector developments integrated and implemented by major market players. For example, the 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.
- Considerable value can be extracted from the MOD Ecosystem data points, such as understanding travel patterns, requests, preferences, where people come from and go to, where goods are delivered, and deviation of services. The current MOD Marketplace shows a number of tactical moves from the private sector with acquisitions and mergers for an increased market share.

1.6 How to Use this Document

This document will be of value to public agencies, local communities, individuals, and businesses who want to know more about how to implement a MOD Marketplace technical platform. The ConOps describes the proposed System as seen and understood by the stakeholders of interest.

This document is organized to closely mirror the template suggested by the Institute of Electrical and Electronics Engineers (IEEE) 1362, which is a guide for developing ConOps for technology projects (IEEE, 2007).

This ConOps frames the overall MOD Ecosystem and defines a blueprint and technical course for future projects. It describes how various stakeholders can use this document as well. Overall this document is intended to:

- Capture and document user needs as they relate to a MOD Marketplace technical platform
- Describe the proposed system and components from a user's point of view.
- Help understand the institutional, operational, technical, and policy constraints and challenges when considering a MOD Marketplace system deployment
- Assist stakeholders in starting a MOD program

This ConOps specifies what should be achieved, with a focus on the user needs, but does not describe how this might be achieved. It also includes a proposed system architecture and identifies interdependencies in the MOD Ecosystem. This ConOps provides a foundation for more detailed analyses that will follow with each organization planning to implement MOD, such as system requirements definitions. This document also references and expands on most of the USDOT MOD initiatives and publications, including the Operational Concept Report (FHWA-JPO-18-611) released in September 2017. This ConOps is based on industry research and lessons learned from ongoing MOD pilot projects, which helped to identify user needs for the system.

This document is organized into the following sections:

- Section 1 introduces MOD, including providing context on the MOD Ecosystem and Marketplace concepts, and providing an overview of how this document should be used.
- Section 2 (Referenced Documents) describes the external documentation referenced throughout this document.
- Section 3 (Current Situation) describes the current situation regarding existing MOD implementations in the MOD Ecosystem, MOD business models and partnerships, and MOD Ecosystem stakeholders.
- Section 4 (Justification for and Nature of Changes, and Goals and Objectives) describes deficiencies or shortcomings of the existing situation specifically as it relates to the needs of the users of the MOD initiative as well as the goals and objectives of the MOD program.
- Section 5 (MOD Marketplace System) describes an overview of the proposed system and functionality required to meet the user needs and the changes identified in Section 4. This section will describe the key MOD subsystems, functions, environment needed to support MOD, constraints and assumptions, and high-level operational requirements.

- Section 6 (Operational Scenarios) provides a user-oriented description of how the system works for given contexts and conditions.
- Section 7 (Summary of Impacts) describes the operational impacts of the proposed system on the users, developers, maintenance organizations, and support organizations.

2 References

The following sources were used as forms of reference in the production of this ConOps document:

Beeline Singapore. (2020, February 3). *https://www.beeline.sg/*. Retrieved from https://www.beeline.sg/: https://www.beeline.sg/

Bialik, K. (2017, July 27). *7 facts about Americans with disabilties.* Retrieved from Pew Research Center: https://www.pewresearch.org/fact-tank/2017/07/27/7-facts-about-americans-with-disabilities/

Bliss, L. (2019, October 29). *Uber's Beef With L.A. Is Bigger Than Data.* Retrieved from Citylab: https://www.citylab.com/transportation/2019/10/uber-lawsuit-data-privacy-scooter-tracking-los-angeles/600985/

Chang, A., Guan, A., Okunieff, P., Heggedal, K., Brown, L., Schweiger, C., & O'Reilly, K. (2019). *Multimodal and Accessible Travel Standards Assessment - Survey of Standards and Emerging Standards White Paper.* Manuscript Submitted for Publication.

City of Columbus. (2020). *Smart Mobility Hubs.* Retrieved from Smart Columbus: https://smart.columbus.gov/projects/smart-mobility-hubs

Cohen, A., Sarkhili, S., Shaheen, S., & Yelchuru, B. (2017). *Mobility on Demand Operational Concept Report.* Washington, DC: Intelligent Transportation Systems Joint Program Office - U.S. Department of Transportation.

Cordahi, G., & Shaheen, S. (2018). *MOD Sandbox Demonstrations Independent Evaluation (IE) Vermont Agency of Transportation (VTrans) OpenTripPlanner Evaluation Plan. U.S. Department of Transportation Federal Transit Administration Office of the Assistant Secretary for Research and Technolog.*

Derby, A. (2019, July 8). *Fare Capping: How it works in Portland.* Retrieved from Mass Transit: https://www.masstransitmag.com/technology/passenger-info/article/21087563/fare-capping-how-it-works-in-portland

Federal Communications Commission. (n.d.). *Section 508 Information*. Retrieved from www.fcc.gov: https://www.fcc.gov/general/section-508-information

Federal Deposit Insurance Corporation. (2018, October 22). *2017 FDIC National Survey of Unbanked and Underbanked Households.* Retrieved from Federal Deposit Insurance Corporation: https://www.fdic.gov/householdsurvey/

Ghoseiri, G., Haghani, A., & Hamedi, M. (2018). *Real-time Rideshare Matching Problem. Mid-Atlantic Universities Transportation Center. Grant DTRT07-G-0003.*

Godavarthy, R. (2019). *NCHRP 20-65: Opportunities for State DOTs (and Others) to Encourage Shared Use Mobility Practices in Rural Areas.* Manuscript in preparation.

gov.uk. (2020). *G8 Open Data Charter and Technical Annex*. Retrieved from gov.uk: https://www.gov.uk/government/publications/open-data-charter/g8-open-data-charter-and-technical-annex

Government of India Ministry of Electronics and Information Technology. (n.d.). *Open Government Data*. Retrieved from National Informatics Centre: NA

Grossman, A., & Lewis, P. (2019). *Contracting for Mobility: A Case Study in the Los Angeles and Puget Sound Regions.* Washington, DC: Eno Center for Transportation.

HACON. (2020). *Trip Planner and Travel Companion*. Retrieved from HACON: https://hacon.de/en/solutions/trip-planner-and-travel-companion/

Herron, E. (2019, June 14). *Electric Scooters With Seats Hit Portland Streets.* Retrieved from Willamette Week: https://www.wweek.com/news/2019/06/14/electric-scooter-with-seats-hit-portland-streets/

Hord, Jennifer. (n.d.). *How Electronic Payment Works*. Retrieved from How Stuff Works: https://money.howstuffworks.com/personal-finance/online-banking/electronic-payment.htm

IEEE. (2007). *Guide for Information Technology - System Definition Concept pf operations Std 1362™ - 1998 [R2007].* IEEE Standard Association.

Knight, M. (2017, December 18). *What is Data Governance?* Retrieved from dataversity.net: https://www.dataversity.net/what-is-data-governance/

Mass Transportation Authority. (n.d.). *Rides to Wellness.* Retrieved from Mass Transportation Authority: https://www.mtaflint.org/rides-to-wellness.html

NACTO. (2017, April 17). *Bike Share in the US.: 2017*. Retrieved from nacto.org: https://nacto.org/bike-share-statistics-2017/

NACTO. (2018, December 31). *Shared Micromobility in the U.S.: 2018.* Retrieved from nacto.org: https://nacto.org/shared-micromobility-2018/

National Association of City Transportation Officials. (2013). *Urban Streets Design Guide.* New York: Island Press.

National Disability Authority. (2020). *National Disability Authority. The 7 Principals*. Retrieved from universaldesign.ie: http://universaldesign.ie/What-is-Universal-Design/The-7-Principles/

Neudeck, A., & Vanbeveren, G. (2017). *Mobility-as-a-Service: Real-time routing service reducing travel time of air passengers.* Retrieved from globalrail.com: https://www.globalairrail.com/images/events/2017/Airport_Access_Ideas_Forum_2017/Case_Studies/AAIF2017%20-%20Case%20Studies-MaaS.pdf

Newcomb, D. (2016, June 27). *Inside Audi, BMW and Daimler's $3 Billion Bet On HERE's Mapping Business*. Retrieved from Forbes.com: https://www.forbes.com/sites/dougnewcomb/2016/06/27/inside-audi-bmw-and-daimlers-3-billion-bet-on-heres-mapping-business/#3aa5f0c96343

NITI Aayog and Rocky Mountain Institute. (2018). *Data-driven Mobility: Improving Passenger Transportation Through Data.*

O'Kane, S. (2018, July 2). *Lyft buys the biggest bike-sharing company in the US*. Retrieved from theverge.com: https://www.theverge.com/2018/7/2/17526892/lyft-buys-motivate-bike-sharing-expansion

Pew Research Center. (2019, June 12). *Mobile Fact Sheet*. Retrieved from www.pewinternet.org: http://www.pewinternet.org/fact-sheet/mobile/

Pew Research Center. (2019, June 12). *Mobile Fact Sheet.* Retrieved from Pew Research Center: https://www.pewresearch.org/internet/fact-sheet/mobile/

Plummer, L. (2011, August 22). *This is how Netflix's top-secret recommendation system works*. Retrieved from wired.com: https://www.wired.co.uk/article/how-do-netflixs-algorithms-work-machine-learning-helps-to-predict-what-viewers-will-like

Portland Bureau of Transportation. (2020). *Adaptive BIKETOWN Pilot.* Retrieved from Portland Bureau of Transportation: https://www.portlandoregon.gov/transportation/73371

PR Newswire. (2018, January 8). *PRNewswire*. Retrieved from www.prnewswire.com: https://www.prnewswire.com/news-releases/here-launches-global-marketplace-for-on-demand-transportation-and-mobility-services-300578912.html

Reagan, C. (2018, June 28). *"Amazon reveals a new plan to deliver more packages: Recruit people to run small-scale delivery services"*. Retrieved from CNBC: https://www.cnbc.com/2018/06/27/amazon-is-recruiting-entrepreneurs-to-start-delivery-networks.html

Rouse, M. (2020, February). *Personally Identifiable Information (PII)*. Retrieved from Search Financial Security: https://searchfinancialsecurity.techtarget.com/definition/personally-identifiable-information

Rowe, K. (2018, February 23). *How Search Engines Use Machine Learning: 9 Things We Know for Sure*. Retrieved from searchenginejournal.com: https://www.searchenginejournal.com/how-search-engines-use-machine-learning/224451/#close

Rubenstein, D. (2018, June 13). *New York City and Uber reach settlement on wheelchair accessibility.* Retrieved from Politico: https://www.politico.com/states/new-york/city-hall/story/2018/06/13/new-york-city-and-uber-reach-settlement-on-wheelchair-accessibility-466459

SAE. (2018). *Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies.*

Shaheen, S., Cohen, A., Broader, J., Davis, R., Brown, L., & Neelakantan, R. (2019). *Mobility on demand planning and implementation: Current practices, innovations, and emerging mobility futures.* Manuscript in Preparation.

Shrikant, A. (2019, January 11). *Transportation experts see Uber and Lyft as the future. But rural communities still don't use them.* Retrieved from Vox: https://www.vox.com/the-goods/2019/1/11/18179036/uber-lyft-rural-areas-subscription-model

Société de transport de Montréal. (2020). *Combined Mobility*. Retrieved from http://www.stm.info: http://www.stm.info/en/info/fares/special-offers/integrated-mobility

Transportation Sustainability Research Center. (2016). *Mobility on Demand and Social Equity.* Unpublished Manuscript.

USDOT. (2016, May 01). *Accessible Transportation Technologies Research Initiative (ATTRI): User Needs Assessment: Stakeholder Engagement Report*. Retrieved from https://www.its.dot.gov: https://rosap.ntl.bts.gov/view/dot/31320

USDOT. (2017). *Mobility on Demand (MOD) Deployment Scenarios. Draft v1.0.*

USDOT. (2019, November 08). *Mobility on Demand (MOD) Sandbox Program*. Retrieved from USDOT - Federal Transit Administration: https://www.transit.dot.gov/research-innovation/mobility-demand-mod-sandbox-program

USDOT. (n.d.). *Accessible Transportation Technologies Research Initiative.* Retrieved from Office of the Assistant Secretary for Research and Technology Intelligent Transportation Systems Joint Program Office: https://its.dot.gov/research_areas/attri/index.htm

WebFinance, Inc. (2020). *Payment Method*. Retrieved from Business Dictionary: http://www.businessdictionary.com/definition/payment-method.html

Wikipedia. (2020, February 22). *E-ZPass*. Retrieved from Wikpedia: https://en.wikipedia.org/wiki/E-ZPass

Zipper, D. (2018, October 25). *Helsinki's MaaS App, Whim: Is It Really Mobility's Great Hope?* Retrieved from Citylab: https://www.citylab.com/perspective/2018/10/helsinkis-maas-app-whim-is-it-really-mobilitys-great-hope/573841/

Zipper, D. (2019, October 8). *'Walled Gardens' vs. Open Mobility: The Battle Begins.* Retrieved from Citylab: https://www.citylab.com/perspective/2019/10/transport-trip-planner-app-lyft-citibike-open-mobility-data/599650/

2.1 Key Terms Used in this Report

Table 1 - List of Key Terms

Acronym/ Abbreviation	Definition
Application	Software application running on an Android or iOS smartphone.
Data Privacy	The reasonable expectation that data of a sensitive nature will be kept confidential, sanitized and/or encrypted, and respectfully and responsibly maintained by all users, managers, and collectors of the data.
Data Retention	The continued storage of data for compliance or business reasons.
Data Security	The tools, policies, practices, and procedures used to protect data from being accessed, manipulated or destroyed or being leveraged by those with a malicious intent or without authorization, as well as the corrective actions taken when data breaches are suspected or have been identified.
Electronic Payment	An electronic payment is any kind of non-cash payment that doesn't involve a paper check. Methods of electronic payments include credit cards, debit cards and the ACH (Automated Clearing House) network (Hord, Jennifer, n.d.).
E-Wallet	An E-Wallet is a stored value system with individual user accounts connected to the mobile ticketing platform.
E-ZPass	E-ZPass is an electronic toll collection system used on most tolled roads, bridges, and tunnels in the Midwestern and Eastern United States, as far south as Florida and as far west as Illinois, (Wikipedia, 2020).
Geocoder	An application providing geographical coordinates corresponding to a location from addresses or names of places.
GTFS Flex	GTFS Flex is a transit feed specification that allows agencies to apply typical public-transit metrics to demand-responsive transit or paratransit.
KML	An open standard officially named the OpenGIS® Keyhole Markup Language (KML) Encoding Standard (OGC KML). It is maintained by the Open Geospatial Consortium, Inc. (OGC).
MOD	MOD is a vision for “an integrated multimodal network of safe, carefree, and reliable transportation options that are available to all” that is built on four guiding principles: user-centric, technology-enabled, partnership-driven, and mode-agnostic.
Open Payment	The use of open industry interface standards and specifications for the electronic remuneration and provision of transport services.
Payment Method	“The way that a buyer chooses to compensate the seller of a good or service that is also acceptable to the seller. Typical

Acronym/ Abbreviation	Definition
	payment methods used in a modern business context include cash, checks, credit or debit cards, money orders, bank transfers and online payment services such as PayPal", (WebFinance, Inc., 2020). .
Shared Mobility	"Shared mobility is [an] innovative transportation strategy that enables users to have short-term access to a transportation mode (e.g., vehicle, bicycle, or other low-speed travel mode) on an as-needed basis" (Cohen, Sarkhili, Shaheen, & Yelchuru, 2017).
Smartphone	A mobile phone capable of using apps; in this case limited to iOS and Android devices.
Touch ID	A trademarked and patented technology, accessible for use by third party developers to enhance app security by requiring a fingerprint. Can be used in lieu of prompting the user to enter a PIN code. Touch ID technology is available, for example, on Apple and Android devices.
Wi-Fi	Wireless networking technology that uses radio waves to provide wireless high-speed Internet and network connections.

3 Current Situation

3.1 Current MOD Implementations

The MOD Ecosystem is at a very early stage in its development, with much innovation and research underway. MOD services have quickly evolved from prototypes to real-world implementations to respond to local needs. They are combining rapidly emerging mobility services and technology offerings.

However, it is important to note that at the time of writing of this document, no true, integrated MOD Marketplace platform exists in the United States, and it is unlikely that local areas have an integrated mobility platform that serves as a MOD Marketplace.

This section address the "current situation" in the marketplace, founded on strategic partnerships between the public sector, significant institutions, and private sector mobility and technology providers. Various MOD implementations, listed in Figure 1 - Public-Private Sector Initiatives and Partnerships, presented later in section 3.1.1, Public-Private Sector Initiatives and Partnerships, were deployed to respond to a broad set of needs summarized in the following table. This list of needs was developed based on extensive research done on the state of the industry. The table lists the needs along with suggestions that describe methods and solutions in which the needs can be addressed.

Table 2 - MOD Marketplace – Implementation Needs

Need	Solution
Fill gaps in the transit system	Encourage connections between transit and other mobility services such as carsharing, bikesharing, ridesharing, Transportation Network Companies (TNCs)/ridesourcing, scooter sharing, microtransit and shuttle services. Use technology and incentives to promote the use of alternate mobility services.
Multimodal trip planning application with electronic payment option	Connect the MOD supply and demand chain through a multimodal trip planner engine, combining alternative mobility options based on user choices, including an integrated payment system and non-payment transactions for ease and convenience.
Reducing parking demand	Encourage efforts to mitigate parking shortages or forestall the need for investments in parking lots in downtown districts, areas of public assembly, transit stations, and other locations. Use discounts and other financial incentives to promote the use of shared mobility services to reduce parking demand.
Promote Mobility for Travelers with Special Needs	Implement programs providing transportation service for people with special needs, such as people with disabilities, caregivers, those on medical trips, and older adult populations as alternatives to conventional paratransit service.
Specialty mobility programs	Implement specialty programs to promote access to work, healthcare, airports, and special venues using shared or alternative transportation services such as “guaranteed ride home” for commuters.
Goods delivery on demand	Provide on-demand delivery modes responding to changes in how consumers shop, make purchases, and receive goods and services.

3.1.1 Public-Private Sector Initiatives and Partnerships

Research was done to evaluate current MOD implementations. This industry scan was completed in February 2019. In reviewing the current state of the practice, relevant projects were reviewed and are listed and classified in Figure 1 - Public-Private Sector Initiatives and Partnerships below. These projects have been classified based on the MOD categories listed above in Table 2.

The projects in the list have been broken down into categories. These categories include the following:

- **Smart Cities projects**: In December 2015, the USDOT launched the Smart Cities Challenge initiative to demonstrate the potential of integrated data, ITS, and applications to improve safety, enhance mobility, and address climate change. The USDOT committed $40 million (with up to an additional $10 million from Vulcan Inc.) in ITS research funding as part of this process. The funding was intended to stimulate partnerships among the public sector, major institutions, and private sector in the form of committed funds, in-kind contributions, and administrative streamlining.

- **MOD Sandbox Projects**: "The MOD Sandbox Demonstration provides a venue through which integrated MOD concepts and solutions (supported through local partnerships) are demonstrated in real-world settings. The Sandbox helps with exploration of types of MOD partnerships, new business models, integration between transit and MOD solutions, and investigating new enabling technical capabilities such as integrated payment systems, decision support, and incentives for traveler choices." (USDOT, 2019)
- **Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Grant Projects**: The Fixing America's Surface Transportation (FAST) Act established the ATCMTD program to make competitive grants for the development of model deployment sites for large-scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment (ROI). Most projects have not started yet or the procurement has been delayed, particularly in the areas of traveler information systems, transportation management technologies, data collection, analysis, and dissemination systems, and dynamic ridesharing.
- **Shared-Use Mobility Center On-Ramp Projects**: The Shared-Use Mobility Center (SUMC), a national nonprofit organization that works to foster cooperation in shared mobility, announced the selection of six public transportation agencies to receive free technical assistance to develop MOD projects through its MOD On-Ramp Program, funded by USDOT's Federal Transit Administration (FTA).
- **Public-Private Partnerships**: Municipal governments, metropolitan planning organizations (MPOs), and transit agencies around the country are embracing the idea of greater synergy between TNCs and emerging mobility services. Most partnerships are motivated by a desire to improve mobility in areas in which transit options are inadequate or nonexistent, there are limited transit service schedules, or where the supply of parking is insufficient.

#	Category	Initiative	1. Fill gaps in the transit system and first mile/last mile solutions	2. Multimodal trip planning app with electronic payment option	3. Reducing parking demand	4. Promote Mobility for Travelers with Impairments and Social Equity	5. Specialty mobility programs	6. Goods delivery on demand	Project Timeline
1	Smart Cities	City of Portland and Portland Bureau of Transportation (Mobility Marketplace - 122nd Avenue Corridor Pilot)	★	★	★	★	★		Planning
2	Smart Cities	City of San Francisco (Transportation as a Service, Shared Van Shuttle Service, Shared Mobility Hubs)	★	★	★	★	★		Planning
3	Smart Cities	City of Denver (Mobility on Demand Enterprise, One-Card Payment System, FMLM Pilot, Interactive Kiosks)	★	★		★	★		Planning
4	MOD Sandbox Projects	Regional Transportation Authority of Pima County	★	★			★		Completed
5	MOD Sandbox Projects	Valley Metro Rail	★	★					Operational
6	MOD Sandbox Projects	City of Palo Alto	★	★			★		In Deployment (Oper. Q4 2018)
7	MOD Sandbox Projects	Los Angeles County Metropolitan Transportation Authority and the Puget Sound transit	★	★		★	★		Operational
8	MOD Sandbox Projects	San Francisco Bay Area Rapid Transit	★		★		★		Operational
9	MOD Sandbox Projects	Pinellas Suncoast Transit Authority	★	★			★		Operational
10	MOD Sandbox Projects	Chicago Transit Authority	★	★					In Deployment (Q1 or Q2 of 2020)
11	MOD Sandbox Projects	Tri-County Metropolitan Transportation District	★	★		★			Operational
12	MOD Sandbox Projects	Dallas Area Rapid Transit	★	★		★	★		Operational
13	MOD Sandbox Projects	Vermont Agency of Transportation	★	★		★			Operational
14	MOD Sandbox Projects	Pierce Transit	★	★			★		Operational
15	ATCMTD	Texas Department of Transportation - ConnectSmart (Awarded Oct 2016)	★	★		★	★		Planning
16	ATCMTD	Seattle Department of Transportation - The MICMA project (Awarded Oct 2017)	★	★		★	★		Planning
17	Shared Use Mobility Center On-Ramp Projects	The Maryland Department of Transportation Maryland Transit Administration	★				★		Planning
18	Shared Use Mobility Center On-Ramp Projects	Capital Metro-Austin Public Transit	★			★			Planning
19	Shared Use Mobility Center On-Ramp Projects	Indianapolis Public Transportation Corporation (IndyGo)	★			★	★		Planning
20	Shared Use Mobility Center On-Ramp Projects	Tompkins County	★	★		★	★		Planning
21	Shared Use Mobility Center On-Ramp Projects	Memphis Area Transit Authority (MATA)	★				★		Planning
22	Shared Use Mobility Center On-Ramp Projects	San Francisco Bay Area Rapid Transit District (BART)	★			★	★		Completed
23	Public-Private Partnerships	San Joaquin County in partnership with National Express, Ecolane, Uber	★			★	★		Operational
24	Public-Private Partnerships	Livermore Amador Valley Transit Authority (LAVTA) in partnership with Uber, Lyft and DeSoto.	★				★		Operational
25	Public-Private Partnerships	Capital Metropolitan Transportation Authority (CapMetro) in partnership with RideAustin	★				★		Operational
26	Public-Private Partnerships	The City of Cincinnati with Uber	★						Planning
27	Public-Private Partnerships	Massachusetts Bay Transportation Authority (MBTA) in partnership with Lyft and Uber	★			★	★		Operational
28	Public-Private Partnerships	San Diego Association of Governments in partnership with Uber				★	★		Operational

Figure 1 - Public-Private Sector Initiatives and Partnerships

3.1.2 Relevant Private Sector Initiatives and Partnerships

In this very competitive marketplace, new alliances and partnerships in the private sector are forming. Some of the most relevant partnerships identified in the previously mentioned industry scan include the following:

1. **Groupe PSA and other private mobility providers:** Groupe PSA, the maker of brands such as Peugeot, Citroen and Opel, launched its Free2Move carsharing services in Washington, DC. Free2Move Carsharing is an active mobility aggregation platform that enables users to book and pay for a variety of transportation services, including multiple carsharing options, bikeshare, and scooters, in one mobile app. As of October 2019, Free2Move carsharing, car2go, Bird, Lime, Skip, Jump, and Capital Bikeshare (in the Washington, DC region) are all available in the app.
2. **Lyft and JetBlue**: Lyft previously partnered with JetBlue in an arrangement that let Lyft riders earn JetBlue loyalty rewards for using the service, as well as direct integration of Lyft services into the JetBlue mobile app. As of 9/9/19, the partnership between Lyft and JetBlue was terminated.
3. **Uber and Masabi**: In April 2018, Uber unveiled that it signed a deal with Masabi, a company that facilitates mobile transit ticketing in 30 cities worldwide, and was working to provide its services in the Uber app. Users in New York, Los Angeles, Boston, and beyond should be able to book regular transit tickets with the same app they might use to order a regular Uber pickup. This functionality has already been deployed in Denver, CO with the Regional Transportation District (RTD) in May of 2019. Additionally, Bay Area users will be able to book and drive “Uber Rent” carsharing vehicles.
4. **Lyft and LeasePlan USA.** In April 2018, Lyft partnered with LeasePlan, a car-as-a-service company, to provide corporate customers with an integrated mobility service. The partnership will lead to the integration of ridesharing into fleet finance and management services. LeasePlan will be able to provide its customers with vehicle leasing and fleet management services as well as access to Lyft services for customers on a budget.
5. **Via and Harvard University:** In August 2018, Via on-demand mobility solutions announced a partnership agreement with Harvard University for the provision of Via’s rideshare technology and support services for the University’s evening van service. Students, faculty, and staff can book rides around campus using the Via mobile app. This mobile technology directs passengers to the proper location for pick-ups and drop-offs, allowing for shared trips without detours that take riders out of their way. An algorithm directs the vehicle in real-time along an optimized route, keeping passenger wait times to a minimum and reducing inefficient detours.
6. **Amazon partnership with small delivery companies:** Amazon announced in June 2018 a new Delivery Service Partners program designed to help small delivery companies run their own local delivery networks of up to 40 vans. Each delivery unit will help fill the first mile/last mile gap to the 75 current Amazon stations in the US where parcels ordered from Amazon.com are picked up. Algorithms will determine which packages are sent to these delivery stations, and which are sent to other delivery partners, like FedEx and UPS, (Reagan, 2018).
7. **Uber acquires JUMP bikes**: In 2018, Uber purchased JUMP bikes in a move to further partner with cities they service and become a mobility platform provider. The acquisition of the dockless, pedal-assist bike provider allows for Uber to provide a broader array of

modes of mobility services to its customers in urban areas and reach a wider spectrum of consumers.

8. **Lyft acquires Motivate**: In July 2018, Lyft acquired Motivate, the bikesharing company that operates several bikeshare systems, including Citi Bike in New York and GoBike in San Francisco. This acquisition helped Lyft expand its services beyond standard ride hailing service. As of July 2018, Motivate accounted for about 80% of bikeshare trips in the US including cities such as New York, San Francisco, Chicago, Boston, Washington DC, Portland, Oregon, Columbus and Minneapolis, (O'Kane, 2018).

3.1.3 Mobility as a Service (MaaS) and International Projects

Agencies and mobility providers all over the world are working to improve transportation experiences and access for travelers. A concept for personal mobility that is similar to MOD is the practice of Mobility as a Service (MaaS), which was originally piloted in Europe. The definition of MaaS, according to the MaaS Alliance (https://maas-alliance.eu/), a European public-private partnership creating the foundations for a common approach to MaaS, is:

> "The integration of various forms of transport services into a single mobility service accessible on demand. To meet a customer's request, a MaaS operator facilitates a diverse menu of transport options, be they public transport, ride-, car- or bike-sharing, taxi or car rental/lease, or a combination thereof. For the user, MaaS can offer added value through use of a single application to provide access to mobility, with a single payment channel instead of multiple ticketing and payment operations. For its users, MaaS should be the best value proposition, by helping them meet their mobility needs and solve the inconvenient parts of individual journeys as well as the entire system of mobility services."

In addition to MaaS, there are many similar projects that use creative, technology-driven solutions to address various transportation needs. Numerous European projects have been implemented since 2014, such as the Whim app used to book door-to-door trips in Helsinki, Finland, Rejseplanen's MinRejseplan app ("my travel planner") in Denmark, the SMILE app in Vienna, and the REACH NOW (formerly Moovel) implementation in Stuttgart and Hamburg. This section is not intended to be comprehensive, but rather to cover innovative international MOD projects with diverse views on improving travelers' experiences, for example by integrating mobility services at an airport , by leveraging crowdsourcing to fill a transportation gap, or by building a large public-private partnership to improve the mobility of a community. The following list includes relevant project examples:

1. **Munich Airport - Real-time routing service reducing travel time of air passengers:**
   In 2017, Munich Airport and Siemens developed an information service for passengers travelling from the city center to the airport and vice versa (Neudeck & Vanbeveren, 2017). The service offers guidance on expected processing times at the airport, traffic jams on the road or delays on public transport. The service is based on Siemens SiMobility Connect, enabling integration of multiple mobility services like taxi, train, car-sharing, and Lufthansa Airport Bus and real-time information on traffic. Munich Airport added data on service processing and waiting times, such as check-in, security and baggage handling, resulting in

an integrated offering for passengers.

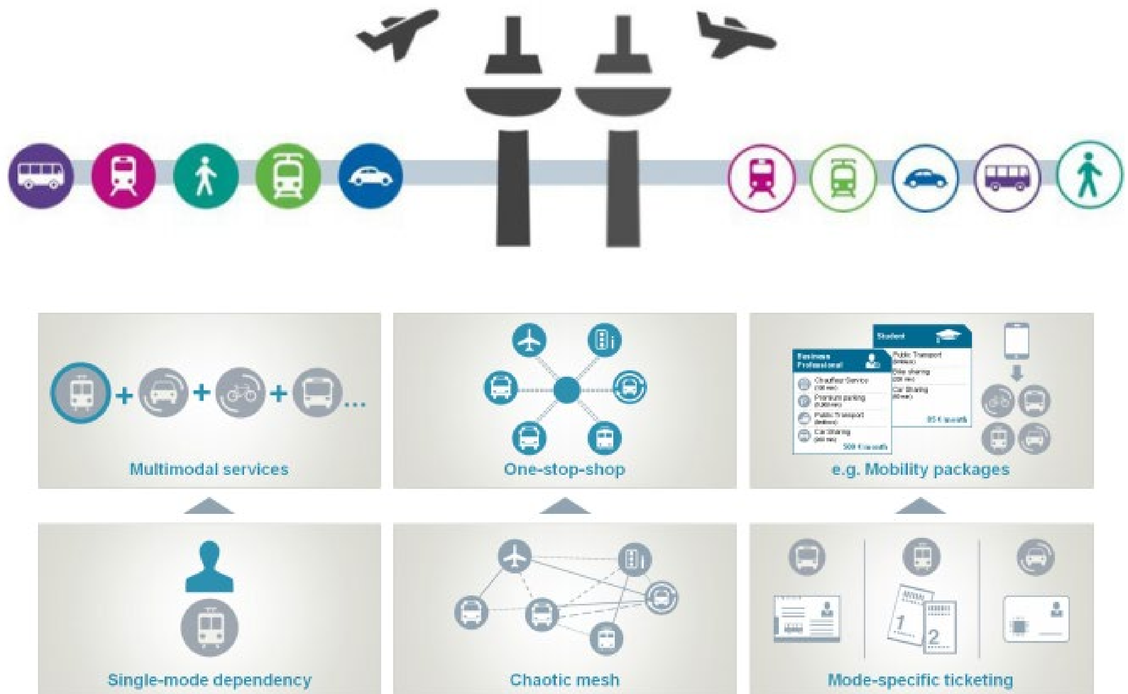


Figure 2 - Munich Airport Real-time Routing Service
Source: Global AirRail Alliance

2. **Singapore's first marketplace for crowdsourced bus services:**
In Singapore's crowdsourced bus service, users can book a seat on buses listed by private bus operators and track their location (Beeline Singapore, 2020). They can also suggest new routes which are activated by community demand. Private bus operators can make use of these findings to bring transportation alternatives to those who want them the most. Infocomm Development Authority (IDA) and Land Transport Authority (LTA) developed and launched the service in April 2015 in partnership with transportation operators, academia, and the private sector.

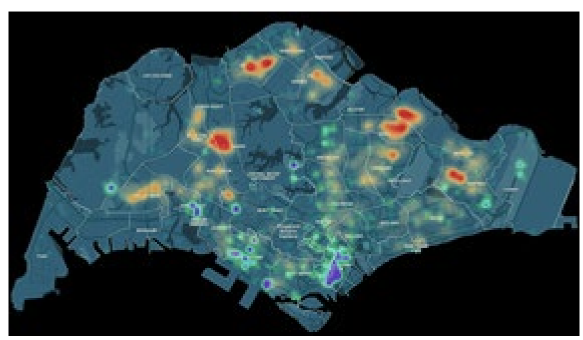


Figure 3 - Singapore's crowdsourced bus services heat map

3. **Communauto/BIXI/Opus:**
In Quebec, the municipal transport authorities have offered mobility packages that include bikesharing by BIXI and carsharing provided by Communauto, (Société de transport de Montréal, 2020). For example, a user can receive a discount on public transport passes and bikesharing by subscribing to the BIXI-AUTO-BUS package. The Société de transport de Montréal (STM) plans to expand the service by testing a new, integrated transit app to combine transit services, and private mobility providers including BIXI bikes, taxis and car-share services. More than 300 businesses have joined up with Montreal's public transportation authority to offer riders discounts and other rewards. The app collects data on riders' locations and choices and how often they use public transportation and sends them offers from relevant retailers. It promotes the city's goals of encouraging users to rely more on public transportation and directs would-be customers to businesses they might not have known about.

Figure 4 - Quebec mobility packages

4. **Audi, BMW and Daimler acquisition of HERE:**

A consortium led by German automakers acquired the digital mapping company HERE in 2015 to expand their portfolio of location-based services, (Newcomb, 2016). While HERE's maps and data are essential to autonomous driving, they're an equally crucial component in connected mobility services such as car-sharing and ridesharing. Therefore, a company called HERE Mobility was created in 2017 to combine advanced mapping with a multimodal trip engine that would provide a one stop shop for cities and municipalities, state agencies, large employers, airports, hotels and many other MOD providers. According to the PRNewswire/Jan. 8, 2018: HERE mobility launched by HERE Technologies, aims to provide an Open Mobility Marketplace platform connecting global supply and demand complementing the Mobility Dispatch system provides a powerful real-time fleet utilization and optimization solution, (PR Newswire, 2018).

Figure 5 - HERE Mobility

3.2 MOD Business Models and Partnerships

Multiple MOD business models have expanded in the mobility marketplace to meet the diverse needs of consumers, service providers, and partners. Ultimately, the benefits of participating in new business models and creating partnerships within the MOD Ecosystem will allow stakeholders to harness positive impacts and meet its goals (further details are presented in Table 7 - MOD Goals and Objectives). Essential to MOD partnerships are the underlying business models, operational agreements which specify service offerings, data sharing, and payment terms.

As most partnerships are tailored to respond to regional MOD needs and can therefore leverage their relationships and resources, it is recommended that public agencies consider opportunities for public and private collaboration as the main stepping-stone toward delivering a MOD Marketplace platform. These partnerships can be categorized in the following categories:

Table 3 - MOD Business Models, (SAE, Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies, 2018)

Model	Description
Government-to-Citizen (G2C)	G2C partnerships can provide consumers with access to transportation services operated and maintained by government agencies. Examples: Public transit, paratransit, microtransit, MOD Sandbox projects, Active Transportation and Demand Management (ATDM) programs, and goods delivery with United States Postal Service (USPS) delivery.
Business-to-Consumer (B2C)	B2C partnerships can provide individual consumers with access to business-owned and operated transportation services such as a fleet of vehicles, bicycles, scooters, or other modes through memberships, subscriptions, user fees, or a combination of pricing models. This includes goods delivery by businesses to consumers. Examples: Carsharing, bikesharing, and goods delivery services
Business-to-Government (B2G)	B2G partnerships can include mobility services provided to government agencies to cover the gap for the first and last mile, ridesharing programs, paratransit and parking limitations, among others. Examples: Summit New Jersey (ridesharing partnerships with private companies), Marin County, California (discounted rides from private companies to and from transit stations), Boston, Massachusetts (subsidizes ridesharing rides from private companies as paratransit options), MOD Sandbox projects such as the Dallas Area Rapid Transit (DART) and Los Angeles County First and Last Mile Solutions.
Business-to-Business (B2B)	The B2B model includes mobility service provider partnerships built to expand on their service offerings. Examples: Private ridesharing companies add public transit mobile ticketing into their apps.
Peer-to-Peer Mobility Marketplace (P2P-MM)	P2P-MM services offer a marketplace—usually as an online platform—to facilitate transactions among individual buyers and sellers of personally owned and operated mobility services, in exchange for a transaction fee. Examples: Private peer-to-peer mobility service providers.
Peer-to-Peer Goods Delivery Marketplace (P2P-GDM)	P2P-GDM goods delivery services include logistics and courier network services (CNS), apps that provide for-hire delivery services for monetary compensation using an online application or platform (such as a website or smartphone app) to connect couriers using their personal vehicles, bicycles, or scooters with goods (e.g., packages, food). Examples: Private peer-to-peer goods delivery service providers.

3.3 MOD Marketplace Stakeholders

"Supply and demand" is one of the most fundamental concepts of economics and it is the backbone of a market economy. For transportation, the components of the supply and demand sides are identified based on the concept of consumption choices in relation to trip generation - for example the available options for travelers to accomplish their daily trips. The supply side consists of mobility service providers, operators, and all stakeholders that touch on the delivery of the transportation services for people or goods delivery. The demand side consists of system users (travelers and consumers).

MOD stakeholders go beyond the suppliers and consumers of transportation services and also include technology providers and the operators and maintainers of these services and systems, creating a complex network of supply and demand actors. In some cases, stakeholders might be considered both service suppliers and demand consumers. One case where a user is both a mobility provider and consumer is with on-demand ridesharing/carpooling, where a user can determine for any given trip whether they want to be driver or a passenger. These mixed supplier and consumer stakeholders are called "Prosumers".

Overall, the relationship between supply and demand determines the allocation of resources in the delivery of MOD services. The stakeholders involved in the MOD Marketplace supply chain are summarized in Table 3 - MOD Stakeholders – Supply and Demand Sides, below.

3.3.1 Supply and Demand Sides

A core element of MOD is the provision of a dynamic supply of mobility services relying on integrated and linked information systems and applications. The richer the supply side of the mobility services, the more choices available on the demand side. The following table, Table 4, provides a list of supply stakeholders grouped into functional categories with specific examples of each. Stakeholders on the demand side are those that would benefit from the provision of MOD services. Additionally, this section will identify the MOD stakeholders based on architectural description definition of the International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC)/IEEE 42010:2011 standard (https://en.wikipedia.org/wiki/ISO/IEC_42010): "*A stakeholder in the architecture of a system is an individual, team, organization, or classes thereof, having an interest in the realization of the system.*"

Table 4 - MOD Stakeholders – Supply and Demand Sides

Stakeholder	Supply Side	Demand Side
Federal Government USDOT, Department of Energy (DOE), Department of Labor (DOL), Department of Commerce (DOC), Department of Defense (DOD), among others	Many branches of the government can influence MOD. These organizations can play a role in establishing transportation strategies, policies, and legislation. They can also implement those strategies, make investments in pilot programs, and provide guidance for nationwide development of strategies put forth.	Government agencies want to collect ridership/travel data to guide public policy decisions and make informed decisions regarding economic and transportation policy, and to be able to forecast economic changes and travel behavior.
State and Local Authorities Cities, municipalities, MPOs	These comprise state, regional and local government entities playing a role in ensuring a fast, safe, efficient, accessible, and convenient transportation system meeting the regional and national interests to enhance the quality of life of travelers, today and into the future.	State and local authorities desire to collect ridership/travel data to guide public policy decisions and make informed decisions regarding economic and transportation policy, and to be able to forecast economic changes and travel behavior in the region.
Public Transit Agencies Buses, trolley buses, trams (or light rail), rapid transit (metro, subway), ferries, paratransit, microtransit	These include all the agencies that provide, operate, and maintain public transportation.	Public transit agencies desire to collect ridership/travel data to guide public policy decisions and make informed decisions regarding economic and transportation policy, and to be able to forecast economic changes and travel behavior in the region.

Stakeholder	Supply Side	Demand Side
Transportation Service Providers TNCs/ridesourcing, carsharing, ridesharing, bikesharing, scooter sharing, CNS logistics companies, car manufacturers, aerial delivery services	TSPs provide prearranged and on-demand transportation services for compensation, which connect drivers of personal vehicles with passengers. Smartphone mobile applications facilitate booking, ratings (of the service, drivers, and passengers), with the option of electronic payment. These are mostly part of the supply side of the MOD Ecosystem. These include logistics management and goods delivery providers who manage and run the flow of goods and materials from origin to destination, in addition to handling inventory, warehousing, packaging, security, and dispatching functions.	
Transportation/Operation Managers Departments of Transportation (DOTs), tolling agencies, airports and port authorities	These stakeholders include transportation agencies responsible for operating and maintaining the roadway infrastructure, ITS field devices, road safety, and traffic operations centers allocating resources as necessary, including parking, tolls, roadways, curbs and airports.	Transportation/operation managers desire to collect ridership/travel data to guide public policy decisions and make informed decisions regarding economic and transportation policy, and to be able to forecast economic changes and travel behavior in the region
Apps and Technology Providers App developers, MOD integrated mobility platforms, mobile ticketing systems, e-wallets and integrated payment systems, mapping services, multimodal trip planner engines, Data as a Service (DaaS) collectors and providers, Original Equipment Manufacturers (OEMs)	Application and technology providers deliver solutions and services to implement, maintain and operate the various MOD subsystems. DaaS providers deliver parking, traffic conditions, weather, direction, elapsed travel time, and data services that impact travel.	

Stakeholder	Supply Side	Demand Side
Volunteer groups / programs and neighborhood advocacy groups Volunteer transportation providers, volunteer drivers, casual carpooling	Volunteer individuals or programs deliver transportation services for communities and special groups to fill transportation gaps. For example, volunteer groups or programs can provide transportation services in rural areas for travelers with disabilities and elderly travelers.	Communities and organizations desire and advocate for transportation accessibility for special groups such as the elderly or individuals with disabilities.
MOD Platform Providers, Operators and Maintainers Transit agencies, MPOs, state, cities or municipalities, transportation service providers, systems and data aggregators, technology providers, developers, property managers, auto manufacturers, large employers	A public agency, private entity, or a consortium could provide the procurement, operations and maintenance of the MOD platform.	
Large employers and organizations Universities, employers, medical centers, special venues, property developers, entertainment and recreation centers, shopping malls, airports, hotels.	This category includes large employers and establishments that provide mobility to employees, customers, patients, students, etc.	This category includes employees, customers, patients, students, etc. that desire to consume mobility services provided by large employers and establishments.
Consumers Travelers, goods consumers, logistic services brokers		These stakeholders are the ultimate end users of MOD services who affect the system by the type of demand requirements they have for the movement of people and services.

Stakeholder	Supply Side	Demand Side
Goods delivery consumers Goods consumers, businesses, CNS		Goods delivery consumers are end users of MOD services who affect the system by the type of demand and requirements they have for the movement of goods and services.

3.4 Issues and Limitations of the Current Systems

This section covers institutional/policy, operational, and technical issues and limitations related to the implementation of a MOD platform in the marketplace. As previously noted, at the time of writing no true MOD platform implementation exists in the US.

It is worth noting that there are areas of overlap among the issue categories presented below. For example, users affected by economic, financial, or social challenges may also be affected by a lack of accessible services to provide them with MOD services. Therefore, the following sections should be looked at with the understanding that the categories are siloed.

3.4.1 Institutional/Policy Issues

3.4.1.1 Economic, Financial, and Social Issues

Access to affordable and equitable mobility services are not always available to commuters and travelers. Some groups that may encounter issues include:

- Consumers in underserved/disadvantaged communities might lack access to MOD platforms or find them prohibitively expensive.
- Long and/or expensive commutes whether utilizing a personal vehicle, mobility services, or public transportation can result in economic hardship for low income riders.
- Unbanked and underbanked users require alternate methods of payment for mobility services, where credit or debit card as method of payment is not an option for these consumers.
- Consumers who either cannot afford or do not wish to have a smartphone have limited access to MOD services where a smartphone is required to deliver the services to the end users.

3.4.1.2 Accessibility Issues

The implementation of transportation services also brings forth physiological constraints where the use of some shared mobility services presents challenges for older adults or persons with cognitive or physical disabilities. Initiatives such as the USDOT's Accessible Transportation Technologies Research Initiative (ATTRI) lead efforts to develop and implement transformative applications to improve mobility options for all travelers, particularly those with disabilities, (USDOT, 2016). Some accessibility issues include:

- Lack of accessible services in MOD platforms.

- Lack of proximal, accessible services for consumers situated in rural or underserved locations.
- Lack of voice enabled or accessible mobility applications.
- Lack of accessible services in one or more legs of the travel chain, which means that the trip is inaccessible for those with physical or cognitive disabilities, and therefore cannot be completed.

3.4.1.3 Privacy/Data Sharing Issues

Data generated through the operation of MOD services creates important policy and privacy considerations. Some important privacy/data sharing issues include:

- Consumers who do not wish to share their personal information may be deterred from using MOD services.
- Consumer privacy laws differ from state to state, creating inconsistent standards for collection and sharing of data that contains personally identifiable information (PII) and compliance challenges for both agencies and service providers.
- Lack of a widely adopted mobility data sharing standard.
- Attempts to create standards for the sharing of mobility data between public and private sector partners may be challenged in states that have enacted stricter consumer privacy laws (e.g., the California Consumer Privacy Act and Illinois Personal Information Protection Act).
- Private transportation service providers may fear exposing trade secrets to competitors or jeopardizing users' PII in sharing proprietary data generated through MOD operations.
- Public agencies have limited ability to enact and enforce data sharing regulations that would give them access to mobility data.

3.4.1.4 Workforce Issues

The proliferation of mobility data and the growing importance of mobility management creates new opportunities and challenges for the public sector. Some workforce challenges include:

- Institutions may have a lack of capability around data science and Information Technology (IT) necessary to perform analyses on the mobility data generated by the platform to provide insights on travel behavior and patterns.

3.4.1.5 Business Model/Revenue Sharing/Partnership Issues

New business models and financial considerations create challenges for MOD public-private partnerships. Some business model/revenue sharing/partnership issues include:

- MOD business models are emerging and evolving at a much quicker pace than institutions can plan for and adapt to.
- Lack of financial transparency can create revenue sharing challenges in MOD public-private partnerships.

3.4.1.6 System Efficiency Issues

Public agencies have a stake in ensuring the overall efficiency of the transportation system. System efficiency issues include:

- Consumers may choose lower occupancy MOD services on platforms leading to decreased system efficiency.
- Increased demand on the transportation network risks decreased multimodal level of service and lower travel time reliability for public transportation modes.
- Proliferation of MOD service providers creates redundant options for consumers and regulatory challenges for institutions.

3.4.2 Operational Issues

A successful MOD deployment depends on the ability to provide a full multi-modal trip planning application with integrated electronic payment services to all users regardless of education, disability status, or financial status. The following operational constraints should be considered when designing and implementing a MOD Marketplace platform solution, ensuring access to a seamless, tailored, equitable, accessible, and traveler-centric service MOD service for all travelers.

3.4.2.1 Geographical Issues

The ability to provide dependable MOD services to consumers relies heavily on the availability of a transportation infrastructure and mobility service providers. Consumers living in rural areas where service options are very limited suffer challenges that urban settings may typically not be affected by, including, but not limited to:

- Access to public transportation may be limited and consumers may have to walk or travel long distances to connect with the public transportation network.
- Access to mobility services may be limited in rural communities.
- Cost of commuting is affected by the need to travel further distances to access jobs.
- Travel time may be increased due to the need to travel longer distances to and from origin to destination and the use of public transportation could become a deterrent when factoring in travel time to complete a journey.

3.4.2.2 Infrastructural Issues

The availability of a fully developed transportation infrastructure is a necessity in the delivery of multimodal MOD services and a lack thereof presents some of the following challenges:

- Demand for parking space creates space consumption problems.
- Utilizing lanes on a street for temporary parking can lead to increased congestion.
- Lack of bike and pedestrian infrastructure creates challenges for encouraging certain type of mobility services.
- Infrastructure maintenance costs can affect transportation service providers and their ability to provide reliable and efficient service.

3.4.3 Technical Issues

In addition to institutional and operational constraints, many technical constraints should be considered. Technical constraints describe the challenges in implementing a MOD solution from a technical perspective, where technology to support the delivery of MOD goods and services is either not advanced enough, or institutional, operational, or policy constraints limit the willingness for stakeholders to fully participate in a MOD Marketplace. For example:

- The multimodal trip planner engine requires extensive development in order to realize the full vision of the MOD Marketplace. Trip planner engines are still at the early stages of technology maturity and further advancements are needed to cover all mobility options in a trip chain.
- There is a need for a seamless multimodal Advanced Traveler Information System (ATIS). Currently, no comprehensive network modeling provides an inclusive routing capability with multiple attributes, dynamic travel times, dynamic demand, and timetables in large-scale transportation networks.
- Getting the right data in the correct format is key to solving challenges with machine learning algorithms. Lack of data, or lack of willingness to share data for all legs of the trip chain poses challenges in the ability to deliver machine learning, predictive analytics, and accurate trip routing.
- New technology used to provide MOD goods and services to consumers is still not considered to be mature and needs to be tested in Proof of Concept or pilot deliveries at a smaller scale to ensure accurate results.
- Lack of willingness of stakeholders to comply with IT and data governance standards poses challenges in the ability to share data among the MOD stakeholders and fill gaps in the trip chain.
- Lack of availability of real-time data leads to gaps in the trip chain, uncertainty in trip planning and taking, and ultimately an incomplete door-to-door user experience. A complete door-to-door, multimodal trip depends on real-time data for each leg of a user's trip in order to provide accurate trip routing from origin to destination.
- The volume of data can be expected to continue to grow with technological innovations, especially related to Connected Vehicles (CV), drones, robotics, etc. Therefore, it is imperative to develop a plan for the management of the data during the project implementation and strategies for maintaining and preserving the data after the project has been delivered.
- Ensuring the protection of data that is collected by the MOD platform from these sources is critical as the data being collected may be highly sensitive and may contain PII. Therefore, the data must be scrubbed and secured to ensure the privacy of the source of the data.
- A fully integrated payment solution relies primarily on the planning results of the trip generated by the multimodal trip engine. The completeness and accuracy of all of the options to be considered in the trip chain are a crucial part of structuring fare payment for travelers who opt for pay-as-you-go and is not as critical for subscription-based services.
- MOD services must be delivered to all end users regardless of technical, educational, physical, or equity levels. Apps developed to deliver these services must consider all aspects of the end user's requirements.
- Lack of standardization for various modes of transportation creates challenges for the delivery of MOD services to its consumers. The diversity of the data imposes additional challenges that can only be mediated through the development and implementation of standards.
- Device limitations, such as battery life, memory, disk space, and other constraints pose challenges to delivering a full, responsive multimodal app experience to end users.

- Network connectivity and bandwidth constraints pose challenges to delivering app services to users due to potential outages or insufficient coverage.

4 Justification for and Nature of Changes

This chapter describes the shortcomings of the current system or situation that motivates development of a new system or modification of an existing system. These are expressed as a set of system/user needs that drive the scoping of the system and its future development. This section discusses core system operational goals, system needs, and user needs. Operational goals establish parameters and targets for system performance. The needs describe what the system needs to do in order to meet operational goals.

4.1 Justification for Changes

As discussed, many MOD initiatives have been launched across the US, but there are gaps between the currently planned and implemented MOD platforms and the overall goals and objectives. The presented justification for changes emphases technical implementation of the MOD platform and its subsystems.

The table below describes the current situation for each MOD stakeholder on the demand side and includes recommendations on how the gaps (user needs) could potentially be filled with the implementation of a MOD platform by employing some of the concepts and technologies (system needs) discussed in this ConOps. The table is grouped by stakeholder and each grouping contains a list of the user needs, the needs needed by the various MOD subsystems to fill the user need gap, and the changes required to fulfill the needs of the users. Note that the term “Public Agencies” in the table is used to describe the consolidation of a list of several stakeholders.

Table 5 - User and system needs

ID	Stakeholder	User Need	Change Required	Recommendations for Implementation (System Needs)
CONS-01	Consumers	Users need access to a comprehensive list of mobility providers and real-time information about which mobility providers are currently operating in the area. Travelers are not informed when new mobility providers come online or when an existing mobility provider suspends service or exits the marketplace.	Provide reliable, convenient, comprehensive, and efficient mobility options in a multimodal network that prioritizes individual on-demand mobility.	▪ Identify mobility providers and develop Extract Transform Load interfaces (**ETLs)** to collect, transform, and load the data efficiently into the **data hub** and eliminate gaps in the trip chain. For detailed information on ETLs and the data collection subsystem, see section 5.2.1, Data Collection. ▪ Develop a true **multimodal trip planner engine**, capable of **trip optimization** and **machine learning**, that is backed by a centralized **data hub** as the source for mobility data ▪ Develop a single, unified, and standardized interface for the sharing and distribution of data to consumers
CONS-02	Consumers	Gaps exist in the trip chain, e.g. first- and last-mile connections to public transportation. Users need reliable mobility services, but options are limited.	Provide multimodal mobility options using all available mobility providers based on the user's choices.	▪ Identify mobility providers and develop **ETLs** to collect, transform, and load the data efficiently into the **data hub** and eliminate gaps in the trip chain ▪ Develop a true **multimodal trip planner engine**, capable of **trip optimization** and **machine learning**, with the ability for user customized trips, that is backed by a centralized **data hub** as the source for mobility data
CONS-03	Consumers	Users cope with inconvenient trips that include highly variable travel times, long connections, and safety concerns. Users need safe and reliable mobility services and options.	Provide an accessible, reliable, and safe mobility service to all travelers.	▪ Identify data providers and develop **ETLs** to collect, transform, and load the data efficiently into **the data hub** and eliminate gaps in the trip chain ▪ Develop a true **multimodal trip planner engine**, capable of **trip optimization** and **machine learning**, that is backed by a centralized **data hub** as the source for mobility data ▪ Develop a single, unified, and standardized interface for the sharing and distribution of the data to consumers

ID	Stakeholder	User Need	Change Required	Recommendations for Implementation (System Needs)
CONS-04	Consumers	Users need insight into the private information they are exposing and consenting to sharing in clear privacy policies.	Set data privacy policies.	▪ Develop a **Data Management Plan (DMP)** to outline data storage policies to ensure security and privacy of the data ▪ Identify and implement secure data standards and policies related to the collection and storage of personal and sensitive data ▪ Identify and implement standards and policies related to the distribution of all data ▪ Identify and distribute clear privacy policies that outline the data that is collected from app users as well as how the information will be used and/or distributed
CONS-05	Consumers	Users need to gather travel information from multiple sources, individual websites or applications, but are unable to book trips or plan and pay for an entire multimodal trip from origin to destination in a single application.	Create an integrated electronic payment system.	▪ Identify data providers and develop **ETLs** to collect, transform, and load the data efficiently into the **data hub** and eliminate gaps in the trip chain ▪ Develop a true **multimodal trip planner engine** and **integrated electronic payment system**, capable of **trip optimization** and **machine learning**, that is backed by a centralized **data hub** as the source for mobility data and allows users to use their personal financial information and method of payment to pay for an entire trip all in one app ▪ Develop a single, unified, and standardized interface for the sharing and distribution of the data to consumers ▪ Identify and implement secure data standards and policies related to the collection and storage of personal and sensitive data ▪ Identify and implement standards and policies related to the distribution of all data

ID	Stakeholder	User Need	Change Required	Recommendations for Implementation (System Needs)
CONS-06	Consumers	Provide mobility services and tools for older adults and people with disabilities.	Develop and promote the use of services and tools to meet the needs of older adults and people with disabilities.	▪ Identify data providers and develop **ETLs** to collect, transform, and load the data efficiently into the **data hub** and eliminate gaps in the trip chain ▪ Develop a true **multimodal trip planner engine**, capable of **trip optimization** and **machine learning**, with the ability for user customized trips and accessible options, that is backed by a centralized **data hub** as the source for mobility data ▪ Develop a single, unified, and standardized interface for the sharing and distribution of the data to consumers ▪ Identify and implement standards and policies related to ensuring the accessibility of the data for all consumers regardless of ability
CONS-07	Consumers	Provide mobility services for those who are poorly served by transportation.	Increase and monitor availability of travel options in poor neighborhoods.	▪ Identify data providers and develop **ETLs** to collect, transform, and load the data efficiently into the **data hub** and eliminate gaps in the trip chain in underserved communities ▪ Develop a true **multimodal trip planner engine**, capable of **trip optimization** and **machine learning**, with the ability for user customized trips, that is backed by a centralized **data hub** as the source for mobility data
PA-01	Public agencies	Studies and customer surveys are completed to understand modal shift and access to certain facilities. Transit ridership is declining for certain routes. Operations and planning staff need ways to gather information about how residents and customers move around the transportation network.	Collect and archive operational Key Performance Indicators (KPIs) and data, Origin/Destination (OD) routes, trip/mobility choices, travel times, capacity utilization, person miles traveled (PMT), service availability, service disruption and modal split availability.	▪ Implement a centralized **data hub and data warehousing** architecture capable of storing large amounts of data for analysis and interpretation from all MOD subsystems ▪ Develop new requirements, business rules, and business logic to create visual representations (**dashboards and reports**) of all collected transportation data (real-time and archived) to analyze KPIs

ID	Stakeholder	User Need	Change Required	Recommendations for Implementation (System Needs)
PA-02	Public agencies	Data generated by the pervasive use of cellular phones and mobility apps has offered insights into characteristics of human mobility patterns. Government agencies need a single point of information about how travelers are accessing, consuming and paying for transportation.	Integrate, store, and archive the data sources available in the MOD Ecosystem, including mobility service data providers, public agencies, private data providers, social media data streams and other data streams. Data sharing and management will be integral not only to the growth of MOD, but to the continued advancement of connected, automated, and other Internet of Things (IoT) applications.	▪ Implement a centralized **data hub** and **data warehousing** architecture capable of storing large amounts of data for analysis and interpretation from all MOD subsystems ▪ Develop new requirements, business rules, and business logic to create visual representations (**dashboards and reports**) of all collected transportation data (real-time and archived) to analyze KPIs ▪ Implement a **Data Mart** platform to allow for the distribution of shareable data collected and stored in the MOD platform among the agencies
PA-03	Public agencies	Data gaps exist and intensive manual efforts are necessary to generate MOD Key Performance Indicators (KPIs) and measurements. Stakeholders need a centralized data warehouse for the collection, storage, and analysis of data.	Implement an integrated MOD data hub platform for the storing and archiving of all data generated by public and private data providers and individual users to generate MOD KPIs and Measurements.	▪ Identify all mobility data providers develop **ETLs** to collect, transform, and load the data efficiently into the **data hub** ▪ Implement a centralized **data hub** and **data warehousing** architecture capable of storing large amounts of data for analysis and interpretation from all MOD subsystems ▪ Develop new requirements, business rules, and business logic to create visual representations (**dashboards and reports**) of all collected transportation data (real-time and archived) to analyze KPIs

ID	Stakeholder	User Need	Change Required	Recommendations for Implementation (System Needs)
PA-04	Public agencies	Lack of standards for public or private mobility data leads to one-off data interfaces to each data source, reducing the MOD value proposition and increasing the length of technology implementation cycles. Agencies need a way of standardizing data to provide common formats and interoperability among the MOD stakeholders and subsystems.	Standardized technologies and open data standards could accelerate the pace of MOD growth and support multimodal integration.	▪ Identify all mobility data providers and develop **ETLs** to collect, transform, and load the data efficiently into the **data hub** ▪ Implement a **Data Mart** platform to allow for the distribution of shareable data collected and stored in the MOD platform among the agencies ▪ Identify and implement secure data standards and policies related to the collection and storage of personal and sensitive data ▪ Identify and implement standards and policies related to the distribution of all data
PA-05	Public agencies	Lack of integration of MOD data into ATDM, Transportation Demand Management (TDM), Integrated Corridor Management System (ICMS) and Transportation Systems Management and Operations (TSMO) strategies.	Integration of MOD data, generated by users, trip requests, planned and actual trip trajectories, real-time conditions into traffic operations tools such as ATDM, TDM, ICMS and TSMO strategies.	▪ Identify all MOD stored in the **data hub** that can be used for operational purposes ▪ Implement a **Data Mart** platform to allow for the distribution of shareable data collected and stored in the MOD platform among the agencies ▪ Identify and implement secure data standards and policies related to the collection and storage of personal and sensitive data ▪ Identify and implement standards and policies related to the distribution of all data

ID	Stakeholder	User Need	Change Required	Recommendations for Implementation (System Needs)
PA-06	Public agencies	Use of the MOD Platform to implement ATDM, TDM, ICMS and TSMO strategies.	Integration of ATDM, TDM, ICMS and TSMO strategies. into the MOD platform.	▪ Identify agencies operational systems **ETLs** to collect, transform, and load operational data efficiently into the **data hub** ▪ Include and consider the operational strategies as part of the **multimodal trip planner engine.** ▪ Implement a **Data Mart** platform to allow for the distribution of shareable data collected and stored in the MOD platform among the agencies ▪ Identify and implement secure data standards and policies related to the collection and storage of personal and sensitive data ▪ Identify and implement standards and policies related to the distribution of all data

4.2 Goals and Objectives of the MOD Marketplace

As described in the MOD Factsheet, the program is guided by three goals:

- Goal 1: Explore emerging technology solutions and new business approaches that have the potential to transform mobility services.
- Goal 2: Prepare the transportation industry to deliver innovative mobility solutions that will enhance transportation efficiency and effectiveness, improve customer service, and foster personal mobility and access to goods and services.
- Goal 3: Enable the widespread deployment of integrated mobility solutions that are connected, equitable, and effective to enhance the personal mobility of everyone and provide access to all users.

Its vision is to empower “a safe, reliable and carefree mobility ecosystem that supports complete trips for all, both personalized mobility and goods delivery.”

This section will cover potential goals and objectives of the stakeholders, gathered from the industry scan, in participating and delivering comprehensive, accurate, seamless, and situationally appropriate mobility options for travelers through a MOD platform. These items may be used to inform and shape the future deployment of the MOD Marketplace. They may be used to create a “menu” of possible objectives that guide the process of identifying what the implementation aims to accomplish.

The industry scan revealed an emerging stakeholder consensus for the following MOD Ecosystem goals:

1. Enhance mobility and transportation efficiency
2. Expand customer experience with access to a seamless, tailored, equitable, accessible, and traveler-centric MOD service for all travelers
3. Promote environmental stewardship
4. Review relevant policies and standards
5. Generate revenue
6. Maintenance and operation of the system

Each of the goals’ objectives are listed below.

Goal 1: Enhance Mobility and Transportation Efficiency.

Stakeholders see a need to expand the transportation options available to travelers. To accomplish this, the Marketplace should consider the following objectives:

- Provide travelers with convenient access to comprehensive modes of transportation through a single interface with the ability to create personalized trip itineraries based on user-defined preferences
- Reduce single occupancy vehicle travel and car ownership through mode shift to transit and/or shared mobility services
- Promote mode shift to transit and other mobility services by offering incentives
- Collect and archive multimodal data for demand management
- Monitor facility and regional KPIs (mobility, safety, operations, sustainability, accessibility, operational costs) to guide operations, planning and public policy

decisions, and to make informed decisions regarding economic and transportation policies and investments
- Partner with communities and the private sector to improve regional mobility
- Increase and optimize usage of available transportation services
- Limit congestion, particularly during peak travel periods
- Increase transit ridership and ROI
- Create a model that supports the funding of transportation infrastructure and services
- Measure the impacts of MOD on traveler demand and transportation systems
- Promote agile, responsive, accessible, and seamless multimodal service inclusive of transit through enabling technologies and innovative partnerships
- Use existing infrastructure more effectively and create economies of scale
- Ensure that transit is fully integrated and a vital element of a regional transport network that provides consistent, reliable and accessible service to every traveler
- Provide funding to support MOD pilot projects, research and promote knowledge transfer
- Assist the transit industry to develop the ability to integrate MOD practices with existing transit service
- Validate the technical and institutional feasibility of innovative MOD business models, and document MOD best practices that may emerge from the demonstrations
- Expand service coverage and offerings to fill trip chain gaps
- Provide a convenient transportation service customized to travelers' needs

Goal 2: Expand customer experience with access to a seamless, tailored, equitable, accessible, and traveler-centric MOD service for all travelers.

Following the MOD vision of traveler-centric mobility, the Marketplace should be accessible to all travelers, not just a portion of them. In order to accomplish this, the deployment should consider the following objectives:

- Provide an integrated multimodal trip planner engine, including seamless connection points between mobility services and access to electronic payment
- Ensure ease and convenience of the MOD interface for all travelers
- Generate a customized trip journey based on the user's choices
- Generate a customized goods delivery service based on the user's choices
- Provide access to the seamless MOD services through a mobile app, an Application Programmer Interface (AP)I, kiosk, web widget or Software Development Kit (SDK)
- Select trip based on cost, duration, carbon footprint, accessibility features, etc.
- Provide visual aids through a user interface reflecting trip progress with real-time data and a map suited for all travelers
- Use appropriate wayfinding aids for travelers with disabilities prior to and during the trip journey
- Provide information on the go with details about each leg of the trip
- Provide an enhanced customer experience through the use of technology, services, and DaaS
- Provide accessible mobility services focused on increasing access to employment, education, healthcare, and other services

- Provide accessible mobility services for various communities (City Center, Suburban, Edge City, Exurban, Rural)
- Integrate USDOT work/initiatives into the MOD framework: Integrated Dynamic Transit Operations (IDTO) Connection Protection (T-CONNECT), Dynamic Transit Operations (T-DISP), and Dynamic Ridesharing (D-Ride), Travel Management Coordination Center (TMCC), Integrated Corridor Management (ICM), and ATDM
- Use technology and services to provide each individual equitable, accessible, traveler-centric service leveraging public transportation's long-standing capability and traditional role in this respect
- Remove mobility barriers for individuals with disabilities and in disadvantaged communities
- Enable payment for all portions of a multimodal trip from a single convenient Consumer Payment Solution account
- Increase access of underserved communities to transportation to places of employment, education, healthcare, and other services
- Ensure that underserved/disadvantaged populations have affordable and equitable access to mobility services
- Provide integrated mobility application and account-based fare payment systems to accommodate unbanked users
- Provide subsidies for riders
- Provide low-income commute gap filling work
- Provide equitable geographic access to transit
- Provide service to accessible paratransit customers
- Leverage technology to provide access to modal options for all travelers
- Provide seamless transfers for transit riders
- Unlock tax savings for property managers and employers
- Provide an enhanced customer experience through the use of on-demand service using technology and services

Goal 3: Promote Environmental Stewardship.

In addition to mobility goals, stakeholders have a desire to promote responsible resource usage. The MOD Marketplace may enable this effort by prioritizing the following objectives:

- Promote mode shift from a single occupancy vehicle to public transit, ridesharing, carsharing mobility options
- Inform traveler of the carbon footprint of mobility choices
- Reduce single occupancy vehicle travel and car ownership
- Promote and fund projects geared toward meeting environmental KPIs

Goal 4: Review relevant policies and standards.

The deployment may further extend its benefits by ensuring that relevant policies and regulations are in sync with the MOD vision and are agreeable to all stakeholders.

- Oversee relevant public sector and Federal requirements, regulations and policies that may support or impede public sector adoption of MOD
- Enhance relevant policies and standards to enable MOD

- Protect customer privacy and transaction security by applying data privacy policies

Goal 5: Generate Revenue.

The MOD Marketplace offers the opportunity to improve revenue collection. By improving the transportation experience, it can encourage the usage of transit and other transportation options, increasing the profitability of stakeholders. This goal is tied to the following objectives:

- Provide profitable services
- Collect data on consumers' preferences and behavior
- Innovate and remain competitive
- Upsell additional services
- Secure a marketplace share

Goal 6: Maintenance and Operation of the System.

Finally, it is important to prioritize the smooth operation of the overall system to ensure that all aspects of the deployment work properly and efficiently. To this end, the following objectives should be considered:

- Generate and implement operations and maintenance procedures
- Enhance the system
- Ingest new data elements
- Respond to system load and demand
- Track system performance
- Adjust to market needs and new data sources
  Ensure availability, accuracy and reliability of the services and information provided.

5 MOD Marketplace System

5.1 System Overview

The MOD Marketplace system design is based on a multi-tier architecture and comprises a data collection, integration and distribution layer (data hub, data warehouse, ETLs, and data mart), a business logic layer (multimodal trip engine, route planner for goods, trip optimization and machine learning engine, and Integrated Electronic Payment System [IEPS]) and a presentation layer (APIs and web widgets, data analytics and reporting, and mobile application) to deliver MOD services to consumers. The components of the data collection, integration, and distribution and business logic layers are deployed primarily on backend servers while the presentation layer components run primarily in a mobile app, web browser, and/or web widgets and APIs.

Data collection, Integration and Distribution layer (data hub, data warehouse, ETLs, and data mart): As depicted in Figure 6 - MOD High Level Systems Architecture below, the data hub is the central backbone of the MOD platform and is responsible for collecting data from the data suppliers, fusing and integrating it into a database, supplying the data to the various MOD subsystems, and disseminating the data to travelers and other third party consumers. This layer includes the data collection from all of the various MOD suppliers and the extraction, processing and archiving of the data into the data hub. This layer is also responsible for the distribution of the data to the various MOD sub-systems such as the multimodal trip engine, APIs and web widgets, mobile application, and data analytics dashboards and reports.

Business logic layer (multimodal trip engine, route planner [goods], IEPS, trip optimization and machine learning engine): The business logic layer is responsible for the computation, functional process logic, and data transformation performed on the data in the data collection, integration, and distribution layer to be delivered to the presentation layer based on a traveler's request. It is recognized that the multimodal trip engine is considered to be the core subsystem of this layer, supported by the route planner, IEPS and the trip optimization and machine learning engines, providing multimodal origin/destination journey results in response to an OD request from a traveler or goods provider.

Presentation layer (APIs and web widgets, data analytics and reporting, and mobile application): The presentation layer is responsible for the formatting, delivery, and display of information to a frontend user. This can include APIs and web widgets, data analytics visualization and reporting tools, and/or mobile application.

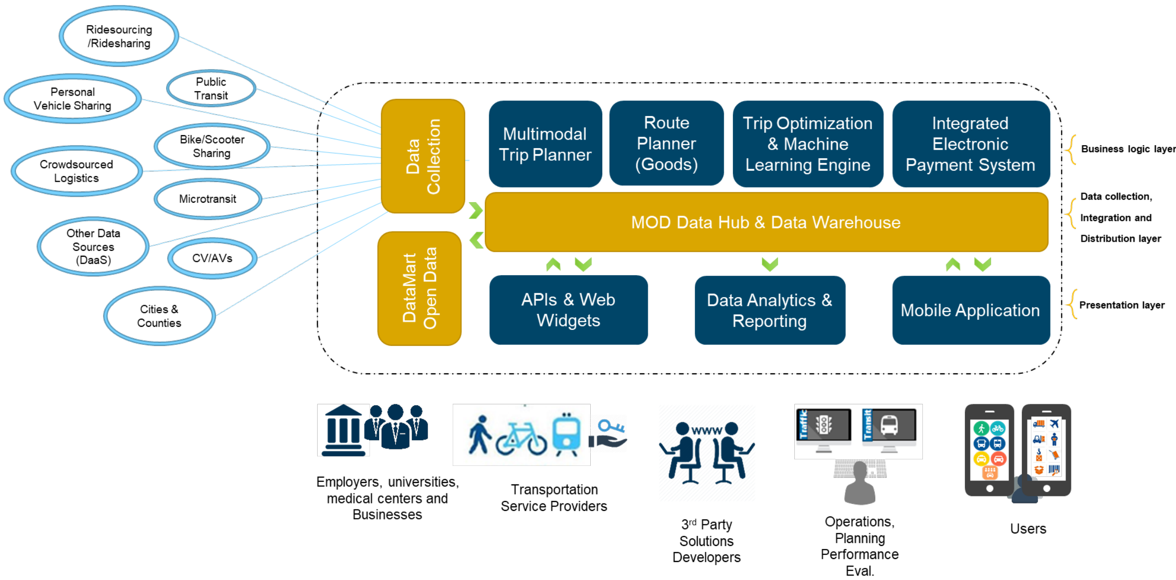


Figure 6 - MOD High Level Systems Architecture

The following integrated subsystems provide the functionality necessary to deliver a MOD platform that will have the main objective of transforming the traveler experience every step of their journey and optimizing their travel time from door to door.

5.2 Subsystems and Functions

A MOD platform must be flexible and responsive as technology evolves and new mobility and services become available. The following subsystems provide the functionality necessary to deliver a MOD platform that will have the main objective of transforming the traveler experience and optimizing their travel time throughout every step of their journey.

5.2.1 Data Collection

The data collection subsystem is an integral component of the MOD architecture and is responsible for the collection of static and real-time data from a variety of data sources provided by the MOD stakeholders (supply side). It involves the identification of various sources of data in the mobility marketplace and the mechanism for consuming that data. The processes for collecting or extracting the data from the individual sources, translating or transforming the data into a format that can be fused into the central data repository, and fusing or loading the data into the central data repository are known as Extract, Transform, and Load (ETL), and Extract, Load, and Transform (ELT). Both of these methods, which differ in the manner in which data is transformed, are described below.

After the data is collected from the source in the Data Collection process, the data must be translated, or transformed, so that it can be fused into the central repository. The ETL process contains the logic for transforming the data into a format recognized by the central repository and validating that it meets the required criteria for being loaded into the repository, as well as any logic required for filtering data prior to loading. When the data has been transformed, it will then be ready for loading into the central repository where it will be fused with data from other sources. The MOD data architecture will involve multiple ETL processes in order to integrate the data from various sources and varying data types into the data hub.

Extract, Load, Transform (ELT), on the other hand, is used when collecting data in large datasets. The process includes first collecting and extracting the data, loading the data into the target area, and then transforming the data there. This process is most useful for performing analysis on big data datasets where it is more feasible to first load the raw data prior to performing the transformation, as this reduces the load time of the data and allows the processing to be done after the data has been loaded to the target system.

5.2.2 Data Hub and Data Warehouse

The MOD Marketplace system architecture calls for a data hub as a big data management model that uses a platform as the central data repository responsible for data aggregation collected from multiple sources organized for distribution, sharing, and often subsetting. Data hubs support discovery, harmonization, indexing, searching, and data analytics all from a central repository. Data stored in the data hub is homogenized and can be served in different formats. The data hub will provide quick, efficient access to the content that has been collected during the data collection process and stored through the provision of standardized query services. The data hub will serve as the centralized source of data collected from the MOD providers, providing a hub and spoke framework, in which a centralized repository (hub) connects to multiple sources of data (spokes or nodes), to enable the ingestion, processing, and distribution of large amounts of data across clusters of computers. The MOD Marketplace system architecture will rely on the data hub as the backbone and core component of the data pipeline that will enable and facilitate the secure sharing, distribution, and analysis of MOD data from and to the various suppliers and stakeholders.

As the MOD data ecosystem is captured by the data collection subsystem, fused, transformed and distributed to the various subsystems, it also gets archived in the data warehouse which will become an important asset with potential use for operational, planning, and strategic analysis. All data collected from the MOD Marketplace users and providers is recorded in the data warehouse and archived for post analysis and reporting purposes. Data stored in the warehouse should handle and be scrubbed for PII as defined in a provider's DMP (data security is discussed further in section 5.4, Data Governance and Security). Therefore, data stored in the data warehouse may not be completely raw in nature, as it may require anonymization prior to storage.

The richness of the data collected and stored in the MOD Marketplace is key to delivering a successful MOD user experience. The data warehouse will serve as the consolidated and structured repository needed to perform the reporting and analysis on the data collected from the disparate systems.

5.2.3 Multimodal Trip Planner

To achieve efficient travel planning for users, information from all relevant transportation providers in the trip chain must be integrated and readily accessible to users. A multimodal trip engine (MMTE) is, by definition, a routing algorithm that allows for users to enter a destination, select an optional mode of getting to their destination, defining certain trip parameters such as maximum cost, travel time, wheelchair access, carbon footprint, or a combination thereof, and receive a reliable, comprehensive, tailored trip including all the mobility modes with transfer times. The MMTE should have the capability of combining travel modes, including both fixed-schedule and on-demand services, while considering individual user preferences and the availability of transportation services.

The implementation of a MMTE relies on integrating static and dynamic data from the various transportation providers, comprised of the following required and optional sources and functionality:

Fixed-route transit data (required): Although some transit trip engines still use proprietary transit data formats (for schedule, route, stops, etc.), an increasing number of transit trip engines are implemented using the General Transit Feed Specification (GTFS) (https://developers.google.com/transit/gtfs). The development of GTFS facilitated transit data integration into trip engines and made possible the inclusion of more than one transit agency in the shortest path calculation. GTFS Realtime (GTFS-R) (https://developers.google.com/transit/gtfs-realtime/reference/) was created as a GTFS extension data feed specification to allow public transportation agencies to provide real-time updates about their fleet such as delays, cancellations, changed routes, service alerts and vehicle positions.

Demand-responsive data (required): Transit agencies often employee flexible public transportation services in addition to an established fixed-route service or as a replacement for fixed route services. In some cases, the flexible model provides options for a wider base of users than fixed-route services. In demand-responsive transportation, buses do not run on a fixed schedule nor a fixed route. Instead, the buses or vans respond to real-time passenger demand and dynamic schedules and routes are created to meet this demand. To respond to this type of service, the GTFS-flex (https://github.com/MobilityData/gtfs-flex) data specification was created as an extension to GTFS. GTFS-flex also facilitates trip planning that involves fixed routes that allow for deviations. Demand-responsive data includes additional data sources for carsharing, ridesharing, and bikesharing services publishing their data in propriety APIs.

Geocoder (required): Trip engine users typically require a user to enter an OD pair to develop a trip itinerary. Geocoding, or address locating of the OD pair, is the first step in data validation and geographical location recognition. This task requires the recognition of a Point of Interest (POI), a transit station, an address or a generic location, followed by geo-translation into latitude/longitude coordinates. Most geocoders are provided through a DaaS model such as Google (https://developers.google.com/maps/documentation/geocoding/intro), ArcGIS (https://developers.arcgis.com/features/geocoding/) and HERE (https://developer.here.com/documentation/geocoder/topics/what-is.html) geocoders. There also an increasing number of open-source, non-proprietary and non-restrictive options for geocoding, lowering the barrier to entry for many MOD providers to offer trip planning services. Some examples include: ImpOSM Geocoder (https://imposm.org/docs/imposm.geocoder/latest/), Foursquare Twofishes (https://github.com/foursquare/twofishes/blob/master/docs/twofishes_requests.md), QGIS Geocoding Plugins (https://www.qgis.org/en/site/), and Pelias (https://trimet.org/mod/about_pelias.htm) used by the TriMet OpenTripPlanner (OTP) implementation.

Walking & Wayfinding Systems (required): Routing and displaying walking directions on a map along with navigation instructions, physical distance, traffic, etc., is a vital part of a trip engine. Walking is often used from origin to the first pickup or transit point, for transfers between routes or modes, or from the last transit stop to the destination. A comprehensive multimodal trip engine will have to include walking directions for all links between other modes in the trip chain meeting the walking criteria of the user.

Geographic Information Systems (GIS) will contain all the spatial and geographic data required to generate step-by-step walking directions. Some of the most common walking direction engines and APIs include Google (https://developers.google.com/maps/documentation/directions), MapQuest (https://developer.mapquest.com/documentation/open/directions-api/), Mapbox (https://docs.mapbox.com/api/navigation/) and OpenStreetMap (OSM) (https://wiki.openstreetmap.org/wiki/API_v0.6).

Augmented Reality (optional): With Augmented Reality (AR), users can add digital objects into the real world during a trip, when needed. AR wayfinding provides an enhanced view by combining turn-by-turn directions overlaid on a real-world setting. Some of the most widely implemented applications of augmented reality, markerless AR (also called location-based, position-based, or Global Positioning System (GPS) AR), requires no pre-knowledge of the user location, or of the user's environment, to overlay the three-dimensional (3D) content into a scene, and hold it to a fixed point in space. This type of AR utilizes GPS, a digital compass, and a velocity meter, or accelerometer, which is embedded in the device, to provide data based on the user's location. Projection mapping is another technique that could be used; it creates an optical illusion by analyzing a 3D object, projecting images, and then precisely aligning them. The application of the projection based augmented reality will be done during the trip; for example, finding the subway entrance, walking from the subway station to the bus stop or tagging a destination.

Figure 7 - LiveSight AR Sample View

For example, LiveSight HERE (https://developer.here.com/documentation/android-premium/dev_guide/topics/ar.html) introduced in the HERE Maps app, is a discoverable option alongside more traditional views such as satellite imagery and traffic overlays. The user can tilt the phone upwards and watch POIs transition from the Two-Dimensional (2D) map into selectable markers in the real world.

Real-time Conditions (optional): Generally, trip engines rely on scheduled or on-demand service data to provide trip information. Yet, scheduled and projected trip information may be inaccurate due to delays caused by traffic congestion, accidents, service disruption, detours, etc. In order to provide accurate and seamless trip information, the MMTE should take into consideration, in real time, a number of variables that can possibly affect the trip such as:

- Real-time bus/train departure information and notifications available under GTFS Realtime to produce more accurate results
- General and route-specific service alerts
- Notifications regarding detours and temporary bus stops

- Parking availability
- Real-time traffic conditions
- Construction, incidents and special events
- User location
- Elevator and escalator availability

5.2.3.1 Trip Considerations

As described in the previous section, a comprehensive multimodal trip engine will rely on relevant user selected trip preferences as input to generate a reliable tailored trip meeting the proposed criteria. This section will cover additional trip considerations derived from the stakeholders' needs from Section 4, Justification for and Nature of Changes. The trip considerations included in this section will impact the business logic of the MMTE and trip results generated.

Some of the considerations to include in the MMTE are described in the sections below.

5.2.3.1.1 Accessibility

As described in the MOD Operational Concept Report, accessibility for older adults and users with disabilities is a significant challenge for the MOD Marketplace, (Cohen, Sarkhili, Shaheen, & Yelchuru, 2017). Through the implementation of a MOD Marketplace platform, accessibility can be realized by leveraging existing technologies and also by providing new technologies to inform and deliver services to a specific group of users. This section will review the various accessibility elements to consider in a MMTE and delivered to users through the mobile app, API and web widgets (to be possibly used by specialized applications).

The MMTE should include accessibility considerations to generate trips based on traveler needs for accessibility including transfers, sidewalks, curb ramps, and street crossing navigation aids. The MMTE should factor in the accessibility needs of the user in the entire trip chain from the starting points, route services, stations, stops and transfers. It should also include the maximum walking speed and maximum walking distance parameters creating more nuanced estimates of accessibility and providing up to date information on elevators, escalators, and disabled parking. For fixed route services, GTFS includes wheelchair boarding and wheelchair accessibility data attributes associated with stops, stations and station entrances as optional fields.

The delivery of trip results should be made available through a 508 compliant user interface (website or mobile app). Per the Federal Communications Commission (FCC) "Section 508 requires that individuals with disabilities, who are members of the public seeking information or services from a Federal department or agency, have access to and use of information and data that is comparable to that provided to the public who are not individuals with disabilities." (Federal Communications Commission, n.d.).

MMTE integration of accessible TNC or ridesharing services such as wheelchair-accessible vehicles or drivers with training to provide additional rider assistance should also be considered. It is worth noting, however, that on-demand mobility providers do not currently provide wheelchair accessibility data in their APIs, limiting possibilities of integration to a MMTE at this time.

5.2.3.1.2 Multimodal Trip Engine Routing Choices

All route planners use a routing algorithm to calculate a path from a starting point to a destination. It is anticipated that a multimodal trip engine includes the following choices/services in order to provide a comprehensive trip chain:

Public Transit Providers (Fixed Route Services): An increasing number of transit agencies publish their data in GTFS format and its extensions allowing trip engines to standardize the data import process into the trip engine's engine database. As of December 2018, GTFS supports the following route types: tram, streetcar, light rail, subway, metro, rail, bus, ferry, cable tram, aerial lift and funicular. For the full list of extended GTFS route types, visit https://developers.google.com/transit/gtfs/reference/extended-route-types.

The use of standard static data by transit agencies has allowed trip engines to expand on service and geographic coverage providing comprehensive transit options to users. It is also worth noting again that transfers between various carriers have to be improved to provide seamless touchpoints between services and connections.

Flexible Transit Services: While microtransit and paratransit differ in functional services, they both use flexible routing and demand-responsive methods to deliver transportation services, presenting similar challenges from a trip-planning viewpoint. There is increasing interest from transportation operators in using demand-responsive trip engines with the GTFS-flex specification. This specification will allow public agencies to publicize and consume information about demand-responsive microtransit or paratransit such as:

- When do riders board the bus?
- Is there a fixed or flexible route schedule? Or is it completely on-demand?
- Where do riders board the transit vehicles? Is a fixed stop a flexible service area (defined by a centroid or a polygon), or any point along a fixed route?
- How do riders make a service request? Is it a matter of flagging the operator? Calling ahead? Using an app?
- How do riders connect between flexible or fixed routes?

A sample deployment is the Vermont Agency of Transportation's (VTrans) (and its partners) FTA MOD Sandbox project. They are implementing a trip engine for both fixed and flexible transit services and also working on the GTFS-Flex specification to bring flexible transit to rural residents and paratransit users. This project extends OTP (which is further described in section 3.1.7) including trip engine enhancements and GTFS-Flex specifications. The flexible transit services included in the VTrans application include the following (Cordahi & Shaheen, 2018):

- Hail-and-Ride: One of the most common forms of semi-flexible transit in rural areas. Because designated stops aren't needed every few blocks, as in urban areas, buses will stop anywhere that's safe along a road. To comply with this need, the trip engine will conform to route data but will have flexible stops generated by user requests. To provide this type of service, it is important for the routing algorithm to include real-time Automatic Vehicle Location (AVL) and Automatic Passenger Count (APC) information to generate forecasted arrival time at the requested stop and available capacity of the on-demand vehicle.
- Dial-a-Ride: Allows for those unable to use standard transit systems, such as seniors, individuals with disabilities, or those living in low-density areas without fixed-route

service, to call ahead for curbside service to take them to their destination. Vermont has a plethora of Dial-a-Ride options that current trip engines cannot display, even though they cover a large portion of the state at a reasonable cost. Most searches in trip engines return no possible trips so Dial-a-Ride options are not typically helpful to include in a trip planner. Dial-a-Ride services do, however, provide extensive curb-to-curb services to the public.

- Deviated fixed routes: These types of routes are exceptionally complex and contain both fixed route and dial-a-ride-like elements, but the GTFS-Flex data model combines these elements in a way that lets the flexible trip engine show those elements all in one cohesive plan.
- Flex-to-fixed connections**:** Provides connections from flexible to fixed route transit. Today's trip engines will only show connections between fixed routes and walking, biking, or driving modes–they leave out potentially efficient transit trips that connect the commuter to a fixed route via Dial-a-Ride. The new OTP code is meant to improve connections from flexible and fixed route transit.

Ridesharing: Ridesharing is defined as "the formal or informal sharing of rides between drivers and passengers with similar origin-destination pairings. Ridesharing includes carpooling and vanpooling, which consists of 7 to 15 passengers who share the cost and operating expenses of a van, and may share driving responsibility", (SAE, 2018). The ridesharing service can be provided based on set and pre-arranged pick up and drop off schedules, but can also be delivered on-demand, which is known as real-time ridesharing.

One of the most advanced integrations of ridematching services with other transportation modes was led by the City of Austin under the SmartCommute (https://smartcommuteaustin.com/) program. The MMTE implementation provided a multi selection trip engine integrated with the ridematching information and a carbon footprint tracker. Results of testing performed on the SmartCommute service before launch showed that the service algorithm generated one trip per mode, including various mobility options such as ridesharing, transit, walking, biking and driving. However, as the algorithm does not generate a combined route of transportation modes, it cannot be considered a truly multimodal trip engine.

Ridesourcing and Taxis: According to SAE J3163, ridesourcing services are "prearranged and on-demand transportation services for compensation in which drivers and passengers connect via digital applications. A mobile app is typically used for booking, electronic payment and ride ratings." TNCs are an example of ridesourcing services.

Taxi services provide prearranged and on-demand transportation services for compensation through a negotiated price, zone pricing, or taxi meter (either traditional or GPS-based). Passengers can schedule trips in advance (booked through a phone dispatch, website, or a mobile app), street hail (by raising a hand on the street, standing at a taxi stand, or specified loading zone), or e-Hail (by dispatching a driver on-demand using a smartphone app), (SAE, 2018).

A growing number of ridesourcing services are making their services and data available through APIs. As an example, the Uber API (https://developer.uber.com/docs/riders/references/api/v1.2/requests-estimate-post) provides the ability to request, select and book a ride through a single interface. The integration of this service into the MMTE will require an interface or service extension to submit a request based on the origin (latitude/longitude), destination (latitude/longitude), and the number of seats required for Uber and receive the following returned fields:

- The estimated vehicle arrival time in minutes. (Null if no cars are available.)
- Estimated fare details.
- Estimated trip duration.
- The minimum trip fares.
- Estimated distance.
- The distance unit.

The returned value can be then factored in the multi-modal trip engine algorithm to identify the best route possible based on the user's selections.

Bikesharing/Scooter Sharing: According to National Association of City Transportation Officials (NACTO), bikeshare in the U.S. has continued its brisk growth, with 35 million trips taken in 2017, 25% more than in 2016, (NACTO, 2017). In 2018, people took 84 million trips on Shared Micromobility (bikes, e-bikes, and e-scooters) in the United States, more than double the number of trips taken in 2017, (NACTO, 2018). This growth is attributed to increasing ridership in existing systems as well as the launch of several major new bikeshare systems across the country.

Under the North American Bikeshare Association's leadership, public and private sector entities, as well as non-profit bikeshare system owners and operators, application developers, and technology vendors, developed the General Bikeshare Feed Specification (GBFS) to publish bikesharing data in standard formats. GBFS is intended to provide data specifications for real-time and read-only information providing the status of the current system, with no specified access to historical information. GBFS data has been integrated into some trip engines such as the TriMet OTP enhancement. An increasing number of bikesharing and scooter sharing service providers, both docked and dockless, publish GBFS data, including Bcycle, CitiBike, Capital Bikeshare, Jump, Spin and Lime.

It is also worth noting that the Mobility Data Specification (MDS) (https://github.com/openmobilityfoundation/mobility-data-specification), initially developed by the Los Angeles Department of Transportation (LADOT) and now currently owned by the Open Mobility Foundation (OMF), provides a data standard for mobility providers, such as dockless bikeshare and scooter sharing services. The MDS was inspired by GTFS and GBFS and was designed to publish the data into a standard API format to facilitate data integration, help ingest, compare and analyze mobility service providers and possibly allow for integration into a MMTE.

Carsharing: Carsharing allows users to access vehicles by joining an organization that maintains a fleet of cars at various locations. Carsharing and other forms of shared mobility, have also been associated with greater use of public transit and higher levels of walking, hence the importance of including these transport modes in the MMTE.

The integration of these services into a MMTE can be achieved through APIs. An increasing number of mobility service providers are publishing their data through APIs such as Zipcar API (https://developer.zipcar.com/documentation) which provides real-time information on nearby vehicle availability and a transactional interface to book a car. Other companies such as Getaround, Turo, Maven, and Gig (AAA) do not yet provide APIs.

5.2.4 Route Planner (Goods)

Retailers and their logistics partners have been pushed to meet growing customer demands for increasingly speedy shipping, and the steady rise of e-commerce has caused the daily volume of parcel shipments to skyrocket. The P2P-GDM as defined in SAE J3163 standard (SAE, 2018) includes “courier network services such as apps providing for-hire delivery for monetary compensation […]”.They use a website or smartphone app to connect delivery drivers using a company or personal transportation mode with users seeking goods delivery services. Goods delivery planners can serve as dedicated for-hire delivery services or be mixed mode (for-hire drivers can deliver both passengers and packages). These services are also referred to as Flexible Goods Delivery services.

Taking this into account, the MOD Goods Delivery Planner subsystem will allow for a matching and routing engine to connect delivery services or delivery drivers with users. Inclusion of goods delivery into the MOD Marketplace requires the integration of the various delivery, logistics and courier services data using their respective APIs.

5.2.5 Mobile Application sub-system

Under the current shared economy model, MOD is a vision for on-demand, real-time, data-driven, user-centered model of providing transportation services, powered by the growth of smartphones. The mobile application sub-system, being the main user interface to all the various sub-systems described previously, brings together the seamless user experience to explore mobility options, to book and pay in one click. The next generation of smartphones will provide additional opportunities to improve the MOD offering for a broader set of users.

According to a Pew study, (Pew Research Center, 2019), Americans today are increasingly connected to the world of digital information via smartphones and other mobile devices. The share of Americans that own smartphones is now 77 percent up from just 35 percent in Pew Research Center’s first survey of smartphone ownership conducted in 2011. Hence, the mobile application (or app) is envisioned to be the main subsystem used to deliver MOD Marketplace functionality and service to users. Mobile app user interface (UI) design should focus on anticipating user needs, ensuring ease of access, and should be intuitive and comprehensible. The mobile app being the main access point will have to be designed using criteria, constraints, filters, visual and audio effects that are appropriate for all users, so the app is accessible, usable and inclusive for everyone, regardless of their ability, age, education or language.

The MOD Marketplace mobile application should contain all the features described in the multimodal trip engine section to provide a seamless door-to-door travel experience for all users following the Universal Design Principles, (National Disability Authority, 2020):

Principle 1: Equitable Use

The design should be useful and marketable to people with diverse abilities to use an app to request MOD services.

Principle 2: Flexibility in Use

The design should accommodate a wide range of individual preferences and abilities. For example, wheelchair access, transfer preferences, cost, walking speed etc.

Principle 3: Simple and Intuitive Use

The design should be easy to understand, regardless of the user's experience, knowledge, language skills etc.

Principle 4: Perceptible Information

The design should communicate necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities. The trip information should be presented as simple, step by step directions with text, visual aids, audio and maps.

Principle 5: Tolerance for Error

The design should minimize hazards and the adverse consequences of accidental or unintended actions, such as providing users with confirmation prior to charging them for service or ensuring walking directions provide safe roadway crossings.

Principle 6: Low Physical Effort

The design efficient and comfortable to use and should minimize user fatigue. For example, a multimodal trip response should be obtainable with minimal effort to the user, limiting click-through fatigue while using the app.

Principle 7: Size and Space for Approach and Use

Appropriate screen layout sizing and spacing should be provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility. Additionally, most smartphone manufacturers provide accessibility design guidelines applied to:

UI Design: UI design consists of the components and layout with which all users can interact including simple screen flows, choice of colors, responsive design and custom profiles with preferred color scheme, avatar, finger friendly design.

User Experience (UX) Design: UX design is the overall experience of the user using the MOD application. This includes the usability and the navigation through menu and option settings. The application could also introduce new technological concepts such as AR, which will require specific attention to adequate screen flows and UX designs.

5.2.5.1 Smartphone Technologies

With the advancement in cloud computing, most of the computing process is accomplished on backend subsystems, often hosted within virtual servers or cloud services. This means less trip planning or data processing is done on smartphones, permitting more advanced user interfaces or user experiences such as advanced maps, AR, and deep linking of multiple apps. In addition, the next generation of smartphones, with advanced mapping interfaces, visual and audio aids, and supporting 5G communication, will provide additional opportunities to improve MOD service offerings for a broader set of users.

5.2.5.2 Network Connectivity

It is anticipated that a mobile app would require cellular network connectivity or Wi-Fi access for map accessibility, trip engine user interface, trip generation, device positioning, real-time information, AR applications, and external systems data and transaction processing. The mobile application design should take into consideration cases where a network connection is intermittent or unavailable, such as in the case of subway stations or more rural areas where network coverage may be sparse; for example, using caching, state management, and data access mechanisms with intermittent or batch communications.

5.2.5.3 Device Resource Constraints

During the design phase, every mobile app design decision should consider the limited Central Processing Unit (CPU), memory, storage capacity, and battery life of mobile devices. Battery life will be the most limiting since GPS and AR applications will require intense battery usage. Backlighting, reading and writing to memory, wireless connections, specialized hardware, and processor speed all have an impact on the overall power usage. The mobile app should be designed to optimize and minimize its power and memory footprint while considering performance and data processing.

5.2.5.4 Virtual Maps

The map view in a mobile app will provide the traveler situational awareness where they can zoom to view the closest transit stations, POIs, street names and other map information available on the iOS and Android native maps. Additional layers could be added to the map such as real-time traffic, AVL, APC, transit information, stations with wheelchair access, service disruption and the OD selection with a mapped route through the trip path.

5.2.6 Trip Optimization and Machine Learning Engine

Trip optimization refers to the integration of static, dynamic and predictive transportation information to generate an optimized and customized trip based on a user's choices. Today, when a user selects a trip, the multimodal trip engine will include in the algorithmic calculation a combination of scheduled (GTFS) and other static data (roadway nodes, segments), and when possible real-time information from GTFS Realtime or GTFS-Flex to provide a combination of transportations services for the entire trip chain.

In order to optimize mobility, a machine learning engine applied to all transportation modes could be used to optimize the trip results based on short-term conditions. The accumulation of high-quality historical data is a precondition to leveraging machine learning techniques, which could allow significant management of future demand of the MOD Ecosystem at a macro level. The proposed predictive engine approach learns over time, using the contents of the MOD Data Hub to predict conditions and generate a tailored trip. The iterative aspect of the trip optimization engine is important, because as the model is exposed to new data, it can automatically and independently adapt to generate new trip results. The engine learns from previous computations to produce reliable, repeatable decisions and results. Of course, the volume of data required to implement true, effective machine learning requires increasing the hardware needed to run the predictive algorithms, thus presenting increasing cost over where trip planners currently are in the marketplace today.

As users have access to an increasing number of mobility choices, how can a trip be optimized based on changing parameters and on users' individual preferences? The personalization and optimization of a trip engine can be implemented using two concepts:

- **Building trip context awareness:** By observing past travel choices and their situational context, the trip optimization engine learns a model of the user and leverages this model to provide tailored trip choices reflecting the unique preferences of each user. The learning data set for each user could be achieved through UI inputs and a satisfaction score for the generated trips. Other methods include generating a profile or creating a profile based on user preferences such trip duration, distance, elevation, transport mode, cost, physical effort, wheelchair access, weather, illumination, safety, pollution, purpose of the trip, companionship, use of incentives, etc.

- **Use of predictive conditions:** The use of predictive conditions could be achieved by factoring in variables such as weather conditions or the availability of mobility services or parking depending on the time of the day or day of the week into the trip engine algorithm calculation. The predictive data stream could be made available through a regional transportation project such as Integrated Corridor Management predictive engines or other advanced mobility deployment projects using machine learning for predictive conditions. It is also conceivable that a predictive engine be embedded in the trip optimization subsystem, using machine learning libraries (neural network) to predict short-term conditions. The accumulation of high-quality historical data (a training data set) is a precondition to leveraging machine learning techniques. As the name suggests, the engine learns over time using the contents of the archived data (Data Hub) to predict conditions. The iterative aspect of machine learning is vital, because as the model is exposed to new data sources and types, it can automatically learn and independently adapt to changing transportation patterns, travel choices and situational contexts. This allows the optimization engine to learn from that training data set and provide tailored trip results reflecting the unique preferences of each user. This method is used in most search engines such as Google, (Rowe, 2018) and also by other services such as Facebook, Amazon, and Netflix to make recommendations to their users (Plummer, 2011).

5.2.7 Data Analytics and Reporting

Dashboards, reports, and performance measures that provide accurate and actionable results play a key role in situational awareness that can help to improve operations and regional conditions.

5.2.7.1 Performance Measures

As more and more transportation data are made available from a variety of sources such as mobility services and connected vehicle services, the ability to analyze and understand the current state of the transportation infrastructure is drastically improved. Performance measures and analytics are a crucial component in deriving the big, overall picture of the state of the transportation network and its agencies' ability to operate efficiently and manage assets effectively, providing the best, most reliable services for its riders.

With huge amounts of demand and supply side data (transportation information for users and travel pattern data for operators) brought together, regional agencies can get a clearer understanding through KPIs of whether the supply meets the demand. The insight that operators can gain from effective data analytics can show them where and how to introduce operational changes to solve some of the customers' pain-points.

5.2.7.2 Dashboards and Reports

Dashboards provide a visual representation and insight into the data that is collected and stored in the data hub. The graphical representation of KPIs can provide real-time and offline assessment into the performance of a transportation network and provide operational staff with full situational awareness that can lead to informed decisions. The goal of these visualization tools is to present actionable information in a less technical manner to help identify potential bottlenecks, pain-points, breakdowns in infrastructure, poor operating conditions, etc. so that decisions can be made to address any potential contributing factors leading to degradation of service. While dashboards present a more real-time, interactive, drill-down approach to the presentation of the data, reports provide canned statistical analysis of the data, usually in a standardized format.

Some of the information that can be provided through visualization of data collected and analyzed from the MOD data warehouse include:

- Identification of travel patterns
- Transactions
- Information on who is performing mode shift
- Ability to track demand and identify where the gaps in the trip chain are
- Customer feedback
- Service availability
- System availability
- Traveler deviation from a standard trip

The performance measures, dashboards, and reporting subsystems are key consumers of the aggregated and harmonized data that will be provided from the MOD data warehouse. In addition to helping to identify potential issues with the services being provided, the visual representations also help to obtain an understanding of potential gaps in the data.

5.2.8 Integrated Electronic Payment System

The transportation industry employs a variety of electronic payment systems across various transportation services, such as tolling, transit, parking, etc. In the early 2000s, transit agencies began adopting electronic fare payment systems where riders could wave a “smart” card or smartphone app in front of an electronic validator before boarding the transit vehicle. These fare payment systems provide customers with common payment instruments across a region for services offered by different transit providers.

Private mobility service providers such as TNCs rely mainly on electronic transactions and ticketing to process booking and payments through mobile apps. There is also a high adoption rate of cashless solutions and electronic payment systems for transportation services such as parking and tolling with ParkMobile, E-ZPass, BancPass and Passport, among others. An integrated payment system will allow multiple electronic payment transactions to be processed. The IEPS could be embedded within the mobile app, accessible through an API, or available from a kiosk in a transit station.

Emerging fare payment technologies using mobile devices and third-party contactless media and e-ticketing solutions provide opportunities to integrate these payment methods into a single solution. An IEPS allows a traveler to pay for an entire trip generated by the multimodal planning tool, encompassing multiple modes and payment methods, where the payment is processed as pay-as-you-go or based on a subscription model.

An IEPS works as follows: It starts with the multimodal trip engine's integration of functionality to calculate fare(s) based on a user's trip parameters, where the cost for each mobility provider and for each leg of the user's journey is calculated. When the desired trip option is selected and the user opts to pay for their trip, the payment request (utilizing the user's desired method of payment) is sent through the secure multivendor integrated payment platform. As multiple vendors can potentially be included in a journey, the secure payment platform has the capability of communicating with payment APIs from various shared mobility service providers, transit agencies, tolling agencies, parking providers, and any additional providers to ensure that secure, encrypted payment transactions are processed. The IEPS should be agnostic to the desired method of payment utilized by a user to pay for their journey, whether the method is a credit, debit, or stored transit value card, or payment through the use of transit benefits, cash, e-wallet or other method. When the transaction is complete, the user is notified by the app (on a smartphone or kiosk) that the transaction was either successful or the transaction failed so that they can act as necessary. The costs of the transactions can then be split among the various providers so that proper payment can be applied for the user's journey. Lastly, an added benefit of this architecture is the ability to track usage and provide data for later analysis.

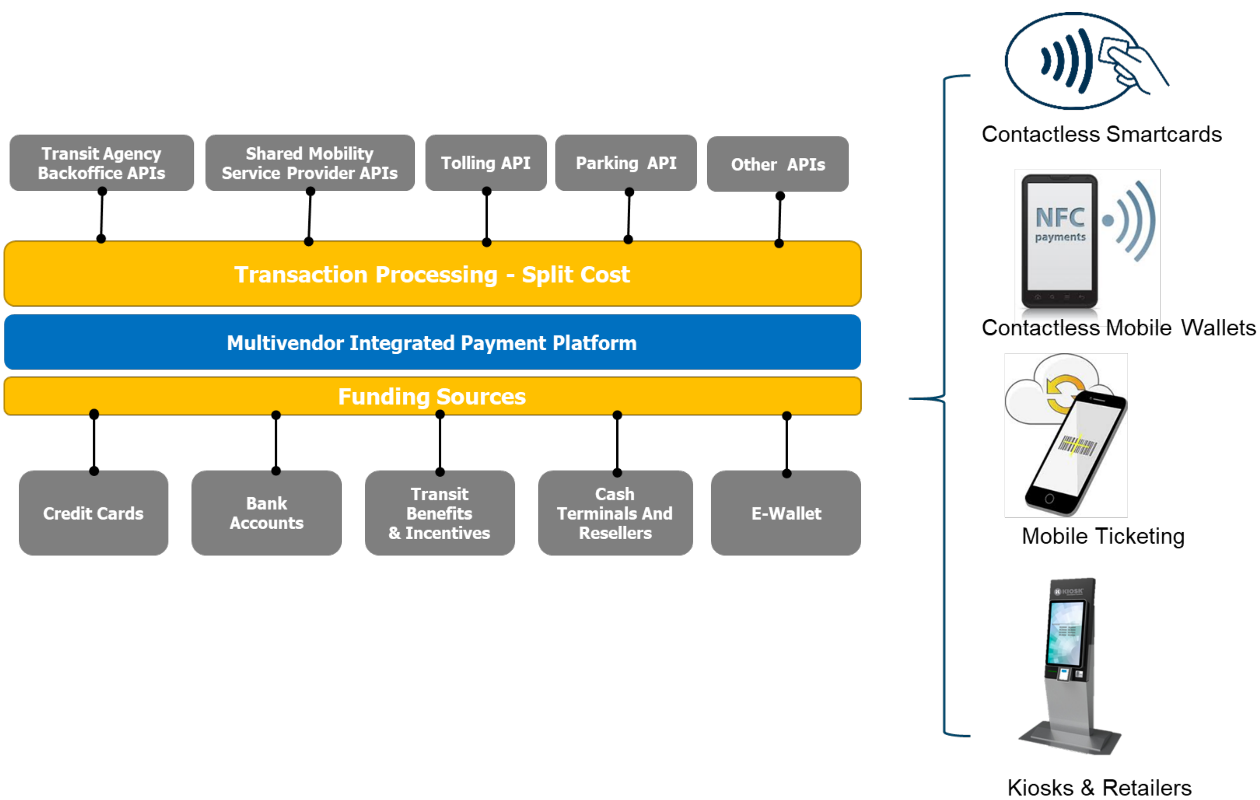


Figure 8 - Integrated Payment Platform Conceptual Diagram

From a user's perspective, the delivery of an IEPS includes the following functional groups (see Figure 9 - Integrated Payment Platform Conceptual Diagram for more details):

Planning: The planning part of the trip or goods delivery will be the input to the IEPS where the trip is either part of a subscription package or sliced, based on the split cost between all mobility service providers included in the trip chain.

Booking and Payment: Once a user selects a trip itinerary, ticket payments are processed following the appropriate payment model for pay-as-you-go or a subscription based model, in addition to fare structure for each service provider in the journey, including time limited products, zone-based products, point-to-point / destination-based products and pre-defined products (e.g. roundtrip, bundles, event/special tickets, etc.). The transaction processing is then submitted through the various service provider APIs. It is assumed that the transportation services included in the trip chain can support electronic payments through their APIs. In the case of a subscription-based MOD package, a clearinghouse subsystem will be required to track and reconcile transactions with the backoffice transportation providers' systems. The funding sources to process the payment can either be linked to the service provider's account included in the trip chain (for example linked to a TNC account or transit agency account), processed through electronic funding sources associated with the user's profile such as credit cards, bank accounts, transit benefits, cash terminals or resellers, or through incentives.

Payment Validation and Inspection: The completed electronic transaction will include information for each part of the trip that can later be used for validation purposes if necessary, including the ticket type, transaction identification, total sum, date and time of activation, date and time of expiration, payment type and barcode (2D barcodes are most frequently used). The validation of payment is often required during the trip chain and can be done using one of the folloiwng methods:

- Visual inspection of a mobile app e-ticket or a printout from a Kiosk
- Inspection of an e-ticket or printout using a handheld scanning device (a handheld device can either be a smartphone with a camera or a dedicated)
- Protected access where the passenger is physically restricted from entering the transportation network or accessing the vehicle until they scan a valid ticket: a printed ticket, a contactless smart card, or a mobile app using Near-Field Communication (NFC), Bluetooth Low Energy (BLE) or barcode technology.

Customer service: Customer service can be a function of the kiosks and retailers or the mobile ticketing app and aid travelers who encounter difficulties with one of the above steps or otherwise need assistance with planning, reserving, and purchasing services.

5.2.8.1 Integrated Electronic Payment System Models

At its core, the IEPS relies on a digital platform that integrates end-to-end trip planning, booking, electronic ticketing, and payment services across all modes of transportation, public or private. The use of electronic transactions allows for flexibility in delivering goods and services to reach the maximum number of users and providing incentives to meet the MOD program goals and objectives, although functionality must also be provided for unbanked customers. The following sections include some payment models currently used in the industry.

5.2.8.1.1 "Pay as you go" model

A "pay as you go" model offers users a method of payment for any costs they incur as part of their trip without the need to have a subscription. Unbanked users can use kiosks or retail providers to pay for their trip or add value to an account with cash. Mobile tickets can be purchased through a mobile app; a digital e-wallet or contactless card can be used to pay for on-demand services by communicating with BLE, radio-frequency identification (RFID) or NFC reader at entry points, and funds can be deducted from the user's method of payment in real or near-real-time. The "pay as you go" model may be a more suitable option for travelers who do not regularly travel using services available on the MOD Marketplace platform.

For example, travelers using a MOD app could plan their travel options from origin to destination with the app generating travel choices through the multimodal trip engine. Based on a user's selections, the payment for the entire trip chain will be processed by splitting the transactions among the various service providers and processed through their backoffice open payment systems. As observed in Figure 10, the Transaction Processing - Split Costs middleware will securely pass financial transactions to the providers.

The secure multivendor integrated payment platform will be responsible for providing the communication between the IEPS and the providers to ensure seamless transactions and successful payment for services provided.

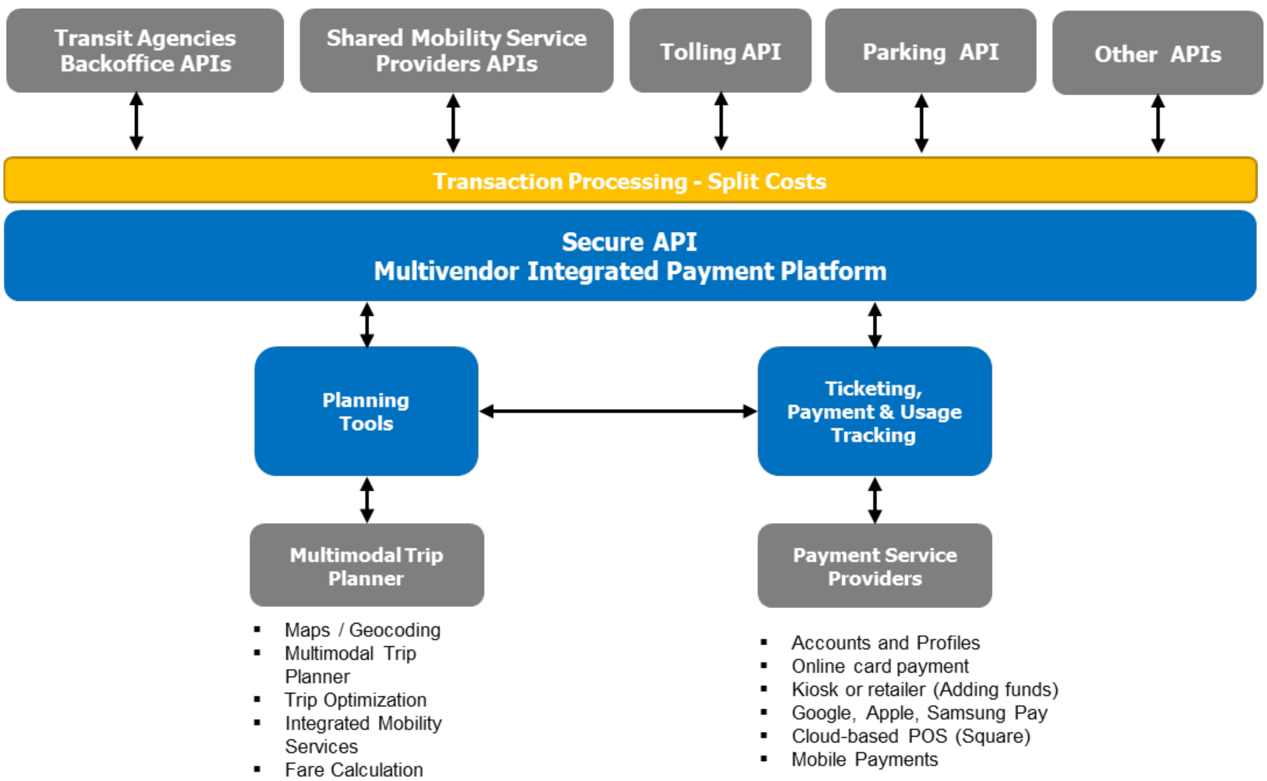


Figure 9 - "Pay as you go" payment

5.2.8.1.2 Subscription-based payment

For travelers and commuters opting to use a subscription-based payment model, users sign up and register for an account, and select their preferred method of payment within their account profile. The preferred method of payment includes options such as credit card, fare card, or mobile digital wallet such as Apple Pay, Google Pay, or Samsung Pay.

Subscribers who choose to prepay their account would typically be aware of the recurring costs for their usual travel so that they can preload into their preferred method of payment an amount that would be enough for their trips. Subscribers who opt for usage-based billing would be billed after the fact, paying from their preferred method of payment on a periodic basis. This model is similar to paying for a utility bill in which subscribers are billed on a monthly basis for their previous month’s usage.

This section focuses on the mechanics of processing the integrated payment and not necessarily the various subscription types. The subscription packages might have various applications including: (1) financial assistance or discounts for low income commuters, (2) a commuter package provided by employers to incentivize employees to use alternatives to driving alone to work, or (3) a monthly transit pass with additional mobility services options for first and last mile segments. The mobility options included in the subscription package will drive the pricing package and how and the transaction is processed through the various service providers. The business logic for the subscription package will be included in the clearinghouse technology stack as illustrated in Figure 11. In this scenario, the clearinghouse subsystem will be required to track and reconcile transactions with the backoffice transportation providers’ systems. Secure transactions are sent through the multivendor integrated payment platform where they are handled by the clearinghouse and distributed to the various transportation providers to dispense funds required for the services provided.

These models can be applied to the MOD Marketplace solution in which subscribers sign up and register for a service that can provide a payment mechanism for an entire trip from their origin to their destination, all in one centralized location, using one app for all transactions. The subscription-based model allows for customers to be billed on a regular basis for any services they use during their travel and may be more suitable for regular users of the system.

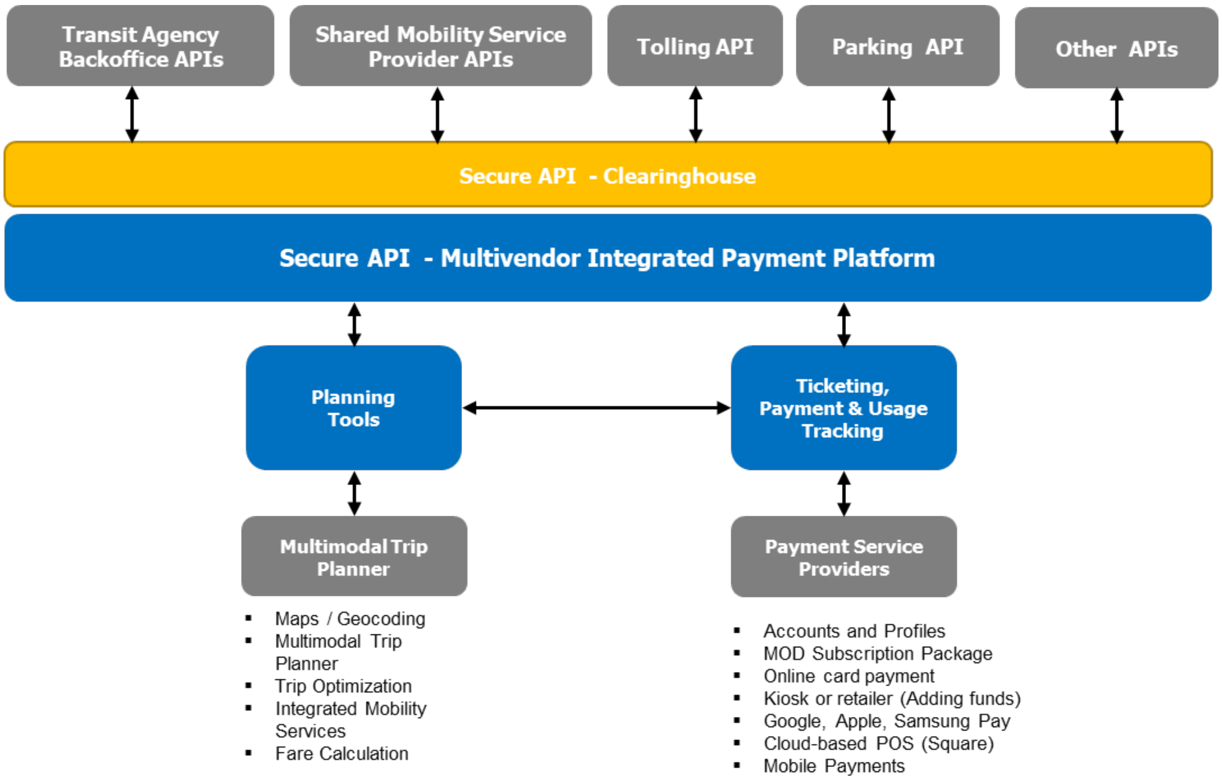


Figure 10 - Subscription-based payment

5.2.9 Data Mart & Open Data

Data distribution involves the sharing of data with stakeholders and consumers. Data in the MOD Marketplace, when standardized, stored, and shared correctly, can open new possibilities for multimodal transportation. The richness and volume of the data available today can help to highlight the value of transit and non-personal vehicle travel modes to travelers when the options are presented, for example, in the form of a multimodal trip engine that can consider multiple modes of transportation in a trip response. Cities can then utilize the data for planning purposes by collecting and analyzing the data.

A Data Mart is defined as a tool to access a subset of real-time or archived data either limited to a specific stakeholder's use or a specific business line or team. The Data Mart provides a unified access mechanism for third parties and MOD stakeholders to easily consume summarized data that has been collected and aggregated by the data hub. Data Mart technologies offer DaaS platforms that provide easy to access, publicly accessible, well documented, and formatted government data to subscribers. The Data Mart can be seen as a companion, or a window into the data hub to enable sharing and interconnectivity between the MOD platform and the demand Marketplace.

More and more agencies are making their data available to third parties, leveraging available tools to streamline the dissemination processes. Data shared in such a manner can be considered "Open Data". Data is said to be open if "if anyone is free to use, reuse, and redistribute it – Open Data should be machine readable and it should also be easily accessible" (Government of India Ministry of Electronics and Information Technology, n.d.). Government and other agencies benefit in many ways from sharing their data. Some benefits include (gov.uk, 2020):

- Allowing individuals and organizations to develop innovative tools and services to help improve the lives of others
- Increasing transparency in what government and businesses are doing
- Enabling people to make better choices about the services they receive
- Vast amounts of data collected by public agencies can be made available to third parties
- Ensuring high quality data is published in a clear, concise, standard, and well documented manner that will allow anyone to understand the content

MOD can benefit from the Open Data concept, provided that the data is of high quality, frequently updated, and standardized. The integration of city data, for example, into a multimodal trip engine can provide real-time, trip affecting, traveler information to travelers to help them make better decisions about their travel choices. Standardizing and documenting the data and then sharing from an Open Data portal offers a viable method for enhancing data distribution services that many consumers can benefit from.

5.2.10 Application Programming Interfaces & Web Widgets

An API is a software intermediary that allows two applications to talk to each other. The MOD platform will consist of multiple APIs that will be responsible for providing data in the data hub to the MOD consumers. The APIs ensure a common format that eases the communication between two entities. An API, for example, could be a Representational State Transfer (REST) API (https://restfulapi.net/) that provides an OD multimodal trip response in either JSON (https://jsonapi.org/) or XML.

APIs are typically readily accessible from the supplier website and many MOD suppliers already provide APIs. For example, Uber (https://developer.uber.com/) allows third party developers to integrate their ride request feature by providing an API for authorized subscribers to access. ZipCar (https://owa.zipcar.com/) provides similar API access to allow developers to integrate their carsharing services into third party apps. By allowing access to their data to third party developers, providers are broadening the reach of their services and facilitating the sharing of information that will maximize the potential for benefitting and serving a much wider audience.

Stakeholders may be interested in embedding MOD services into their app or website through a web widget. A web widget, is a small software application that is designed to provide a specific piece of information that can be added to a website to provide extra functionality. For example, the trip engine interface can be a widget that large employers or universities can insert in their websites for a seamless user experience.

5.3 Support Environment

A MOD platform requires a well thought out, well designed environment to support integration of services and meet operational requirements. Recent advancements in cloud computing have opened new ways of designing systems and databases with cloud-based data storage and virtualized resources. The shift to virtualization and virtualized environments has paved the way for new ideas in the technology industry for the design and implementation of data ecosystems. Agencies are no longer required to manage physical infrastructure to house data platform implementations, as cloud-based hosting platforms and technologies to host solutions are now commonplace. The shift toward virtualization has also opened new possibilities to move from a distributed architecture to a centralized architecture where the core components, subsystems, and data can all reside in one, centralized, virtual environment.

A **centralized** architecture can provide multiple benefits to the MOD platform, because it establishes an environment where the data needed by the MOD subsystems can be accessed from one central, logical location. In order to provide a comprehensive, inclusive response to an origin/destination trip request from a MOD user, for example, there would be no need for the multimodal trip engine to request data to fill gaps in the trip chain by accessing multiple sources to provide a response. The basic information required by the MOD subsystems could simply be accessed from within the central repository. There are several benefits and challenges to a centralized structure including:

Benefits:

- Better security as there is only one location for the data to be attacked
- Updates can be immediately provided to a user as they are accessed from only one location
- No need to request data from additional endpoints
- Data redundancy is minimized
- Less complexity in design

Challenges:

- Risk of loss of data as everything is stored in one location
- Potential bottlenecks
- Poorly implemented centralization can increase the cost of development
- Potential for increased load or strain on a system

Conversely, data can be spread out among multiple locations, in different formats. This is known as a **distributed** architecture. To provide an origin/destination response to a trip request under a distributed architecture, the trip engine would need to make more than one request to an external provider to fill in the gaps in the trip chain. While there are shortcomings to employing a distributed architecture to meet the demands to provide a comprehensive trip response to a MOD user, there are also benefits and challenges to maintaining a distributed architecture as well. Some of these benefits and challenges include:

Benefits:

- Less risk of loss of data due to extra redundancy and fault tolerance
- Less risk of bottlenecks
- Less load as requests are distributed among multiple locations

Challenges:

- Security challenges due to the need to secure multiple systems
- Increased need for data redundancy
- Potential complication of design

With the rise of transportation services and technological advancements in the industry, a shift away from a distributed architecture for the collection, storage, and analysis of transportation data and toward a more centralized, big data framework approach is very likely. The Mobility

Marketplace must now rely on new tools and technologies and new design methodologies to help manage the influx of information that is being generated.

Big data platforms (in this case, MOD in particular) can no longer solely rely on traditional data collection and storage software packages and tools. The immense volume of data collected and stored in multiple formats (structured or unstructured), places heavy constraints on the tools that can be used to store, access, analyze, and distribute the data. Where relational database management systems (RDBMS), such as MS SQL, PostgreSQL, MySQL, etc., provided popular means for data storage and analysis in the past, non-relational or distributed databases such as NoSQL (non-SQL/not only SQL) databases provide high performance and efficient access to large volumes of data storage in raw, unstructured format. NoSQL databases are now commonplace tools in the industry. This is not to say that RDBMS will no longer co-exist in a MOD platform architecture and will be replaced entirely by NoSQL databases. Instead, RDBMS and NoSQL databases must both be included in the architecture to provide varying functionalities in the delivery of MOD services where one technology is more suitable to provide a function than the other. A Systems Engineering approach can be used to identify the business requirements and user needs that will help to drive the platform design.

5.4 Data Governance and Security

Data governance is a collection of practices and processes which help to ensure the formal management of data assets within an organization. Data governance includes concepts such as data ownership, data quality, and others. The goal of data governance is to help an enterprise gain better control over its data assets, including methods, technologies, and behaviors around the proper management of data. It also deals with security and privacy, integrity, usability, integration, compliance, availability, roles and responsibilities, and overall management of the internal and external data flows within an organization (Knight, 2017). It is anticipated that the MOD platform gets deployed with the constraints set by the data governance of the entity that is responsible for the implementation, operation and maintenance of the system.

Some of the key areas included in the business entity data governance are discussed below along with the relationship each plays in a MOD implementation.

5.4.1 Security and Privacy

Data security and privacy are critical in the management of a MOD Marketplace system. A functioning MOD platform requires the integration of data from many sources, including personal data for the end users that interact with the front end. Personal data can include everything from an email address to financial information. Due to the sensitive nature of this data, best practices must be employed to protect the data collected. This section will discuss the need for a secure data platform as well as specific examples on how to meet specific requirements to achieve security and privacy goals.

A true MOD implementation relies on data from a large variety of disparate sources. However, when collecting and aggregating data from some of these sources, privacy and the collection of PII can become a concern. Any information that can be used to distinguish one person from another and can be used for de-anonymizing data is considered PII (Rouse, 2020). PII is rarely necessary in the analysis of transportation data, so should therefore be scrubbed prior to storing the data.

Public agencies play a role in developing best practices that identify data standards and balance data sharing (open data) and privacy among individuals, companies, and public agencies, particularly among app-based MOD service providers. In addition, private service providers need to ensure the privacy and protection of customers that utilize their services. Through the implementation of public-private partnerships, agencies and providers must work together to define new standards and policies and procedures to protect sensitive data, while at the same time leveraging the sharing of data through open data standards to promote technology and innovation, (Cohen, Sarkhili, Shaheen, & Yelchuru, 2017).

The incorporation of an IEPS as a part of a MOD solution requires an even stricter level of data privacy and security as personal financial information. An IEPS can provide consumers with a fast and seamless MOD travel experience where payment for an entire trip can be made within a single application, but action must be taken to ensure that payment transactions are kept private and secure and that any and all transactions are sent through secure channels for processing. Following industry standards for financial processing can help protect users' financial information.

With the rise of emerging digital technologies, the need to protect and secure personal data is becoming more and more evident. Steps are being taken and legislation enacted to protect the rights of citizens and data that is collected about them.

5.4.2 Data Ownership

Data ownership is primarily a data governance process that details an organization's legal ownership of enterprise-wide data. A specific organization or the data owner can create, edit, modify, share and restrict access to the data. Data ownership also defines the data owner's ability to assign, share, or surrender all of these privileges to a third party. This section will discuss the role data ownership plays as a part of data governance. This section will also cover who is responsible for maintaining and managing the data in the MOD platform and who will develop business rules to govern the data such as cybersecurity requirements.

Data owners are the companies or organizations that produce their own datasets (NITI Aayog and Rocky Mountain Institute, 2018). It is the responsibility of the data owner to ensure the safety and the security of the data that is collected. The owning entity must develop the business rules and security measures to protect the data they collect.

Data owners in the context of MOD are made up of a variety of different providers, both public and private. Because MOD relies on data that is distributed between public and private entities, different datasets can have different owners in a single MOD platform. For example, the local DOT can be the data owner for data collected by traffic sensors or connected vehicles, and Uber is the data owner for individual transactional data collected for the use of their ride services. In addition, individual citizens could be considered as private data owners, where they have the right to control their own data that they generate.

Data ownership should be established and well documented in a comprehensive DMP, clearly identifying who the owner of the specific dataset is. The owner can decide who or what subsystems have access to their data and how the data can be distributed, who has legal rights to the data, and who can utilize the data post project completion.

5.4.3 Data Availability, Integrity, Quality, and Usability

The MOD Marketplace platform will rely heavily on the data it contains. This section discusses why it is essential that the data in the data hub is accurate, comprehensive, and ultimately usable by the system. It is also imperative that data is made available to the MOD data hub and is easy to consume from the supplier where required for the platform to leverage the most complete set of data in the industry. This document has focused on the methods of collecting, processing, and distributing data in the context of MOD and has established the importance of ensuring a complete and comprehensive dataset to eliminate gaps in the trip chain. As has been discussed, it is paramount to encourage interoperability and compatibility between the suppliers and consumers in the MOD Marketplace.

Data should be readily available, should be of the highest integrity and quality, and should be provided in a format that is usable to those who wish to and are authorized to consume it. The following sub-sections define the constraints that should be applied to the collection, fusion, and dissemination of data in the MOD platform.

5.4.3.1 Availability

Data should be readily available in a common format, where it can easily be accessed by a consumer. Data suppliers should provide data in Open Data formats, accessible via API or similar, and scrubbed of any PII. Completeness must be ensured to minimize or eliminate gaps in the trip chain. In addition, data should be updated regularly to ensure timeliness and consistent quality over time.

5.4.3.2 Integrity and Quality

Providing incorrect data is worse than providing no data at all. The data distributed among the MOD subsystems and its consumers must be checked for accuracy before the data is shared among the consumers. Distributing data that is incorrect, incomplete, or very low quality offers no value to MOD consumers and diminishes consumer confidence.

5.4.3.3 Usability

The use of standards, ensuring interoperability, and providing well documented datasets can help public and private entities provide innovative solutions to share data and collaborate to provide a MOD experience. Data must be usable and easily understandable to limit the amount of development work and transformation that must be done on disparate datasets.

5.5 Operational Requirements

The operational requirements provided in this section include high-level requirements associated with each subsystem reviewed in this ConOps. Each requirement is labeled with a unique identifier for clarity, indicated in parenthesis in each sub-section title. Not all high-level requirements identified in the sections below will necessarily apply to all future MOD Marketplace implementations. Following the systems engineering process, MOD Marketplace implementers should develop detailed requirements after the development of their concept of operations.

5.5.1 Data Collection (DC)

DC.001 The data collection component shall collect roadway network information.
DC.002 The data collection component shall collect traffic data information.
DC.003 The data collection component shall collect tolling information.
DC.004 The data collection component shall collect event information.
DC.005 The data collection component shall collect transit information.
DC.006 The data collection component shall collect social media information.
DC.007 The data collection component shall collect parking information.
DC.008 The data collection component shall collect weather information.
DC.009 The data collection component shall collect taxi and limousine information.
DC.010 The data collection component shall collect ridesourcing information.
DC.011 The data collection component shall collect store shuttle information.
DC.012 The data collection component shall collect car rental information.
DC.013 Data collection periods shall be applied to each data type as needed.

5.5.2 Data Hub and Data Warehouse (DH)

DH.001 The data hub and data warehouse shall store roadway network information.
DH.002 The data hub and data warehouse shall store traffic data information.
DH.003 The data hub and data warehouse shall store tolling information.
DH.004 The data hub and data warehouse shall store event information.
DH.005 The data hub and data warehouse shall store transit information.
DH.006 The data hub and data warehouse shall store social media information.
DH.007 The data hub and data warehouse shall store parking information.
DH.008 The data hub and data warehouse shall store weather information.
DH.009 The data hub and data warehouse shall store taxi and limousine information.
DH.010 The data hub and data warehouse shall store ridesourcing information.
DH.011 The data hub and data warehouse shall store shuttle information.
DH.012 The data hub and data warehouse shall store car rental information.
DH.013 Data collected and stored in the data hub and data warehouse shall be secured with access allowed only to authenticated consumers.
DH.014 The data hub and data warehouse shall require a username and encrypted password to access the data.
DH.015 The data hub and data warehouse shall be accessible via secure connection (Transport Layer Security [TLS]).
DH.016 Access to the data hub and requests made to the MOD data hub shall be logged.
DH.017 Data collected and stored in the data hub shall be scrubbed for PII where necessary and not required.
DH.018 Data shall be collected and stored in raw format where applicable.
DH.019 Data shall be collected and stored in structured format where applicable.
DH.020 Data shall be collected and stored in semi-structured format where applicable.
DH.021 Data shall be collected and stored in unstructured format where applicable.
DH.022 Data retention periods shall be applied to each data type collected and stored as needed.

5.5.3 Multimodal Trip Engine (MMTE)

MMTE.001 The MMTE shall have the ability to ingest standard data formats (i.e. GTFS, GTFS-Flex, Traffic Message Channel [TMC] Codes, Keyhole Markup Language [KML]) and non-standard data as provided by individual MOD stakeholder APIs.

MMTE.002 The trip planner shall support static and dynamic routing.

MMTE.003 The MMTE shall have the ability to include static and dynamic data provided by all the supported travel modes.

MMTE.004 The MMTE shall have the ability to provide the shortest path between OD based on the user's choices and inclusive of all the supported travel modes.

MMTE.005 The MMTE shall have the ability to generate multimodal trip results including transfers between various modes.

MMTE.006 The MMTE shall have the ability to update the routing path as real-time conditions change.

MMTE.007 The MMTE shall provide route to route and mode to mode transfers.

MMTE.008 The MMTE shall provide transfers based on users' preferences, profiles, and distance, connecting static and dynamic routes.

MMTE.009 The MMTE shall have the ability to optimize the trip results based on users' choices and profiles.

MMTE.010 The MMTE shall have the ability to optimize the trip results based on predictive conditions.

MMTE.011 The MMTE shall have the ability to integrate with ATDM, TDM or ICMS external systems for ICM or TSMO strategy implementations.

MMTE.012 The MMTE shall have the ability to integrate with external geocoders.

MMTE.013 The MMTE shall support various mapping formats.

MMTE.014 The MMTE shall provide audio and visual aids.

MMTE.015 The MMTE shall have the ability to use external wayfinding and AR services.

MMTE.016 The MMTE shall allow users to select incentives.

MMTE.017 The MMTE shall have the ability to capture and store OD requests.

5.5.4 Route Planner (Goods) (RP)

RP.001 The route planner shall have the ability to integrate logistics data from various data sources and APIs.

RP.002 The route planner shall allow users to enter origin / destination and details on the goods to be delivered.

RP.003 The route planner shall generate an optimized delivery path from origin to destination, including first and last mile delivery.

RP.004 The route planner shall allow users to select delivery duration, cost, insurance, size, packaging, content, and special delivery notes.

RP.005 The route planner shall allow users to select pick up, delivery time and drop off time.

RP.006 The route planner shall have the ability to capture and store OD requests.

RP.007 The route planner shall have the ability to optimize the trip results based on real-time conditions.

RP.008 The route planner shall have the ability to integrate with external geocoders.

RP.009 The route planner shall support various mapping formats.

5.5.5 Mobile Application (MOB)

MOB.001 The mobile application shall allow users to access all the MOD app menus.

MOB.002 The mobile app shall allow user to enter trip information.

MOB.003 The mobile app shall have the ability to buffer data for continuous operation in areas with no wireless communications coverage.

MOB.004 The mobile app shall have the ability to provide all the functions available in the MMTE.

MOB.005 The mobile app shall allow users to create profiles and save their favorite trips.

MOB.006 The mobile shall allow have audio, visual and text aids.

MOB.007 The mobile app shall update the trip results based on real-time conditions.

MOB.008 The mobile app shall allow users to view multiple itineraries.

MOB.009 The mobile app shall allow users to select an itinerary.

MOB.010 The mobile app shall have the ability to capture, submit and store OD requests.

MOB.011 The mobile app shall follow principles of accessible design.

5.5.6 Trip Optimization and Machine Learning Engine (TOML)

TOML.001 The trip optimization and machine learning engine shall use an algorithmic calculation of a combination of scheduled (GTFS) and other static data (roadway nodes, segments), and in some cases real-time information from GTFS Realtime or GTFS-Flex to provide a combination of transportations services for the entire trip chain.

TOML.002 The trip optimization and machine learning engine shall have the ability to optimize and generate trip results based on users' travel preferences and profile.

TOML.003 The trip optimization and machine learning engine shall have the ability to optimize and generate trip results based on predictive conditions.

TOML.004 The trip optimization and machine learning engine shall learn and build a model of the user.

TOML.005 The trip optimization and machine learning engine shall utilize the user model to provide tailored trip choices reflecting the unique preferences of each user.

TOML.006 The trip optimization and machine learning engine shall generate or create a user profile based on preferences such trip duration, distance, elevation, transport mode, cost, physical effort, wheelchair access, weather, illumination, safety, pollution, purpose of the trip, companionship, use of incentives, etc.

TOML.007 The trip optimization and machine learning engine shall use predictive conditions such as weather conditions, availability of mobility services, or parking availability depending on the time of the day and day of the week in the trip planner algorithm calculation.

TOML.008 The trip optimization and machine learning engine shall use machine learning libraries (neural networks) to predict short-term conditions.

TOML.009 The trip optimization and machine learning engine shall use the contents of the archived data (Data Hub) to predict trip travel conditions.

TOML.010 The trip optimization and machine learning engine shall learn from the training data set and provide tailored trip results reflecting the unique preferences of each user.

5.5.7 Integrated Electronic Payment System (IEPS)

IEPS.001 A user shall have the ability to use the MOD mobile application to plan a trip from origin to destination, select from one or more available trip options, and pay for their entire trip chain in one transaction using an IEPS.

IEPS.002 The multimodal trip engine shall contain logic to calculate fare and compute the cost of the entire trip chain.

IEPS.003 Prior to submitting a trip for purchase, a user shall be provided with the entire calculated fare for review.

IEPS.004 For trips that include modes where fares are not exact and are time/distance dependent, users shall be provided with an estimated fare for those modes, based on the rates available from the providers at the time of the reservation/transaction.

IEPS.005 Users shall be notified upon submitting a trip request that their transaction was either successful, or some or all of the transactions failed.

IEPS.006 When a transaction has been successfully submitted, the following information will be provided to the user for each leg of their trip:

- Ticket type
- Transaction ID
- Total fare
- Date and time of activation
- Date and time of expiration
- Payment type
- Barcode (where applicable)

IEPS.007 The IEPS shall support two methods of payment including:

- “Pay as you go”
- Subscription-based payment

IEPS.008 The IEPS shall support methods of payment including:

- digital e-wallet
- credit or debit card
- transit benefits
- fare card
- cloud-based Point of Sale (POS)
- kiosk
- retailer stored value cards.

IEPS.009 Users shall have the ability to store their preferred method of payment in a profile for use with the MOD app.

IEPS.010 The IEPS shall allow users to link additional transportation provider accounts to their profile to facilitate payment to the providers using their existing accounts (example TNC, transit agency, etc.).

IEPS.011 Unbanked users shall be provided the option of using kiosks or retailer stored value cards to pay for each leg of their journey.

IEPS.012 For unexpected/unanticipated costs incurred during the course of a journey, additional costs shall be billed from the user’s account at the completion of a trip using the user’s preferred method of payment.

IEPS.013 The IEPS shall support auto-replenishment for pre-paid accounts.

IEPS.014 For unbanked users or cases where auto-replenishment for pre-paid accounts (such as stored value cards) is not available or not functioning, users shall have the option to add alternate methods of payment to pay for their trip.

IEPS.015 Subscription-based accounts shall be billed for usage at the end of the invoice period.

IEPS.016 The IEPS shall integrate with Application Programmer Interfaces (APIs) from the service providers to process electronic payment transactions.

IEPS.017 All transactions shall be sent from the IEPS to the transportation service provider APIs to support electronic payment over a secure connection.

IEPS.018 An integrated clearinghouse subsystem shall track and reconcile transactions with back office service providers for the subscription-based MOD packages.

IEPS.019 Payment validation and inspection shall be provided along a user's journey by the following mechanisms, where applicable:

- Visual inspection of mobile e-ticket
- Printout from kiosk
- Inspection using handheld device in the field by a fare inspector
- Printed ticket
- Contactless smart card
- Mobile app using NFC, BLE, or barcode technology

IEPS.020 IEPS transactions will be governed by relevant financial transaction standards established by the payments industry, such as Payment Card Industry (PCI) standards.

5.5.8 Data Analytics and Reporting (PM)

PM.001 The data analytics component shall provide traffic KPIs.

PM.002 The data analytics component shall provide transit KPIs.

PM.003 The data analytics component shall provide parking KPIs.

PM.004 The data analytics component shall provide weather KPIs.

PM.005 The data analytics component shall provide airport safety KPIs.

PM.006 The data analytics component shall provide flight operation KPIs.

PM.007 The data analytics component shall provide accessibility KPIs.

PM.008 The data analytics component shall provide customer satisfaction KPIs.

PM.009 The data analytics component shall provide MOD usage KPIs.

PM.010 The dashboards component shall provide drilldown access to identified KPIs.

PM.011 The dashboards component shall update in real or near-real-time where applicable.

PM.012 The reports component shall provide canned representations to identified KPIs

5.5.9 Data Mart & Open Data (DM)

DM.001 The Data Mart shall be accessible to authorized consumers only.

DM.002 The Data Mart shall be accessible via secure connection (TLS).

DM.003 The Data Mart shall require a username and encrypted password to access the data.

DM.004 Data provided from the data hub to the Data Mart shall never include any PII.

DM.005 Access to the Data Mart shall be revocable in case of any misuse.

DM.006 Access to the Data Mart and requests made to the data mart shall be logged.

5.5.10 Application Programming Interface (API) & Web Widgets (API)

API.001 The API shall support external systems to capture, submit and store OD requests.
API.002 The API shall support external systems to submit trip options requests.
API.003 The API shall return multiple itineraries.
API.004 The API shall provide all the data attributes with each itinerary
API.005 The API shall support JSON, XML, and REST.
API.006 Third party developers shall have the ability to integrate components of MOD software into their own web applications in the form of a web widget.
API.007 Web widgets shall be provided to third party developers free of charge.
API.008 To access a web widget, third party developers shall be required to authenticate prior to requests for data from the MOD platform.

6 Operational Scenarios

Operational scenarios are scenarios intended to illustrate the operational flows for users and operators of the MOD Marketplace system. Operational scenarios discussed in this section, includes one MOD operator use case and eight end users use cases. Even though use cases reflect the interaction of the user and the mobile or the data analytics user interface, it is anticipated that the subsystems included in section 6.2- Subsystems and Functions are included.

6.1 Use Cases

The cases presented in the section below will provide a textual description that captures the user-system interaction for nine specific MOD scenarios. The use cases will represent the interaction between the user and the subsystems covered in this ConOps. The selected scenarios are based on the previous, unpublished work completed by the USDOT team under the MOD program and the user profiles are drawn directly from that work, (USDOT, Mobility on Demand (MOD) Deployment Scenarios. Draft v1.0, 2017).

6.1.1 Use Case 1: Leverage shared MOD data to analyze infrastructure conditions and improve transportation operations

Table 6 - Use Case 1

Use Case ID:	**1**
Use Case Name:	Leverage shared MOD data to analyze infrastructure conditions and improve transportation operations
Actor:	**Primary Actor** User Profile – Sergey is a Transportation Planner for a public transit agency **Supporting Actors** ▪ MOD Providers, Operators, and Maintainers ▪ Public Transit Agencies

<table>
<tr><td>Use Case ID:</td><td>1</td></tr>
<tr><td></td><td>Transportation Service Providers
Apps and Technology Providers
Stakeholders and Interests
Public Transit Agencies – Have interest in knowing user requested connecting services to provide sufficient drop-off/pick-up space at a transit station.
State and Local Authorities – Have interest in the use of system to ensure mobility of all people.
MOD Providers, Operators and Maintainers – Provide MOD application services to public transit riders on Sergey’s transportation services.
Federal Government – Can make investments or legislation regarding the operation of transportation programs</td></tr>
<tr><td>Description:</td><td>Sergey is a Transportation Planner working for a major transit agency in a suburban region. Sergey’s transit agency provides bus and commuter rail services from multiple locations, located throughout his region. Recently, he noticed that ridership has been declining for two of the main bus lines, that transport travelers from his region into the city, during peak commuting times and has virtually disappeared in the late-night hours. Eager to try to understand what is causing such a serious decline, Sergey discusses the problem with his colleagues who inform him of a new initiative that was undertaken by the local DOT and its partners to share and collect transportation data for many of the traffic, transit (including his own agency), and mobility providers in his region. Sergey, concerned about his agency’s ridership and revenue and the serious decline of both, decides to investigate the data to determine if he could identify potential causes for the downturn and propose changes to improve the current situation.</td></tr>
<tr><td>Preconditions:</td><td>Preconditions
User needs:
Access to MOD data warehouse and all data within
Data warehouse contains relevant current and historical data for the required time period
Data analytics tools to ingest and evaluate the conditions in the data
Knowledge of transportation datasets to minimize the learning curve
Knowledge of relevant KPIs to use for evaluation of data
MOD stakeholders’ willingness to share their data
Shared data scrubbed of PII prior to dissemination
Trigger</td></tr>
</table>

Use Case ID:	1
	User accesses and downloads relevant current and historical data
Postconditions:	**Post Conditions** <u>Success end condition</u> MOD data warehouse provides the necessary current and historical data for the required time period with no gaps in time The user can access and analyze the data and draw conclusions related to the decline in ridership <u>Failure end condition</u>: The user is unable to access the data Gaps in the data or data unavailable for the relevant time period Data not in the correct format or not useful to meet the needs of the user's use case <u>Minimal Guarantee</u> User is either able to access the data in the data warehouse or they are notified that they are not able to.
Performance Goal:	User can access required data within minutes of logging in to the online data portal
Basic Workflow:	Step 1 – User accesses the data warehouse online portal Step 2 – User enters credentials to login to the online data portal Step 3 – User directed to online portal home screen Step 4 – User searches for and finds transportation data related to their agency. Relevant transportation data for the requested time period includes: • Agency transit schedule data for the desired lines • Historical trip schedule deviation • Historical trip fare • Historical trip percent occupancy • Historical transit network conditions including incidents and construction events • Historical roadway network conditions including incidents and construction events • Historical average gasoline prices in the region • Historical average toll prices for related toll plazas • Historical average FHV fare for similar OD trips Step 5 – User downloads the relevant datasets to their data analysis environment

Use Case ID:	**1**
	Step 6 – User imports the data into their Business Analytics tool for graphical drilldown analysis Step 7 – User begins to evaluate the data by first looking at the historical trip schedule deviation and on time performance KPIs Step 8 – User notices on time performance for the time period in question is less than 50% on time during peak periods Step 9 – User notices schedule deviation is greater than 30 minutes longer than estimated trip time Step 10 – User calculates the average cost of the trip for riders who choose personal vehicles over transit by analyzing gasoline and toll prices for trips using a personal vehicle Step 11 – User analyzes average cost of the same trip using FHVs Step 12 – User calculates cost difference between using a personal vehicle, FHV, and taking user's agency buses Step 13 – User notices little difference between the cost of using a personal vehicle or taking transit Step 14 – User analyzes number and impact of related roadway construction events and incidents Step 15 – User analyzes number and impact of related transit construction events and incidents Step 16 – User determines that number and impact of roadway construction events within the timeline and during the commute periods directly impacts the bus lines in question Step 17 – User determines that there is no cost or time savings benefit for riders to choose transit over their own personal vehicle for the same trip from origin to destination Step 18 – User recommends to their agency to partner with microtransit services to provide shuttle services to a nearby rail station where commuters can board and ride a train to their destination and bus tickets and passes will be cross honored during major incidents Step 19 – User recommends extending the hours of a peak-only bus lane to include some time before and after peak commuting time Step 20 – User recommends adding more customer service staff to affected stations to provide additional customer assistance to commuters during the construction phase
Alternative Workflow:	Alt Step 3 – User receives notification that they are unable to login to the data portal and is instructed to create a new login

Use Case ID:	**1**
	Alt Step 5 – User is unable to locate and download all necessary data for their research Alt Step 8 – User notices on time performance is better than 50% Alt Step 9 – User notices schedule deviation is less than 30 minutes slower for the trips Alt Step 10-15 – User does not have access to one or more of the required datasets for analysis in the data analysis steps Alt Step 18 – User suggests an alternate recommendation or is unable to make a recommendation based on gaps or limitations in the datasets available
Special Requirements:	Performance: • Data in the online data portal is current and near-real time where appropriate • Historical and real-time data can be accessed and downloaded within minutes of logging in to the online data portal, depending on the size of the data being requested User Interface Requirements: ▪ Browser based online portal (data mart) for accessing data ▪ Transportation data provided in standard format for dissemination Security: ▪ Access to collected MOD data restricted to authorized users only ▪ Data privacy, stripped of PII prior to dissemination and sharing
Assumptions:	**Assumptions** User is familiar with transportation data User is familiar with KPIs used in the analysis of transportation data to make informed decisions User is authorized and can access the online data portal User is familiar with analytics tools to analyze datasets to make informed extrapolations MOD stakeholders are willing to share their data to ensure no gaps in the trip chain
Notes and Issues:	Issue: System cannot provide data required to make an informed extrapolation • Gaps in data collected and stored • Potential unwillingness of MOD stakeholders and partner agencies to share data

6.1.2 Use Case 2: To fill gaps in existing transportation networks and provide travelers with additional options and flexibility when privately operated vehicles and fixed-route transit services are insufficient.

Table 7 - Use Case 2

Use Case ID:	**2**
Use Case Name:	Provide additional transportation options when current services are insufficient
Actor:	**Primary Actor** User Profile – Cheryl is commuting to work via public transit **Supporting Actors** ▪ MOD Providers, Operators, and Maintainers ▪ Public Transit Agencies ▪ Transportation Service Providers ▪ Apps and Technology Providers **Stakeholders and Interests** ▪ Public Transit Agencies – Have interest in knowing user requested connecting services to provide sufficient drop-off/pick-up space at a transit station. ▪ State and Local Authorities – Have interest in the use of system to ensure mobility of all people. ▪ MOD Providers, Operators and Maintainers – Provide MOD services to Cheryl during her travel. ▪ Federal Government – Can make investments or legislation regarding the operation of transportation programs
Description:	Cheryl is a recent college graduate who lives in a close-in suburb and works in the downtown of a major metropolitan area. She currently does not own a car. For her regular job, she walks to the transit station and takes public transportation to get to work. A few nights a week she travels 10 miles to another suburb of the metropolitan area for a part-time waitressing job to help pay down her student loans. She can catch a ride with co-workers, but this option is often unreliable, and her work schedules shift on a weekly basis. The existing public transportation network is another option, but she must ride the subway/rail all the way into the downtown core and out again to the suburbs in order to get to her job, doubling her travel time. A recently established microtransit route launched by a private company provides a reliable transportation option for her. The service is at a higher cost than traditional rail but provides a much shorter travel time since the trip occurs outside of the downtown core, where transit service is sparse. The extra cost is worth it to her because it allows her to get home earlier from her part-time job.
Preconditions:	**Pre-Conditions**

Use Case ID:	2
	User needs: Smartphone Cell coverage or Internet connection Access to MOD app MOD app contains current data MOD app connected to all required subsystems **Trigger** User opens MOD app
Postconditions:	**Post Conditions** Success end condition MOD app provides trip information for user MOD app to provide trip results including of all applicable modes Selection of a trip from the provided choices Failure end condition: User trip request unable to be processed Gaps in the trip MOD app unable to provide full trip information MOD app exits Loss of communication Minimal Guarantee User redirected to “home” screen to make another trip request
Performance Goal:	MOD app to provide results within 4 secs
Basic Workflow:	Step 1- User launches the trip planning app Step 2- User logs in to the app Step 3- User directed to trip planning home screen Step 4- User inputs trip request information: ▪ Trip start time ▪ Mode/multimodal choice preferences ▪ Maximum walk distance ▪ Optimization based on speed, fewest transfers, quickest route ▪ Wheelchair access selection

<table>
<tr><td>Use Case ID:</td><td>2</td></tr>
<tr><td></td><td>

Origin/destination
Desired arrival or departure time
Number of people making the trip

Step 5- System processes user information
Step 6- System creates complete trip options including:

Available multimodal options
Price of each service
Trip duration of each mode
Number of stops on each mode
Distance travelled for each mode
Estimated arrival time of each service

Step 7- System provides trip details to the user
Step 8- User reviews and selects one option
Step 9- User begins trip
Step 10- System stores summary of the trip
Step 11- User checks real-time status during trip
Step 12- User arrives at destination and provides travel rating
</td></tr>
<tr><td>Alternative Workflow:</td><td>
Alt Step 1- App is unable to launch. Notifies user to connect to the internet
Alt Step 4- User cannot identify origin/destination location
Alt Step 4a- System requests access to user’s current location
Alt Step 6- System does not recognize user address. System sends a corrected address for user confirmation
</td></tr>
<tr><td>Special Requirements:</td><td>
Performance:
MOD app will update information every 2 minutes:

Update trip duration
Update transit arrival and capacity (AVL/APC)
Public transit service disruptions: skipped stations, redirected routes
Update costs of each mode

User Interface Requirements:

Adjustable font size feature available on the MOD app
MOD app provides user with the option to listen to the available trip options
MOD app allows for dictation anywhere user input is required
Visual aids (maps, wayfinding, AR)

</td></tr>
</table>

Use Case ID:	**2**
	Security: ▪ App user security notice ▪ MOD app will not share user location if feature is enabled ▪ Data privacy
Assumptions:	**Assumptions** User understanding of MOD app
Notes and Issues:	Issue: System cannot provide complete trip plan • Time constraints for modal transfer • Services not running during certain time periods • Transportation mode operating at capacity and cannot provide for another user

6.1.3 Use Case 3: On-Demand Neighborhood/Campus/Retirement Community/Employer Services

Table 8 - Use Case 3

Use Case ID:	**3**
Use Case Name:	First and Last mile access to business park
Actor:	**Primary Actor** User Profile - Camille commutes to work via public transit and employer shuttles **Supporting Actors** ▪ MOD Providers, Operators, and Maintainers ▪ Public Transit Agencies ▪ Employer services ▪ Transportation Service Providers ▪ Apps and Technology Providers **Stakeholders and Interests** ▪ Public Transit Agencies – have interest in knowing user requested connecting services—such as Lyft–to provide sufficient drop-off/pick-up space at a transit station. ▪ State and Local Authorities – have interest in the use of system to ensure mobility of all people. ▪ Federal Government – can make investments or legislation regarding the operation of transportation programs.
Description:	Camille is a high-tech worker who lives in an urban area. She just got a great new job with a startup company that requires her to commute to a business district outside the city. Because she recently used all of her savings to buy a condominium in the city, she does not have money to purchase a car, and parking in the city is expensive. Currently, Camille takes rail to a transit station near her new job and depending on the weather, takes another bus, uses bike share, or walks the 1.5 miles to the campus of her employer. None of these arrangements are completely satisfactory because there is a lot of high-speed traffic and wide streets that she must navigate to get to her destination. She just learned that the county transit authority and her employer will be implementing driverless shuttles from the transit hub to the business park where her office is located. Camille is excited about using automated vehicle technology to get to her job and also plans to use it for shopping and lunch plans during the day.

<table>
<tr><td>Use Case ID:</td><td>3</td></tr>
<tr><td>Preconditions:</td><td>Pre-Conditions
User needs:
Smartphone
Cell coverage or Internet connection
Access to MOD app
MOD app contains current data
MOD app connected to all required subsystems
Access to employer driverless shuttle if service is restricted to employees or certain users
Available transportation modes
Trigger
User opens MOD app</td></tr>
<tr><td>Postconditions:</td><td>Post Conditions
<u>Success end condition</u>
MOD app provides trip information for user
Selection of a trip from the provided choices
<u>Failure end condition</u>:
User trip request unable to be processed
Gaps in the trip
MOD app unable to provide full trip information
MOD app exits
Loss of communication
<u>Minimal Guarantee</u>
User redirected to “home” screen to accept another trip request</td></tr>
<tr><td>Performance Goal:</td><td>MOD app to provide results within 4 secs</td></tr>
</table>

Use Case ID:	**3**
Basic Workflow:	Step 1- User launches the trip planning app Step 2- User will login Step 3 – System recognizes user has access to the Employer driverless shuttle service Step 4 – Directed to trip planning home screen Step 5- User inputs trip request information: • Trip start time • Mode/multimodal choice preferences • Maximum walk distance • Optimization based on shortest wait time, speed, fewest transfers, quickest route • Wheelchair access selection • Origin/destination • Desired arrival or departure time • Number of people making the trip Step 6- System processes user information Step 7- System checks employer driverless shuttle demand: • Are other users requesting this service? • When/where will employer driverless shuttle make its next pickup Step 8- System creates complete trip options including: • Available multimodal options • Price of each service • Trip duration of each mode • Number of stops on public transit • Distance travelled for each mode • Wait time before transferring to employer driverless shuttle • Estimated arrival time of each service Step 9- System provides trip details to the user Step 10- User reviews and selects one option Step 11- User begins trip Step 12- User rates MOD app trip experience Step 13- System stores summary of the trip

Use Case ID:	**3**
Alternative Workflow:	Alt Step 1- App is unable to launch. Notifies user to connect to the internet Alt Step 5- User cannot identify origin/destination location Alt Step 5a- System requests access to user's current location Alt Step 6- System does not recognize user address. System sends a corrected address for user confirmation Alt Step 7- Unable meet user wait time restrictions for on-demand employer shuttle transfer Alt Step 7a- System notifies user of wait times/recommends other modes to complete last-mile trip
Special Requirements:	Performance: • MOD app will update information every 2 minutes: • Update trip duration • Update transit arrival and capacity (AVL/APC) • Public transit service disruptions: skipped stations, redirected routes • Update costs of each mode User Interface Requirements: • Adjustable font feature available on the MOD app • MOD app provides user with the option to listen to the available trip options • MOD app allows for dictation anywhere user input is required • Visual aids (maps, wayfinding, AR) Security: • App user security notice • MOD app will not share user location if feature is enabled • Data privacy
Assumptions:	**Assumptions** User understanding of MOD app Employer's driverless shuttle is an established service that already has a defined process for processing user demand and ride requests. Therefore, it is assumed that following questions have already been answered to make the decision that the service can meet the needs of its customers: • Are there fixed or dynamic stops? • Does shuttle pick up any ride request? • What is the maximum allowable trip time a user will experience? MOD app is able to connect to employer's driverless shuttle to provide real-time information to user regarding prospective service times.

Use Case ID:	**3**
Notes and Issues:	Issue: System cannot provide complete trip plan • Time constraints for modal transfer • Employer's driverless shuttle unable to pick up user due to capacity, route, or service constraints • Services not running during certain time periods • Transportation mode operating at capacity and cannot provide for another user

6.1.4 Use Case 4: On-Demand door-to-door and paratransit services

Table 9 - Use Case 4

Use Case ID:	**4**
Use Case Name:	On-demand door-to-door and paratransit services
Actor:	**Primary Actor** User Profile - Adam is a military veteran who uses a wheelchair for day-to-day mobility needs **Supporting Actors** ▪ MOD Providers, Operators, and Maintainers ▪ Public Transit Agencies ▪ Transportation Service Providers ▪ Apps and Technology Providers **Stakeholders and Interests** ▪ Public Transit Agencies – have interest in knowing user requested connecting services—such as Lyft–to provide sufficient drop-off/pick-up space at a transit station. ▪ State and Local Authorities – have interest in the use of system to ensure mobility of all people. ▪ Federal Government – can make investments or legislation regarding the operation of transportation programs.
Description:	Adam is a military veteran who uses a wheelchair for day-to-day mobility needs. Independent travel via public transportation is difficult for him, so he relies on paratransit for all of his travel needs. However, the traditional paratransit service requires bookings 24 hours in advance and is not reliable for his needs. Adam's local transit agency has launched a partnership with a TNC to provide more reliable and cost-effective on-demand paratransit service. Adam uses a mobile application on his smartphone to plan and request trips in real-time. The application automatically recognizes Adam's profile and dispatches the nearest wheelchair-accessible vehicle from the taxi company or TNC to his home. After making his request, he receives an alert that confirms his ride is set

Use Case ID:	4
	and on its way. The van arrives and takes him to his destination. There is also an option to call the transit agency or taxi company to dispatch a vehicle for those without smartphones. The public-private partnership provides flexible mobility options and improved access to employment, healthcare, education, and other community activities for people with disabilities.
Preconditions:	**Pre-Conditions** User needs: Smartphone or any phone device Cell coverage or Internet connection Access to MOD app MOD app contains current data MOD app connected to all required subsystems Available mobility modes **Trigger** User opens MOD app or calls app customer service
Postconditions:	**Post Conditions** <u>Success end condition</u> MOD app provides trip information for user based on needs Selection of a trip from the provided choices <u>Failure end condition</u>: User trip request unable to be processed Gaps in the trip MOD app unable to determine availability of a wheelchair-accessible mode MOD app exits Loss of communication <u>Minimal Guarantee</u> User redirected to “home” screen to make another trip request System sends in a request to participating transportation modes to dispatch Wheelchair service
Performance Goal:	App to provide results within 4 secs

Use Case ID:	**4**
Basic Workflow:	Step 1- User launches the trip planning app Step 2- User will login via the app Step 3- Directed to trip planning home screen Step 4- User inputs trip request information: • Trip start time • Wheelchair access selection • Mode/multimodal choice preferences • Maximum walk distance • Optimization based on speed, fewest transfers, quickest route • Origin/destination • Desired arrival or departure time • Number of people making the trip Step 5- System processes user information Step 6- System creates complete trip options including: • Available wheelchair services • Multimodal options • Price of each service: including payment mechanisms for low-income users • Trip duration of each mode • Distance travelled for each mode • Estimated arrival time of each service Step 7- System provides trip details to the user Step 8- User reviews and selects one option Step 9- User begins trip Step 10- User rates MOD app trip experience Step 11- System stores summary of the trip
Alternative Workflow:	Alt Step 1- User does not own smartphone and calls customer service representative to use MOD app Alt Step 1a– User provides account information to customer service representative Alt Step 1b- App is unable to launch. Notifies user to connect to the internet or call the customer service center Alt Step 4- User cannot identify origin/destination location Alt Step 4a- System requests access to user’s current location

Use Case ID:	4
	Alt Step 5- System does not recognize user address. System sends a corrected address for user confirmation
Special Requirements:	Performance: • MOD app will update information every 2 minutes: o Update trip duration o Update transit arrival and capacity (AVL/APC) o Public transit service disruptions: skipped stations, redirected routes o Update costs of each mode User Interface Requirements: • Larger font feature available on the MOD app • MOD app provides user with the option to listen to the available trip options • MOD app allows for dictation anywhere user input is required • Visual aids (maps, wayfinding, AR) Security: • App user security notice • MOD app will not share user location if feature is enabled • Data privacy
Assumptions:	**Assumptions** User knows how to access MOD app with/without smartphone
Notes and Issues:	Issues: No wheelchair services available at the desired trip time

6.1.5 Use Case 5: Plan trip using integrated MOD application

Table 10 - Use Case 5

Use Case ID:	5
Use Case Name:	Plan trip using integrated MOD application
Actor:	**Primary Actor** User Profile - Ranjith benefits from an integrated MOD application for work-related travel **Supporting Actors** ▪ MOD Providers, Operators, and Maintainers ▪ Public Transit Agencies ▪ Employer services ▪ Transportation Service Providers ▪ Apps and Technology Providers

Use Case ID:	**5**
	Stakeholders and Interests ▪ Public Transit Agencies – has interest in knowing user requested connecting services—such as TNCs–to provide sufficient drop-off/pick-up space at a transit station. ▪ State and Local Authorities – has interest in the use of system to ensure mobility of all people ▪ Federal Government – can make investments or legislation regarding the operation of transportation programs
Description:	Ranjith is health services worker in a hospital in a medium sized metropolitan area. He often works evening shifts and finds it difficult to find a reliable mode of transportation home. When he is about to leave work, Ranjith checks all of his transportation apps separately and traffic conditions to determine his journey home. He usually takes the light rail to a station a few miles from his home, but there is no easily accessible traveler information app to show him options for completing the final leg of his journey. Ranjith downloads a multimodal application to his smartphone on his train ride that provides him travel information before he even arrives at the station. The app provides expected travel, wait times, and cost information for bikeshare, carshare, bus, taxi, and TNC ride from the rail station to home. The app can sort options according to his needs for that day – if he is running late, he can sort by shortest travel time or he can sort by environmental friendliness, cost, and more. He would prefer to bikeshare to be the most environmentally friendly, but on rainy days he chooses to take a one-way carshare ride. The multimodal application automatically redirects him to the 3rd party carsharing app to complete his booking and payment.
Preconditions:	**Pre-Conditions** User needs: Smartphone Cell coverage or Internet connection Access to MOD app: either by smartphone or kiosk MOD app contains current data MOD app connected to all required subsystems **Trigger** User opens MOD app
Postconditions:	**Post Conditions** Success end condition MOD app provides trip information for user

Use Case ID:	**5**
	Selection of a trip from the provided choices <u>Failure end condition</u>: User trip request unable to be processed Gaps in the trip MOD app unable to provide full trip information MOD app exits Loss of communication <u>Minimal Guarantee</u> User redirected to “home” screen to make another trip request
Performance Goal:	MOD app to provide results within 4 secs
Basic Workflow:	Step 1- User launches the trip planning app Step 2- User will login Step 3 – Directed to trip planning home screen Step 4- User inputs trip request information: ▪ Trip start time ▪ Mode/multimodal choice preferences ▪ Maximum walk distance ▪ Optimization based on shortest wait time, speed, fewest transfers, quickest route, environmentally friendly ▪ Wheelchair selection ▪ Origin/destination ▪ Desired arrival or departure time ▪ Number of people making the trip Step 5- System processes user information Step 6- System creates complete trip options including: ▪ Available multimodal options ▪ Price of each service ▪ Trip duration of each mode ▪ Number of stops on public transit ▪ Distance travelled for each mode ▪ Estimated arrival time of each service Step 7- System provides trip options and details to the user Step 8- User reviews and selects one option Step 9- User begins trip Step 10- User rates MOD app trip experience

Use Case ID:	**5**
	Step 11- System stores summary of the trip
Alternative Workflow:	Alt Step 1- App is unable to launch. Notifies user to connect to the internet Alt Step 4- User cannot identify origin/destination location Alt Step 4a- System requests access to user's current location Alt Step 5- System does not recognize user address. System sends a corrected address for user confirmation

Special Requirements:	Performance:
	• MOD app will update information every 2 minutes:
	  ○ Update trip duration
	  ○ Update transit arrival and capacity (AVL/APC)
	  ○ Public transit service disruptions: skipped stations, redirected routes
	  ○ Update costs of each mode
	
	User Interface Requirements:
	• Larger font feature available on the MOD app
	• MOD app provides user with the option to listen to the available trip options
	• MOD app allows for dictation anywhere user input is required
	• Visual aids (maps, wayfinding, AR)
	
	Security:
	• App user security notice
	• MOD app will not share user location if feature is enabled
	• Data privacy

Assumptions:	**Assumptions** User understanding of MOD app
Notes and Issues:	Issue: System cannot provide complete trip plan • Time constraints for modal transfer • Services not running during certain time periods • Transportation mode operating at capacity and cannot provide for another user

6.1.6 Use Case 6: On-Demand first/last mile services

Table 11 - Use Case 6

Use Case ID:	**6**
Use Case Name:	On-demand first/last mile services
Actor:	**Primary Actor** User Profile - Brian requires first/last mile trip services **Supporting Actors** ▪ MOD Providers, Operators, and Maintainers ▪ Public Transit Agencies ▪ State and Local Agencies ▪ Transportation Service Providers ▪ Apps and Technology Providers **Stakeholders and Interests** ▪ Public Transit Agencies – has interest in knowing user requested connecting services—such as TNCs–to provide sufficient drop-off/pick-up space at a transit station. ▪ State and Local Authorities – has interest in the use of system to ensure mobility of all people Federal Government – can make investments or legislation regarding the operation of transportation programs
Description:	Brian is a development officer for a non-profit organization, living in a suburb of a major metropolitan area. He owns a car but uses a carpool to get to work in the central business district to save on parking costs and time spent in congestion. His employer offers incentives such as a reserved parking spot and cash rewards for him to participate since employee carpooling benefits them as well. A few times a month, he has evening meetings and needs to meet visiting donors for dinner. On those days, carpooling is not an option and he parks at the local transit station. On-demand first/last mile services provides Brian with a reliable means of connecting from transit to his home during off peak hours. Brian uses the MOD Marketplace app on his smartphone to schedule the on-demand ride home through a designated TNC. Through a partnership between the transit agency and TNC/local taxi company, first/last mile services to and from transit stations may be subsidized to increase connections to transit. The first/last mile TNC service allows Brian to leave his car at home and helps transit agencies solve parking shortages at transit stations. In addition, because Brian was recently

Use Case ID:	6
	injured while exercising, he requires accessible modes of transportation with accessible paths between all transfer points of his journey.
Preconditions:	**Pre-Conditions** User needs: Smartphone Cell coverage or Internet connection Access to MOD app MOD app contains current data with accessibility options MOD app connected to all required subsystems **Trigger** User opens MOD app
Postconditions:	**Post Conditions** <u>Success end condition</u> MOD app provides optimized trip information fulfilling user requirements Selection of an accessible trip from the provided choices <u>Failure end condition</u>: User trip request unable to be processed. Gaps in the trip MOD app unable to provide full trip information MOD app unable to provide a trip with accessible options MOD app exits Loss of communication <u>Minimal Guarantee</u> User redirected to “home” screen to make another trip request
Performance Goal:	MOD app to provide results within 4 seconds
Basic Workflow:	Step 1- User launches the MOD app Step 2- User will login Step 3- Directed to trip planning home screen Step 4- User inputs trip request information: • Trip departure time • Origin/destination • Mode/multimodal choice preferences

Use Case ID:	6
	• Maximum walk distance • Optimization based on shortest wait time, speed, fewest transfers, quickest route • Wheelchair access selection Step 5- System processes user information Step 6- System creates optimized complete trip options including: • Route optimization based on real-time traffic and transit delays • When to shift modes • Trip duration for each mode used • Distance travelled for each mode • Estimated arrival time, mode shift, and transfer time • Estimated wait time for transfer Step 7- System provides trip options and details to the user Step 8- User reviews and selects one option Step 9- User begins trip Step 10- System will continue to update and optimize route choice based on traffic and transit delays and accessibility options Step 11- System notifies user of any updates to trip time by informing user of delays Step 12- User refers to app to make informed trip changes if necessary Step 13- User arrives at destination Step 14- User rates MOD app trip experience Step 15- System stores summary of the trip
Alternative Workflow:	Alt Step 1- App is unable to launch. Notifies user to connect to the internet Alt Step 4- User cannot identify origin/destination location Alt Step 4a- System requests access to user’s current location Alt Step 4b- System does not recognize user address. System sends a corrected address for user confirmation

Special Requirements:	Performance:
	• MOD app will update information every 2 minutes:
	    ○ Update trip duration
	    ○ Update transit arrival and capacity (AVL/APC)
	    ○ Public transit service disruptions: skipped stations, redirected routes
	    ○ Update costs of each mode
	
	User Interface Requirements:

Use Case ID:	6
	• Larger font feature available on the MOD app • MOD app provides user with the option to listen to the available trip options • MOD app allows for dictation anywhere user input is required • Visual aids (maps, wayfinding, AR) Security: • App user security notices • MOD app will not share user location if feature is enabled • Data privacy
Assumptions:	**Assumptions** None
Notes and Issues:	Issue: System cannot provide complete and optimized trip plan

6.1.7 Use Case 7: Flexible Goods Delivery Services

Table 12 - Use Case 7

Use Case ID:	7
Use Case Name:	Flexible Goods Delivery Services
Actor:	**Primary Actor** User Profile - Marcus uses the MOD app to optimize flexible goods delivery services **Supporting Actors** ▪ MOD Providers, Operators, and Maintainers ▪ Flexible Goods Delivery Service Providers, Operators, and Maintainers ▪ Public Transit Agencies ▪ State and Local Agencies ▪ Employer services ▪ Transportation Service Providers ▪ Apps and Technology Providers **Stakeholders and Interests** ▪ Public Transit Agencies – has interest in knowing user requested connecting services—such as TNCs–to provide sufficient drop-off/pick-up space at a transit station. ▪ State and Local Authorities – has interest in the use of system to ensure mobility of goods ▪ Federal Government – can make investments or legislation regarding the operation of transportation programs

Use Case ID:	**7**
Description:	Marcus is a part-time college student living in a major metropolitan area who uses his personal vehicle to make on-demand deliveries. He picks up orders from a distribution center twice a day and drives the packages to locations around the city. He is mainly concerned about travel delays from moving around the congested city and finding legal parking when he leaves his vehicle to bring the packages to the door. He has gotten several tickets and it cuts into his earnings. He has also considered supplementing his package delivery income by delivering restaurant meals or even taking passengers. By using the Flexible Goods Delivery Service App on his smartphone, Marcus can see that there are restaurant orders ready to be delivered in the same neighborhood as his noon time package delivery. He stops by the restaurant and picks up several orders, thereby increasing his revenue for driving essentially the same route. When he drops off the package and takeout orders at a high-rise office building, he notices a parking spot set aside for couriers near the taxi lane. He is able to safely and legally park his vehicle while he delivers the order to the lobby. By consolidating several deliveries into one trip, vehicle congestion is reduced.
Preconditions:	**Pre-Conditions** User needs: Smartphone Cell coverage or Internet connection Access to MOD App MOD app contains current data MOD app connected to all required subsystems Access to Flexible Goods Delivery Service App **Trigger** User opens MOD app and Flexible Goods Delivery Service App
Postconditions:	**Post Conditions** <u>Success end condition</u> MOD app and Flexible Goods Delivery Service provides trip information as well as pick-up/drop-off locations Selection of a trip from the provided choices <u>Failure end condition</u>: User trip request unable to be processed. Gaps in the trip

<table>
<tr><td>Use Case ID:</td><td>7</td></tr>
<tr><td></td><td>No optimized route based on goods delivery locations
MOD app unable to provide full trip information
MOD app exits
Loss of communication
<u>Minimal Guarantee</u>
User redirected to “home” screen to make another trip request</td></tr>
<tr><td>Performance Goal:</td><td>MOD app to provide results within 4 seconds</td></tr>
<tr><td>Basic Workflow:</td><td>Step 1- User launches the Flexible Goods Delivery Service App
Step 2- User will login
Step 3- System identifies all goods that have similar pick-up and drop-off locations
Step 5- User confirms which goods he/she will deliver
Step 6- System updates server and inventory of delivery requests
Step 7- System notifies purchaser that their goods are en-route for delivery
Step 8- System connects with MOD app
Step 9- Directed to trip planning home screen
Step 10- User inputs trip request information:
Origin/destination based on selected goods pick up and drop off locations
Parking availability and regulations at each drop-off station
Step 11- System processes user information
Step 12- System creates complete trip options including:
Route optimization
Trip duration for each delivery drop-off location
Distance travelled for each delivery drop-off
Estimated arrival time of delivery drop-off
Safe/legal parking options at each delivery drop-off location
Step 13- System provides trip options and details to the user
Step 14- User reviews and selects one option
Step 15- User begins trip
Step 16– System giver purchase an estimated arrival time of their goods</td></tr>
</table>

Use Case ID:	**7**
	Step 17- System stores summary of the trip
Alternative Workflow:	Alt Step 1- App is unable to launch. Notifies user to connect to the internet Alt Step 3- User cannot identify origin/destination location Alt Step 3a- System requests access to user's current location Alt Step 3b- System does not recognize user address. System sends a corrected address for user confirmation

Special Requirements:	Performance:
	• MOD app and Flexible Goods Delivery Service will update information every 2 minutes:
	  ○ Update trip duration and cost
	  ○ Update route if necessary
	  ○ Update traffic event and congestion information
	  ○ Update parking availability information
	
	User Interface Requirements:
	• Larger font feature available on the MOD app
	• MOD app provides user with the option to listen to the available trip options
	• MOD app allows for dictation anywhere user input is required
	• Visual aids (maps, wayfinding, AR)
	
	Security:
	• App user security notice
	• MOD app will not share user location if feature is enabled
	• Data privacy
	• Flexible Goods Delivery Service will ensure purchaser privacy of good contents and address

Assumptions:	**Assumptions** User understanding of MOD app and Flexible Goods Delivery Service App
Notes and Issues:	Issue: System cannot provide complete and optimized trip plan • no combination of goods can be completed in one optimized trip route

6.1.8 Use Case 8: Registration for an integrated multimodal application with integrated e-ticketing solution

Table 13 - Use Case 8

Use Case ID:	**8**
Use Case Name:	Registration/user account creation for integrated multimodal application with integrated e-ticketing solution
Actor:	**Primary Actor** User Profile – Camille benefits from integrated multimodal application for work-related travel and a virtual e-ticketing payment system. **Supporting Actors** ▪ MOD Providers, Operators, and Maintainers ▪ Public Transit Agencies ▪ Apps and Technology Providers ▪ Financial Institutions **Stakeholders and Interests** ▪ Public Transit Agencies – have interest in knowing users are signing up to register with the service, encouraging ridership ▪ State and Local Authorities – have interest in the use of the system to ensure mobility of all people ▪ Federal Government – can make investments or legislation regarding the operation of transportation programs ▪ Financial Institutions – have interest in ensuring seamless integration between the app and the user's financial institution and source of funds
Description:	Camille is a high-tech worker living in an urban area. Due to the high cost of owning a vehicle in the urban area Camille lives in, and costs incurred from her latest purchase of a new condominium, Camille does not own a car. Camille has multiple options for commuting to and from her new startup job, although depending on the weather, the options can change based on current conditions. With the integrated trip engine app and a pre-loaded mobile wallet on her smartphone, or available kiosks that also allow financial transactions for payment, Camille can register with the new service, add funds to her mobile wallet, and plan her trip each day prior to leaving for work or returning to her home.
Preconditions:	**Pre-Conditions** **User needs:** ▪ Cell coverage or Internet connection ▪ Access to MOD app: either by smartphone or kiosk ▪ MOD app connected to all required subsystems

<table>
<tr><td>Use Case ID:</td><td>8</td></tr>
<tr><td></td><td>▪ User has an available method of payment either by credit card, debit card, or mobile wallet for those that are banked or prepaid card from kiosk or retailer for those that are unbanked.
Trigger
▪ User downloads and installs MOD app to begin creating an account</td></tr>
<tr><td>Postconditions:</td><td>Post Conditions
<u>Success end condition</u>
Successful account creation and registration
<u>Failure end condition</u>:
MOD app crashes and/or exits
Loss of communication
App fails to create user account
<u>Minimal Guarantee</u>
User redirected to “home” screen to try to create account again</td></tr>
<tr><td>Performance Goal:</td><td>Successful creation of user account with all required information associated with user account</td></tr>
<tr><td>Basic Workflow:</td><td>Step 1– User downloads, installs and launches the trip planning app
Step 2 – User is prompted to sign into the app or create new account
Step 3 – User accesses sign up/account registration screen
Step 4 – User inputs required account information and submits form
▪ Full name
▪ Username
▪ Password (meeting password requirement specifications)
▪ Email address
▪ Phone number
▪ Payment method(s), including prepaid cards from retailer for unbanked users
▪ Location to send two factor authentication code (text/email)
Step 5 – System validates and processes user information
Step 6 – System sends two factor authentication code to user specified correspondence mechanism (text/email)
Step 7 – User enters and submits two factor authentication code to confirm account
Step 8 – System completes user registration
Step 9 – User receives welcome email
Step 10 – User logs in to the app using new account credentials
Step 11 – User access account profile to modify account information to include new mobile wallet payment information.
Step 12 – User enters new payment information, including the following:</td></tr>
</table>

Use Case ID:	8
	• Credit card information • Minimum auto-replenishment threshold Step 13 – System completes user profile modification Step 14 – User receives profile modification email
Alternative Workflow:	Alt Step 1 – App is unable to launch. Notifies user to connect to the Internet Alt Step 4 – User enters credit card information and minimum auto-replenishment threshold when they first create their account. Alt Step 5 – System cannot complete account registration, notifies user to try again Alt Step 11 – User utilizes app without modifying account information
Special Requirements:	**Performance**: • MOD app will generate a new account within 30 seconds of submitting all required information for registration, providing financial information can be verified with the financial institution **User Interface Requirements**: • Larger font feature available on the MOD app • Accessible for users with visual impairments • Registration/sign up feature to create and modify a user account **Security:** • App user security notice • MOD app will not share user location if feature is enabled • Data privacy • Two factor authentication account registration • Biometric authentication depending on hardware capability • 256bit AES encryption • secure communication required for all transactions between the app, backend and any external communication
Assumptions:	**Assumptions** ▪ User understands MOD app ▪ User has available funds in their financial institution to successfully create an account for a banked user ▪ App is able to access all backend subsystems as well as able to communicate with financial software to validate financial credentials and bank information
Notes and Issues:	▪ System cannot successfully create account ▪ Unable to communicate with backend systems to validate financial information ▪ Two-factor authentication code not received ▪ Account already exists for email address ▪ Internal failure within app to successfully create user account

6.1.9 Use Case 9: Plan trip using integrated multimodal application and pay using integrated e-ticketing solution

Table 14 - Use Case 9

Use Case ID:	**9**
Use Case Name:	Plan trip using an integrated multimodal application and pay with integrated e-ticketing solution in one transaction
Actor:	**Primary Actor** ▪ User Profile – James benefits from an integrated multimodal application for work-related travel and a virtual e-ticketing payment system **Supporting Actors** ▪ MOD Providers, Operators, and Maintainers ▪ Public Transit Agencies ▪ Transportation Service Providers ▪ Apps and Technology Providers ▪ Financial institutions **Stakeholders and Interests** ▪ Public Transit Agencies – have interest in knowing user requested connecting services—such as Lyft—to provide sufficient drop-off/pick-up space at a transit station. Have interest in knowing payment was successfully applied for service. ▪ State and Local Authorities – have interest in the use of the system to ensure mobility of all people ▪ Federal Government – can make investments or legislation regarding the operation of transportation programs ▪ Financial Institutions – have interest in ensuring seamless integration between the app and the user's financial institution and source of funds
Description:	James' commute often changes. Typically, James will check each of his transportation apps separately or view traveler information posted at many public transit stations to make an informed trip decision. James will also need to ensure he carries the appropriate funds or carrier pass with him to complete his commute. However, with the MOD app and a pre-loaded mobile wallet on his smartphone, (or a kiosks that also allows financial transactions), this process is streamlined. James can now use one application to determine how to complete his trip sorting by features such as shortest trip, fewest transfers, or cost and use his smartphone's mobile wallet to pay for his journey, no matter who the providers of the service are.
Preconditions:	**Pre-Conditions** **User needs:** ▪ Smartphone with Bluetooth (BLE) capability ▪ Bluetooth enabled and functional on smartphone ▪ Cell coverage or Internet connection ▪ Access to MOD app from smartphone ▪ MOD app contains current data, including real-time conditions

Use Case ID:	9
	▪ MOD app connected to all required subsystems ▪ Pre-loaded virtual, mobile wallet e-ticketing account with sufficient funds ▪ Automatic replenishment set up for mobile wallet account ▪ Field instrumentation, including contactless payment readers and kiosks for unbanked users for all legs of the user's journey to allow for virtual payment using the e-ticketing solution **Trigger** ▪ User opens MOD app to begin planning a journey
Postconditions:	**Post Conditions** <ins>Success end condition</ins> ▪ MOD app provides trip information for user ▪ Selection of a trip from the provided choices ▪ Successful payment for entire journey <ins>Failure end condition</ins>: ▪ User trip request unable to be processed ▪ MOD app unable to provide full trip cost ▪ MOD app crashes and/or exits ▪ Loss of communication ▪ Gaps in the trip – One or more legs of the journey unable to be financed due to one or more of the following conditions: o BLE contactless reader not functioning o Bluetooth not functioning on smartphone o Insufficient funds o Insufficient funds and unable to automatically replenish mobile wallet o Kiosk not functioning for unbanked users <ins>Minimal Guarantee</ins> ▪ User redirected to "home" screen to make another trip request ▪ User receives bill in the mail for any payment not able to be debited, or mobile wallet automatically replenished
Performance Goal:	Payment for entire journey successfully applied to user's mobile wallet account, including any additional costs incurred during the user's journey due to unexpected deviations or other conditions.
Basic Workflow:	Step 1 – User launches the trip planning app Step 2 – User logs in (or is automatically logged in) to the app Step 3 – User accesses trip planning home screen Step 4 – User inputs trip request information: ▪ Trip start time ▪ Mode/multimodal choice preferences ▪ Maximum walk distance ▪ Optimization based on shortest wait time, speed, fewest transfers, quickest route, carbon footprint, trip cost ▪ Wheelchair access selection ▪ Origin/destination ▪ Number of people making the trip

Use Case ID:	**9**
	Step 5 – System processes user information Step 6 – System creates complete trip options including: ▪ Available multimodal options ▪ Trip duration of each mode ▪ Number of stops on public transit ▪ Distance travelled for each mode ▪ Estimated arrival time of each service ▪ Price for entire trip along with individual price of each segment of the trip clearly indicated Step 7 – System provides trip options and details to the user Step 8 – User reviews and selects best available option, based on their needs and constraints Step 9 – User pre-pays selected trip option from the mobile wallet on their smartphone Step 10 – System automatically replenishes mobile wallet funds if user's account reaches a minimum threshold Step 11 – User begins trip Step 12 – User taps/scans virtual pass at first entry point (bus) and completes first leg of journey Step 13 – User alights from first leg of journey and loses cell coverage in second leg entry point (subway). Since the trip has been prepaid using the mobile application prior to beginning the trip, and the trip information is stored in the phone, the user's trip is not affected by any loss of coverage Step 14 – User taps/scans virtual pass at second entry point and completes next leg of journey Step 15 – User alights from second leg and arrives at taxi depot for next leg of journey and hails a taxicab Step 16 – Due to traffic on original taxi route, taxi is forced to divert to a toll road where extra/unexpected costs are incurred Step 17 – Taxi arrives at user's destination and user taps/scans virtual pass using the taxi's contactless reader and completes next leg of journey Step 18 – System automatically replenishes mobile wallet funds if user's account reaches a minimum threshold. Step 19 – If auto-replenishment does not successfully occur, the user is notified by the MOD app that an error occurred with their preferred method of payment and is prompted to verify their payment information or add new payment information. Step 20 – User disembarks from third leg of journey and taps/scans virtual pass at entry to next mode of travel to pick up a bike at a bikeshare dock Step 21 – Repeat board/scan/alight steps until end of journey is reached, via all relevant modes of travel Step 22 – User disembarks from final leg of journey and rates MOD app trip experience Step 23 – System stores summary of the trip

Use Case ID:	**9**
Alternative Workflow:	Alt Step 1 – App is unable to launch. Notifies user to connect to the internet Alt Step 4 – User cannot identify origin/destination location Alt Step 4a – System requests access to user's current location Alt Step 5 – System does not recognize user address. System sends a corrected address for user confirmation Alt step 12, 14 – Contactless reader or Bluetooth malfunction, unable to communicate with smartphone or vice versa Alt step 13 – No loss of cell coverage, trip continues as planned, unaffected Alt step 16 – No need for taxi to divert to toll road, trip continues as planned, unaffected with no extra cost Alt step 22 – No need for automatic replenishment of funds Alt step 23 – No issue with auto-replenishment of funds in user's account
Special Requirements:	**Performance:** ▪ MOD app will update information every 2 minutes: o Update trip duration o Update transit arrival and capacity (AVL/APC) o Public transit service disruptions: skipped stations, redirected routes o Traffic disruptions: redirected route due to unexpected traffic o Update costs of each mode in near real-time ▪ Fast/secure pairing with contactless readers in the field ▪ Offline mode for MOD app in case of loss of or no connectivity in the field **User Interface Requirements:** ▪ Larger font feature available on the MOD app ▪ MOD app provides user with the option to listen to the available trip options ▪ MOD app allows for dictation anywhere user input is required ▪ Visual aids (maps, wayfinding, AR) ▪ Registration/sign up feature to create and modify a user account ▪ Ability to introduce, seamlessly, new modes/methods of transport without re-design **Security:** ▪ App user security notice ▪ MOD app will not share user location if feature is enabled ▪ Data privacy ▪ Two factor authentication account registration ▪ Device access security technology depending on hardware capability ▪ 256bit SHA encryption ▪ TLS/secure communication required for all transactions between the app, backend and any external communication ▪ Protection against double-tapping/redundant payment
Assumptions:	**Assumptions** ▪ User understands MOD app

Use Case ID:	9
	▪ User has available funds in their financial institution to pay for their journey ▪ If user is unbanked, user has available funds to pay for their journey via available kiosks
Notes and Issues:	Issue: System cannot provide complete trip plan • Time constraints for modal transfer • Services not running during certain time periods • Transportation mode operating at capacity and cannot provide for another user • Bluetooth not currently working on user's smartphone to allow for successful payment of one or more journey legs • Bluetooth or reader not working at one or more of the entry points for any or all legs of the user's journey • User unbanked and kiosks not operational • User unable to reload mobile wallet to replenish their virtual account

6.2 User Journey Map

This section illustrates a common methodology in mobile app planning and design, called the User Journey Map (UJM). It is a visual representation of a collection of touchpoints experienced by the user from the beginning to the end of the provided MOD service or function based on a specific scenario. The UJM visually represents the process of looking at the end-to-end series of events that make up the entire story of the provided MOD service from the trip engine and mobile app points of view. The UJM presented in example of a use case applied to MOD users.

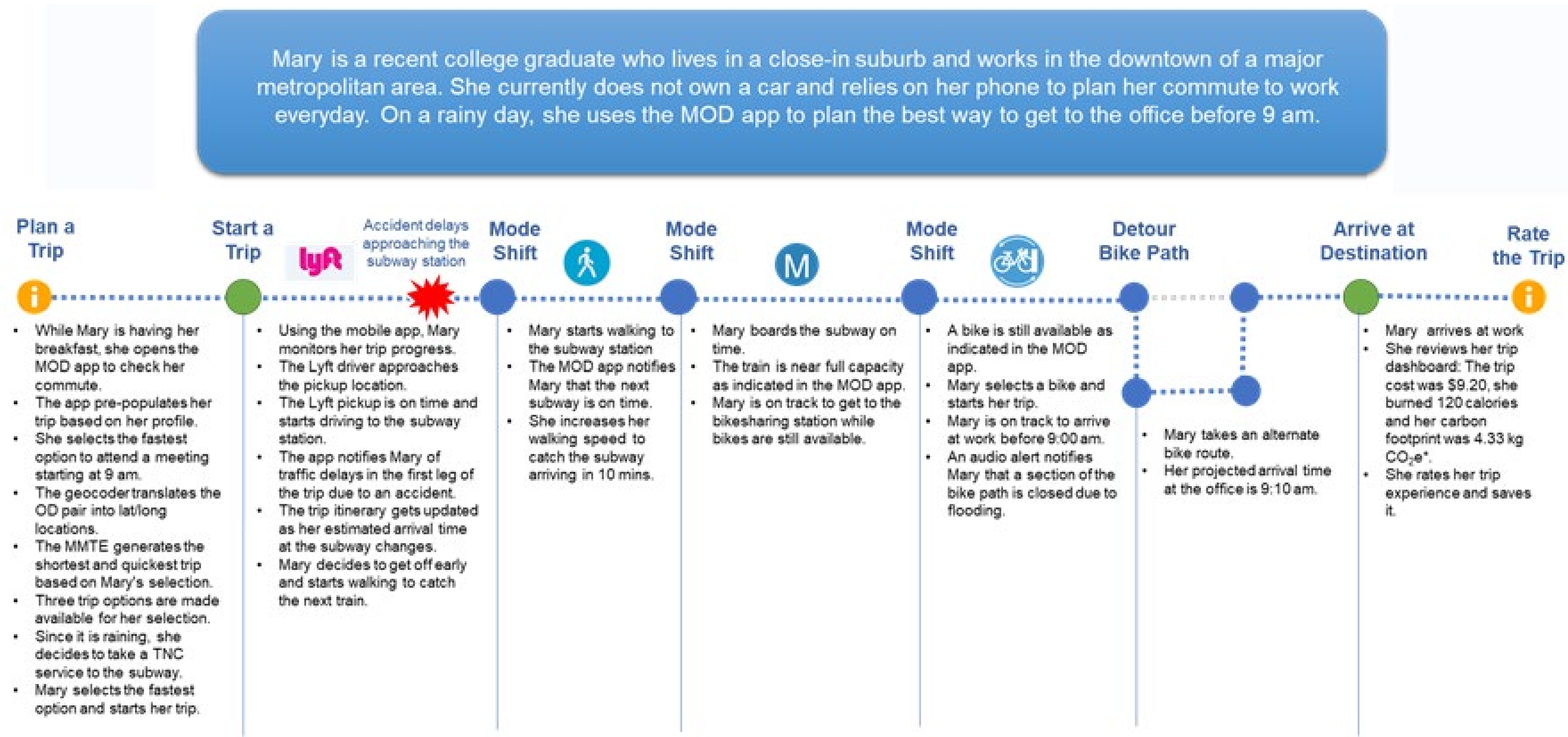


Figure 11 - User Journey Map Example 1

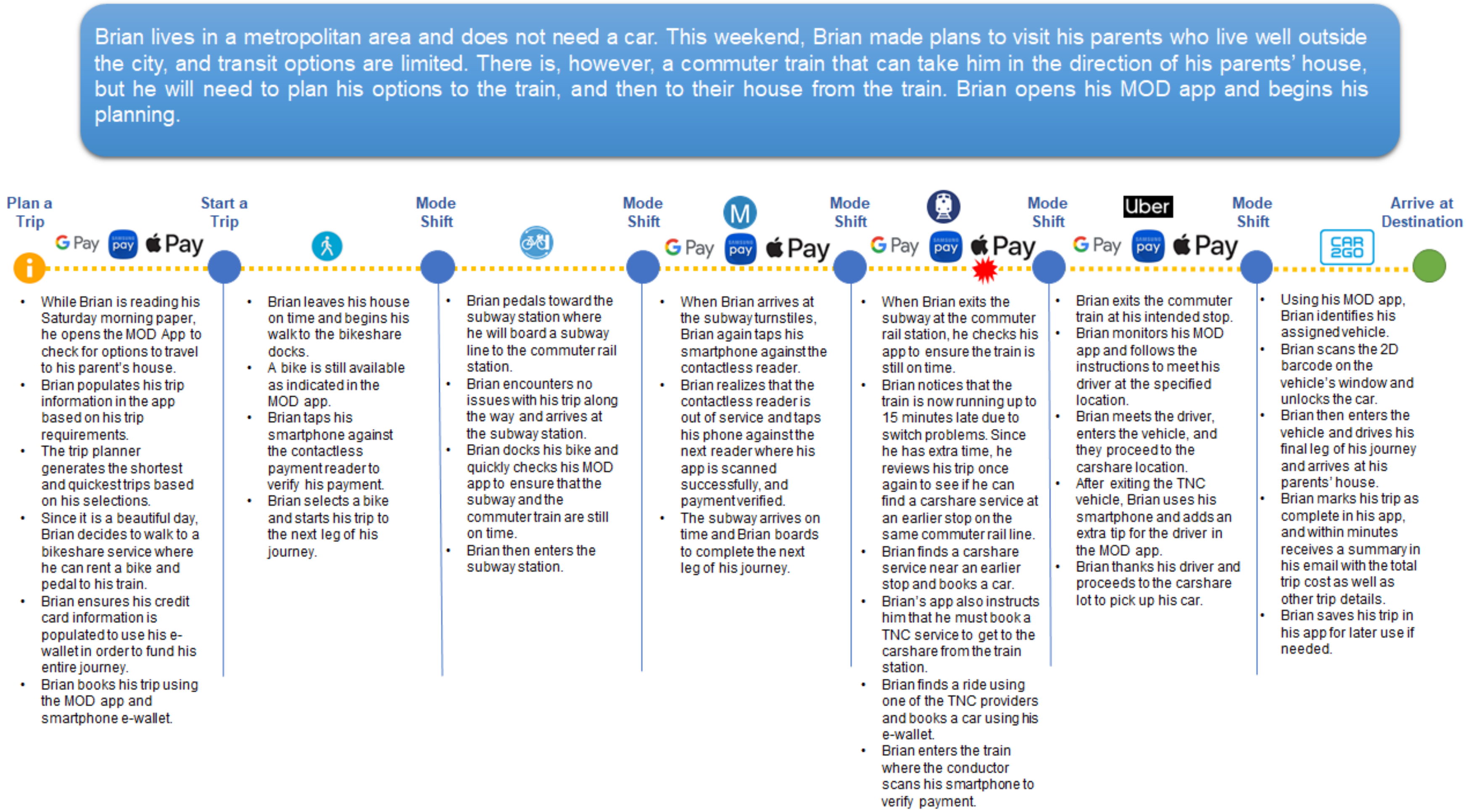


Figure 12 - User Journey Map Example 2

7 Summary of Impacts

This section explores the institutional and policy changes that will be needed to enable a flourishing mobility marketplace. MOD is a concept that will fundamentally change how public agencies and private on-demand mobility service providers interact in the transportation arena. As agencies begin to implement MOD, they might find that public policy goals do not always translate into the private sector. Similarly, private companies might find themselves having to collaborate with erstwhile competitors or alter their business models to support agency requirements. For example, there are many challenges that need to be addressed before the benefits of an IEPS can truly be realized such as: ownership of APIs and the absence of standardization, data rights and data sharing, customer service in an integrated mobility system, data security, providing equitable service to all travelers, and cybersecurity, among others. The USDOT, in cooperation with the payment integration industry, is actively working to address these issues.

This section examines some of the challenges stakeholders can expect to encounter when establishing a MOD Marketplace, as well as the support environment that is necessary to allow these platforms to exist and thrive.

7.1 Support Environment

7.1.1 Institutional Considerations

Public agencies and transportation managers have traditionally considered themselves to be in the business of physical infrastructure. With the advent of MOD, agencies need to position themselves as “mobility managers,” focusing on the integration of physical and digital infrastructure in addition to their more traditional role as mobility providers. This will include hiring people with experience in data governance, but this will also entail a cultural shift away from planning for years-long infrastructure programs to deploying services as pilot projects that start small and incrementally add services and value to the end user. Relatedly, changes may be needed in procurement policy to allow for more flexibility to adapt to changing needs and new technologies. On the private sector side, a shift towards working collaboratively with public agencies and other mobility providers will facilitate the development of the Marketplace and allow for the inclusion of multiple options/modes.

This section will look at institutional changes that will be required to support the MOD Marketplace.

7.1.1.1 Business Models

A variety of MOD business models have developed to meet the dynamic and fast-changing needs of consumers and service providers, and to facilitate partnerships between these stakeholders. These business models range from long-established and widely adopted models like business to government (B2G) to newer models like peer-to-peer marketplaces for mobility services and goods delivery (e.g., the “gig labor” model commonly employed by transportation network companies and courier network services). Understanding these business models can help inform partners and public policy that can further the MOD vision (Shaheen, et al., 2017).

7.1.1.1.1 Mobility Marketplace Business Models

Services that aggregate mobility options into a single digital platform that provides multimodal trip planning and payment integration are fundamental to the MOD Marketplace. To date, these platforms have largely been developed by the private sector following a business to consumer (B2C) model or B2G model with consumers as the end user. For example, Uber and Lyft have developed proprietary multimodal trip planning and payment platforms which they use to promote their respective suites of on-demand mobility services (e.g., ridesourcing, dockless vehicles, and courier network services). In some cases, these proprietary platforms also include transit information and the ability to purchase tickets. However, in some cases public sector actors have developed or are developing such platforms. For example, the City of Columbus, Ohio has contracted with software development companies to develop Pivot, an open-source multimodal trip planning platform and payment platform that integrates many of the region's public and private mobility options. Notably, Pivot does not privilege any private mobility service provider over another.

The costs and limitations associated with these two mobility aggregation approaches – which some have termed the "walled garden" and "open mobility" models, respectively – present important considerations for jurisdictions considering the role of the mobility marketplace in their regions (Zipper, 2019). For example, while the open mobility model can provide a neutral marketplace for goods and services that maximizes customer choice and offers an opportunity to integrate seamlessly with public services, such systems may be costly for government sponsors to develop and have limited value to end users without the participation of companies that have opted to pursue walled garden models.

7.1.1.1.2 Payment Models

Mobility aggregation platforms also vary in their payment models. Most platforms in the U.S., such as those discussed above, offer an "à la carte" model where consumers pay for each trip segment individually. Alternatively, some European platforms, inspired by the MaaS concept, use a subscription model on their platforms where customers pay one price per day/week/month and then have access to a range of mobility options. For example, in addition to à la carte payment options, Helsinki's Whim app offers two monthly subscription options offering consumers different levels of transit, taxi, and carshare access. (e.g., the "Whim Unlimited" package offers unlimited access to each of those modes for approximately $565/month) (Zipper, 2018).

Public agencies may be able to leverage these subscription-based payment models to increase mobility and access for travelers and further core agency goals such as equity and single-occupancy vehicle trip reduction. For example, subscription packages could provide: (1) financial assistance geared toward low income commuters, (2) a commuter package provided by large employers to incentivize employees to take transit or microtransit, or (3) a monthly transit pass with additional mobility services options for first- and last-mile connections to trunk line transit services. In such instances, the mobility options included in the subscription package would drive the pricing package and how the transaction is processed through the various service providers.

Agencies could also explore the establishment of cost ceilings/fare capping in their applications of these payment models. Such models would remove the cost barrier of a large upfront subscription cost while ensuring that travelers paying for services a la carte did not exceed the equivalent cost of a subscription once they reached that spending threshold. Fare capping models have been successfully adopted by public transit providers such as Portland, Oregon's TriMet to establish a cost ceiling for users on daily, weekly, and monthly bus and rail passes (Derby, 2019). Similar caps have not been applied to mobility aggregation services or mobility service bundles to date. However, service providers may wish to consider this option to provide an equity-based incentive for frequent use of these mobility aggregation services and mobility service bundles.

7.1.1.2 Partnerships

On-demand mobility service providers often have very different business models and expectations than their public sector counterparts. While the former relies on venture capital to attract new customers and establish market share, public agencies must operate within the bounds of funding allocations and revenues and seek to serve the public interest, including compliance with statutes and directives that apply to programs and activities receiving Federal financial assistance that may not apply to privately funded operations. Furthermore, some evidence suggests that these new services may compete for ridership with public transportation providers (Grossman & Lewis, 2019). Policies and best practices for establishing public-private partnerships in the Mobility Marketplace are still emerging. Some of the key issues governing these partnerships are addressed in this section.

Transit Cooperative Research Program (TCRP) Report 188 ("Shared Mobility and the Transformation of Public Transit," Feignon and Murphy, 2016), TCRP Report 195 ("Broadening Understanding of the Interplay Among Public Transit, Shared Mobility, and Personal Automobiles," Feignon and Murphy, 2018), and TCRP Report 196 ("Private Transit: Existing Services and Emerging Directions," Feignon, Murphy, and McAdam, 2018) provide additional context on the relationship between public transit and private mobility.

7.1.1.2.1 Contracting and Procurement Practices

Public agencies frequently procure services from private-sector vendors. Procurement contracts form legally binding relationships between the agency and service provider that include the various commitments and work statements needed to form a successful partnership. When successfully executed, these contracts can provide myriad benefits for agencies such as cost savings, enhanced safety, and improved efficiency (Grossman & Lewis, 2019). These contracts are especially important in the formation of partnerships between public agencies and on-demand mobility service providers, allowing for multisectoral partnerships and performance objective setting as well as assignment of liabilities, risks, and terms of payment (Grossman & Lewis, 2019).

Private service providers and public agencies may approach the contracting and procurement process with very different perspective when seeking to establish service partnerships. Clearly defining the roles and responsibilities of each party in writing can provide understanding of each partners goals and aims (Grossman & Lewis, 2019). When successful, the data sharing requirements, performance metric setting, and assignment of risks established in these agreements can serve to guide each partner towards a successful outcome throughout the duration of the contract period. Importantly, contracts should include provisions for modifications as the situation requires.

7.1.1.2.2 Nondisclosure Agreements

Nondisclosure agreements (NDAs) are often designed to protect trade secrets and other proprietary business information. Yet public agencies who enter into NDAs (such as with mobility service providers) must balance these companies' needs to safeguard their data and intellectual property with the need for transparency with the public. Moreover, compliance with state and federal freedom of information laws that compel public disclosure of information on request may further complicate matters (Grossman & Lewis, 2019).

Accordingly, drafting and executing NDAs that balance the needs of public and private partners can be challenging for both parties and may complicate the procurement process. Public agencies can consult with their peers who have successfully navigated the NDA process for guidance and/or ask if they would be willing to share an NDA template. Agencies can also look to programs such as the Shared Use Mobility Center's Mobility on Demand On-Ramp (https://sharedusemobilitycenter.org/mobility-on-demand-on-ramp-program-description/). Finally, agencies may also consider allotting extra time in the contracting and procurement process to account for potential delays in negotiating NDAs.

7.1.1.3 Workforce Issues

The rise of MOD and the Mobility Marketplace will require public agencies to adapt and evolve their workforce policies and practices. Table 1 (adapted from Shaheen et al., 2019) reviews some of the key issues in this area as well as potential actions to address these issues.

Table 15 - MOD Public Sector Workforce Issues.

Issues	Potential Actions
Collective bargaining agreements may make partnering with shared mobility services challenging (e.g., paratransit, late-night service).	Public transit agencies can involve labor unions in partnership discussions, along with other potential project champions, to develop plans for expanding transportation options that include multiple stakeholders.
Workforce roles may change as automated fleets develop, these changes may necessitate different rolls such as data scientists, human assistants for automated paratransit, or new, high-tech skilled staff for inspecting and maintaining automated transit buses at all levels of automation.	Public transit agencies and local regulatory authorities can recognize emerging workforce needs, identify new future career paths, and conduct succession planning in this new environment. Transit worker unions can coordinate with public transportation worker organizations on retraining staff members to gain skills to manage emerging technologies. Public transit agencies can work with FTA, industry associations, and private sector consultants to identify core training needs; academic institutions may be able to assist in implementing training.

Issues	Potential Actions
Automated fleet vehicles may result in the need for a smaller workforce or necessitate workforce development and retraining.	Transit worker unions can coordinate with transit agencies on retraining staff to gain automation-related skills and providing advance notice on the adoption of automated fleet vehicles.

Adapted from Shaheen, et al. 2019.

7.1.2 Policy Considerations

This section details three key policy issue areas in the Mobility Marketplace including an explanation of associated challenges and enabling policies and programs that will help ensure that the MOD Marketplace is usable by all groups and can achieve its goals of providing safe, reliable, and convenient mobility and goods delivery for all. These three issues areas are: 1) the applicability of existing laws and regulations; 2) equity challenges; and 3) policies and practices related to data sharing and standards, digital privacy, and cybersecurity.

7.1.2.1 Applicability of Existing Laws and Regulations

Legislation requiring minimum service standards for the digital platforms and on-demand mobility services that comprise the Mobility Marketplace can help avoid adverse impacts on members of protected classes, including the following (Shaheen et al., 2019):

- Title VI of the Civil Rights Act of 1964 – prohibits discrimination based upon race, color, and national origin in programs and activities that receive Federal financial assistance. The law also requires that information and services be provided in languages other than English when significant numbers of potential recipients have limited English language proficiency.
    - Title 23 CFR Part 200 –provides guidelines for: (a) Implementing the Federal Highway Administration (FHWA) Title VI compliance program under Title VI of the Civil Rights Act of 1964 and related civil rights laws and regulations, and (b) Conducting Title VI program compliance reviews relative to the Federal-aid highway program
    - Title 49 CFR Part 21 – effectuates the provisions of Title VI of the Civil Rights Act of 1964 under any program or activity receiving Federal financial assistance from the Department of Transportation.
- Civil Rights Restoration Act of 1987 –amends title IX (Prohibition of Sex Discrimination) of the Education Amendments of 1972 to define the phrase "program or activity" and the term "program" to mean all of the operations of entities receiving Federal financial assistance, including but not limited to: (1) a department, agency, special purpose district, or other instrumentality of a State or local government; and (2) a State or local government agency which distributes such assistance and the agency or department to which such assistance is extended; (3) a corporation, partnership, or other private organization.
- Executive Order 12898 – directs Federal agencies to identify and address the disproportionately high and adverse human health or environmental effects of their actions on minority and low-income populations, to the greatest extent practicable and permitted by law. The order also directs each agency to develop a strategy for implementing environmental justice. The order is also intended to promote nondiscrimination in federal

programs that affect human health and the environment, as well as provide minority and low-income communities access to public information and public participation.

- Executive Order 13166 – requires Federal agencies to examine the services they provide, identify any need for services to those with limited English proficiency (LEP), and develop and implement a system to provide those services so LEP persons can have meaningful access to them. It is expected that agency plans will provide for such meaningful access consistent with, and without unduly burdening, the fundamental mission of the agency. The Executive Order also requires that the Federal agencies work to ensure that recipients of Federal financial assistance provide meaningful access to their LEP applicants and beneficiaries.
- Section 504 of the Rehabilitation Act of 1973 – states that no otherwise qualified individual with a disability in the United States shall, solely by reason of his or her disability, be excluded from the participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance.
- Americans with Disabilities Act (ADA) of 1990 – This law prohibits discrimination against people with disabilities in several areas, including but not limited to transportation. The USDOT enforces regulations governing transit, which includes ensuring that recipients of Federal aid and state and local entities responsible for roadways and pedestrian facilities do not discriminate on the basis of disability in highway transportation programs or activities. The USDOT also issues guidance to transit agencies (https://www.transit.dot.gov/regulations-and-guidance/civil-rights-ada/americans-disabilities-act) on how to comply with the ADA to ensure that public transit vehicles and facilities are accessible.

Other laws may provide further protections and rights to employees of on-demand mobility service providers, such as the Title VII of the Civil Rights Act of 1964 and the Age Discrimination Act of 1975 (Shaheen et al., 2019). State nondiscrimination laws such as those that extend employment protections to cover sexual-orientation or gender expression may provide further protections to these workers. Also relevant to employees of on-demand mobility service providers are state laws, ordinances, or regulations defining or limiting independent contractor or “gig” work such as California’s Assembly Bill 5 (AB5).

Overall, however, questions remain about how existing laws and regulations that exist to promote equitable access and non-discrimination in transportation apply to private service providers. Public agencies that receive Federal financial assistance may be required to comply with relevant Federal laws and directives, but this is an evolving area and public agencies and private mobility providers should work to keep current with developments.

7.1.2.2 Equity

A well-functioning MOD Marketplace that effectively matches supply and demand for personal mobility and goods delivery has the potential to enhance opportunity and access for underserved populations. However, factors including access to banking services and smartphones; physical and digital accessibility; and the affordability and spatial distribution of on-demand mobility services may adversely affect the distribution of benefits and burdens in the Mobility Marketplace.

Supporting an inclusive Mobility Marketplace can help ensure that all users benefit from mobility improvements and that these systems serve the public good. Further, public and private mobility services can potentially broaden their customer bases by increasing access to these services through an inclusively designed and operated Mobility Marketplace. Moreover, failure to adequately address such issues as they relate to the laws and regulations discussed in the previous section may also create legal risk for entities receiving Federal financial assistance. Stakeholders may be able to overcome such equity barriers and legal risks through the application of policies and programs targeted at meaningfully addressing these issues. This section will review the key equity issues in the MOD Marketplace and highlight strategies successfully employed by public and private stakeholders to help ensure an equitable distribution of benefits and burdens.

7.1.2.2.1 Unbanked or Underbanked Users

A 2017 survey by the Federal Deposit Insurance Corporation (FDIC) estimates that 6.5 percent of U.S. households (8.4 million) were unbanked that year, meaning those households did not have an account with an insured financial institution. The same survey found that a further 18.7 percent of U.S. households (24.2 million) were underbanked, meaning households had an account with an insured financial institution but had obtained "(nonbank) alternative financial services" in the past year (Federal Deposit Insurance Corporation, 2018). Notably, low-income, minority, and less educated individuals tend to have higher rates of "unbanking."

The MOD Marketplace may be challenged to serve these unbanked and underbanked users given many on-demand mobility service providers require a credit or debit card for registration or payment (Transportation Sustainability Research Center, 2016). Further, some services require a security hold on a credit or debit card account, which may be burdensome for some users. For example, users of the Citi Bike bikesharing system in New York City incur a $101 security deposit that remains on their accounts for an amount of time determined by the service provider. These holds also have the potential to result in account overdraft fees that may negatively impact users' financial standing.

Some agencies and service providers have taken actions to minimize these barriers for unbanked or underbanked users. For example, Arlington County, Virginia and Portland, Oregon offer in-person cash payment options for bikeshare membership at the agency's brick and mortar locations and events, respectively. Similarly, Indego bikesharing, in Philadelphia, Pennsylvania, partners with PayNearMe, an electronic payment platform that allows users to purchase monthly passes using cash at nearby retail chains (Transportation Sustainability Research Center, 2016).

7.1.2.2.2 Smartphone Ownership

Smartphone adoption rates have grown rapidly over the past decade. Yet a nationwide survey conducted by the Pew Research Center in 2019 found that 19 percent of Americans do not own smartphones. Smartphone ownership correlates with other equity dimensions such as age, race, ethnicity, and income (Pew Research Center, 2019). Many app-based transportation services in the MOD Ecosystem require smartphones as a prerequisite to participation, raising important equity concerns for users that may be excluded from the benefits of these services.

Agencies can identify such barriers to participation in the MOD Ecosystem by conducting focus groups or interviews with users lacking smartphones. For example, the City of Minneapolis, as a case study, engaged an unbanked man regarding his ability to use a variety of travel modes available in that city following his attendance at a local planning workshop. The man agreed to let City staff join him as he attempted to use these services without a debit card, credit card, or smartphone. This initiative helped the City identify which of the services worked well for him (e.g., cash reloadable transit fare cards) and those that did not (e.g., e-scooters that required a smartphone to unlock and pay for the service) (McMillan et al., 2019).

Digital kiosks can extend on-demand travel and trip planning options for those without smartphones or access to traditional financial services. For example, the USDOT-funded Smart Columbus program began installation of interactive digital kiosks at six Smart Mobility Hubs throughout the city in fall 2019. Several of these hubs are located in areas of concentrated low-income and/or minority residents where prevalence of unbanked, underbanked, and “un-phoned” users may be higher. The kiosks will allow users to access Wi-Fi, emergency calling, social services, maps, and provide access to the region’s comprehensive trip planning and payment application, which is scheduled for launch in the first quarter of 2020 (City of Columbus, 2020).

Other regions have provided access to shared mobility services in the MOD Marketplace by providing a dial-in trip booking option. For example, the Ride to Wellness program in Flint, Michigan uses “cutting edge technology and a ride-hailing like model” to provide on-demand door-to-door service for non-emergency medical transportation and other wellness destinations for qualified users such as veterans and public benefit recipients at a low cost. Notably, the program includes a dedicated line for users without smartphones to call and book trips (Mass Transportation Authority, n.d.).

7.1.2.2.3 Access for Users with Disabilities

According to 2015 American Community Survey estimates, 12.6 percent of Americans have serious physical, cognitive, visual, or auditory disabilities resulting in limitation of activities and restriction on full participation at school, at work, at home, or in the community (Bialik, 2017). However, many of the digital platforms and mobility services that form today’s open market for mobility are not designed to accommodate users with disabilities. Such digital and physical accessibility barriers can prevent the achievement of a “complete trip,” which the USDOT’s ATTRI program defines as “the ability of individuals to go from home to a destination without breaks or in terms of a travel chain with various links such as trip planning, travel to station, station/stop use, boarding vehicles, using vehicles, leaving vehicles, using the stop or transferring, and travel to destination after leaving the station or stop” (USDOT, Accessible Transportation Technologies Research Initiative, n.d.).

As government-sponsored Mobility Marketplace will be required to have accessible front ends as well as business rules that would likely require accessible service provisions, some agencies are taking steps to begin making their services accessible to all users. For example, Valley Metro, the public transportation provider for the Phoenix metropolitan area and a USDOT MOD Sandbox funding recipient, consulted with digital accessibility experts and stakeholder groups to developed a mobile app (Pass2Go) that includes a multimodal trip planning and ticketing interface designed to be accessible to a variety of users with disabilities (Shaheen, et al., 2019).

Other cities and regions have taken steps to address vehicle form factors to improve the accessibility of on-demand travel options. For example, Portland Bureau of Transportation has launched the Adaptive BIKETOWN pilot that makes handcycles, foot-powered trikes, tandems, and youth-sized cycles available for reservation as part of the city’s bikesharing program

(Portland Bureau of Transportation, 2020). Similarly, Portland has prioritized accessibility as part of its e-scooter permitting program, resulting in the selection of a number of vendors that provide seated e-scooter fleets (Herron, 2019). Municipal legal actions, such as a lawsuit filed by New York City against Uber, Lyft, and Via, have also resulted in agreements to improve response times for wheelchair accessible vehicles (WAVs) provided by those companies (Rubenstein, 2018).

7.1.2.2.4 Affordability and Spatial Access

On-demand mobility services may be too expensive for certain populations. To offset such price barriers, many private service providers offer discount programs and cash payment options for qualified users. For example, Uber offers recipients of certain public benefits programs access to its Boost Plan, which provides 60 minutes of daily JUMP bike ride time for a $5 year membership with cash payment options available. Publicly-sponsored transportation services frequently offer similar discounts and/or financial assistance programs for qualified low-income residents, such as the Community Partners Program that allows local nonprofits, government agencies, and social services organizations in Washington, DC and Arlington, VA to offer steeply discounted Capital Bikeshare annual membership to their clients. Residents of Hennepin County, MN who participate in qualifying Federal human services programs such as Supplemental Nutritional Assistance Program (SNAP) and/or local programs such as the Transit Assistance Program (TAP) may qualify for the region’s public bikeshare discount program and discount programs offered by private mobility service providers (e.g., Lime Access and the Lyft Community Pass Program) (McMillan et al., 2019).

While public and private discount programs like those discussed above may be well intentioned, they are frequently underutilized. To improve enrollment in these transportation service discount programs among qualified residents, the City of Minneapolis has begun efforts to build awareness through education and engagement with underserved communities and through partnerships with transit providers and other stakeholders’ groups (McMillan et al., 2019).

In addition to issues with prices for certain populations, certain mobility services may be geographically unevenly distributed. This may result in these services being too far away to be a practical transportation option. To address, some cities, such as Minneapolis, have spatial distribution requirements. In Minneapolis, the city requires a certain percentage of e-scooters approved through the city’s permitting process are distributed in areas of concentrated racial minorities and at transit stops. Similarly, LA Metro has worked to ensure dockless bikeshare availability in the city of Watts, a historically underserved community (McMillan et al., 2019).

Addressing the Urban and Rural Divide: Residents of rural communities and small towns often lack access to the on-demand mobility options available to their urban counterparts. For example, a Pew Research Center found that rural residents use ridesourcing services at roughly half the rate of metropolitan area residents. On the demand side, limited cell service and broadband access in rural areas may suppress consumer demand for these services, by impeding access. On the supply side, lower profit margins for ridesourcing drivers in these areas may suppress supply, making these services less convenient for users (Shrikant, 2019). Further, public funding and technical capacity constraints in small urban or rural areas may prevent agencies in these areas from deploying on-demand mobility pilots and programs increasingly being adopted by their metropolitan counterparts.

Despite these challenges, opportunities exist to further adoption of on-demand mobility in rural areas. These including options such as diversification of state DOT funding between traditional services and on-demand options and pursuing FTA formula grants. Godavarthy (2019) suggests a five-step process for State DOTs and other agencies to establish on-demand mobility services in these areas:

1. Identify mobility gaps and determine service needs
2. Determine the service category that best suits the rural community's needs
3. Pursue public private partnerships
4. Evaluate challenges, accessibility, and impacts
5. Secure funding and implement the pilot or program

Community engagement programs centered around providing transportation access, such as volunteer-led shuttle services, represent additional sources of opportunity. For example, the nonprofit Latino Environmental Advancement and Policy Institute (LEAP) in Huron, California – one of the state's poorest communities – developed the "Green Raiteros" program to improve resident mobility and access to opportunity. The program uses on-demand electric vehicles and is staffed by four retired farmers who serve as volunteer ridesourcing drivers helping reduce program costs (Godavarthy, 2019).

7.1.2.2.5 Design and Management of Physical Infrastructure

The MOD Marketplace depends on the existence of safe, comfortable, efficient, and well-maintained infrastructure network. To ensure that transportation infrastructure is well maintained and can meet the needs of the MOD Marketplace public agencies, policy makers, and infrastructure owner operators can adopt some of the following guidelines:

- Adopt policy frameworks such as Complete Streets and Vision Zero to enable safe, comfortable, and convenient access for all road users.
- Promote use of multimodal and accessible street design principles and practices promulgated in resources such as National Association of City Transportation Officials' (NACTO) Urban Streets Design Guide (National Association of City Transportation Officials, 2013)
- Conduct audits of the travel environment and consult with accessibility and vulnerable road user advocate groups to identify and remedy travel impediments for these groups (e.g., excessive pavement or sidewalk roughness)

- Incorporate curbside management best practices such as those promoted in the Institute of Transportation Engineers' (ITE) Curbside Management Practitioners Guidance to help minimize the negative impacts associated with growing demand for curb space among goods delivery and mobility service providers, including potential fragmentation of multimodal and accessible travel networks (Mitman et al., 2018)
- Use multimodal network connectivity analysis and measurement methods such as those promoted in Federal Highway Administration's Guidebook for Measuring Multimodal Network Connectivity to determine the quality of the travel environment for active travel and to identify potential improvements (Twaddell et al., 2018)

7.1.2.3 Data Policies and Practices

Although the development of MOD will likely rely heavily on private companies, public agencies will have an opportunity to coordinate stakeholders and set guidance to achieve policy goals. Early steps include engagement between public agencies and with private companies to coordinate data sharing, digital privacy, specifications and standards, and cybersecurity protocols. MOD will offer a rich set of user data collected through the mobility marketplace platforms which will allow transportation providers to make their services more efficient. For example, transit agencies may identify underutilized routes or gaps in service based on better user travel choice data collected by the system. However, this necessitates strong data sharing agreements that address both public and private sector needs, such as protecting competitive advantages or meeting public disclosure law requirements. This section will look at potential models or principals for data policies and practices in the Mobility Marketplace.

7.1.2.3.1 Data Privacy

With the proliferation of on-demand mobility service providers, jurisdictions may be challenged to protect travelers' sensitive personal information while effectively managing these companies' operations in the public right of way. In some cases, conflicts between user privacy and the public good have resulted in legal conflicts between private service providers and public agencies. For example, Uber filed suit against Los Angeles DOT in October 2019 regarding the agency's mandate that all dockless scooter and bicycle companies provide real-time trip data to the City. LADOT contends that it "requires reasonable information about the tens of thousands of shared vehicles operated by transportation technology companies that use [the city's] streets for profit" in order to ensure safety and access for all (Bliss, 2019). However, Uber has countered that LADOT's real-time trip info requirement constitutes surveillance. Further, some digital rights advocacy organizations have faulted the City for failing to provide clear policies regarding use of trip data, trip data storage policies, and sharing of trip data with third parties.

The absence of Federal privacy legislation in this rapidly evolving area of the law and the need to comply with a patchwork of state privacy laws – e.g., the California Consumer Privacy Act and the Illinois Personal Information Protection Act – may further complicate privacy compliance issues for multistate agencies. Independent of such legislation, policy makers and practitioners can reference guidelines suggested by Shaheen et al. (2019), to help protect traveler information in the Mobility Marketplace:

- Aggregate and summarize data to the extent that it protects travelers' sensitive personal information while still being sufficiently granular to provide useful insights for planners and system operators

- Educate users of app-based mobility services regarding how their data will be used and the risks associated with those practices
- Require that app-based mobility services offer an opt-in consent process that allows travelers to select the types of data they will share (e.g., location data, search history, etc.). This provides more transparency and control to users of these apps.
- Treat location data as personal information and develop policies for governing such data and handling freedom of information law requests that account for the sensitive nature of this data.
- Make data reported by participating service providers publicly available.

7.1.2.3.2 Data Standards, Protocols, and Open Specifications

Standards, protocols and open specifications (collectively referred to as “standards”) are essential to streamline processes, promote interoperability, and advance adoption of new technologies (Chang, et al., 2019). However, actual standards to support on-demand mobility services remain limited and are not being developed to support the holistic MOD vision of equitable, seamless, and complete trips for all travelers. Accordingly, there is a need for stakeholders in the MOD Marketplace and standards developers to collaborate in harmonizing standards across segments of the travel chain, including individual trip segments and the functions needed to integrate these segments through a seamless digital platform.

The MOD Operational Concept Report (Figure 14), along with the nine dimensions identified in the Survey of Standard and Emerging Standards White Paper (Figure 15), provides the foundational factors for consideration in development of multimodal and accessible travel system standards (Shaheen, et al., 2017; Chang, et al., 2019). USDOT is currently conducting research to address standards gaps in multimodal and accessible travel chains and to harmonize existing standards that may have missing elements or redundancies. These gap-filling and harmonization efforts will help further interoperability of MOD Marketplace system elements and fully accessible door-to-door travel chains.

Figure 13 - Areas for Standards Development Identified in the MOD Operational Concept Report.

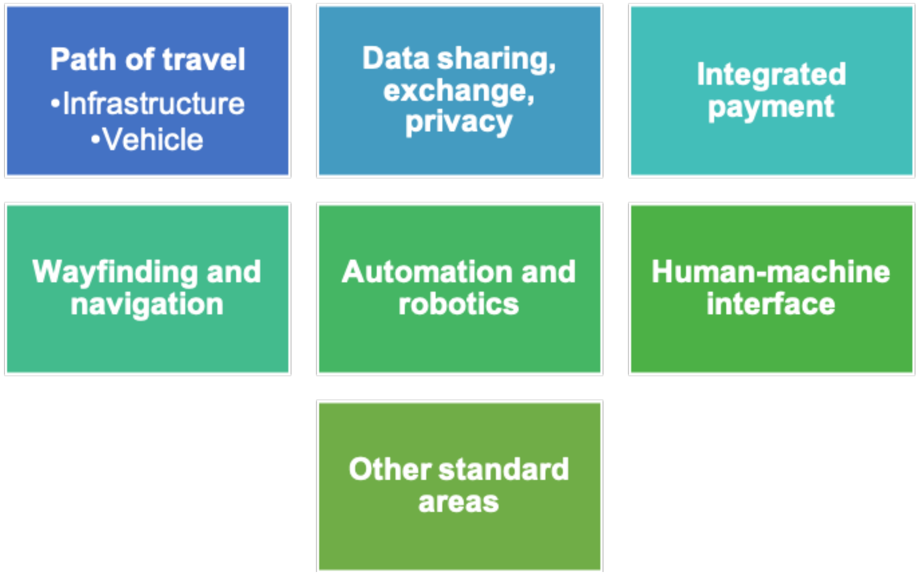
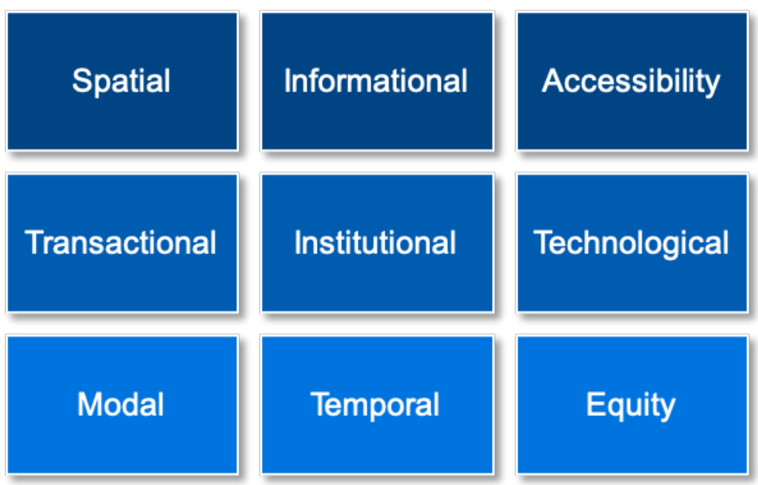


Figure 14 - Dimensions for Multimodal and Accessible Travel System Standards.



To further the adoption of standards in the Mobility Marketplace, Shaheen et al. (2019) recommend that public sector stakeholders take the following actions:

- Coordinate with other agencies and private partners to adopt standardized data formats such as General Transit Feed Specification (GTFS) and General Bikeshare Feed Specification (GBFS)
- Promote the use of standardized, open data formats such as Mobility Data Specification (MDS) among on-demand mobility providers to ensure data sharing and governance is more consistent.
- Consult with the USDOT agencies such as the Federal Transit Administration (FTA) for guidance on how on-demand trips should be defined under public transportation statutes as

well as data reporting requirements for the private companies that provide these trips, particularly when funded by transit agencies.

7.1.2.3.3 Data Security

Secure data governance and exchange is fundamental to the MOD Marketplace and underlies other data policy and practice considerations such as privacy and data sharing between public and private stakeholders. While an in-depth review of data security practices is beyond the scope of this section, public and private stakeholders can follow the guidance below to further cybersecurity in the MOD Marketplace (Shaheen, et al., 2019):

- Adopt standards-compliant digital security methods, protocols for storage, retention, and deletion, data theft or breach plans, and cybersecurity insurance. Carefully consider the potential application of experimental technologies, such as blockchain.
- Regularly update data security practices and policies.
- Encourage all stakeholders who support transportation including vehicle manufacturers, mobility software developers and others to follow industry protocol for managing cybersecurity risks throughout product development lifecycles.

USDOT's cybersecurity approach for the nation's connected transportation system is summarized in a Fact Sheet (https://www.its.dot.gov/factsheets/cybersecurity.htm).

7.1.2.3.4 Public-Private Data Sharing

Strong data-sharing agreements that include provisions on data ownership, clear direction on variables to be shared, the extent of aggregation, data governance, and permissions can help overcome concerns related to public information laws, user privacy, and proprietary business information to help foster mutually beneficial partnerships (Grossman & Lewis, 2019). Shaheen et al. (2019) suggest that jurisdictions adopt some of the following practices related to public-private data sharing:

- As a condition of the permitting process, jurisdictions can mandate that data shared by on-demand mobility service providers and app-based platforms is not shared in proprietary formats and does not contain personal information.
- Public and private stakeholders can work with third-party entities such as non-profit organizations and universities to anonymize and aggregate mobility service provider data before its shared with public end users. These steps can lessen risks associated with freedom of information laws as well as exposure of sensitive personal information and business information.
- To further research and the public interest, jurisdictions should reserve the right to share service provider data with researchers and peer agencies in accord with cybersecurity and digital privacy best practices.

Appendix A. Acronyms and Definitions

Table 16 - List of Acronyms

Acronym/ Abbreviation	Definition
2D	Two-Dimensional
3D	Three-Dimensional
AES	Advanced Encryption Standard
APC	Advanced Passenger Count
API	Application Programming Interface
AR	Augmented Reality
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
ATDM	Active Transportation and Demand Management
ATIS	Advanced Traveler Information System
ATTRI	Accessible Transportation Technologies Research Initiative
AVL	Automatic Vehicle Location
B2B	Business-to-Business
B2C	Business-to-Consumer
B2G	Business-to-Government
BART	Bay Area Rapid Transit
BLE	Bluetooth Low Energy
CNS	Courier Network Services
ConOps	Concept of Operations
CPU	Central Processing Unit
CV	Connected Vehicles
DaaS	Data as a Service
DART	Dallas Area Rapid Transit
DMP	Data Management Plan
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOL	Department of Labor
DOT	Department of Transportation
DSS	Decision Support System
ELT	Extract Load Transform
ETL	Extract Transform Load
FAST	Fixing America's Surface Transportation
FCC	Federal Communications Commission
FHV	For Hire Vehicle
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
G2C	Government-to-Citizen
GBFS	General Bikeshare Feed Specification

Acronym/ Abbreviation	Definition
GIS	Geographic Information System
GPS	Global Positioning System
GTFS	General Transit Feed Specification
GTFS-R	General Transit Feed Specification Realtime
ICM	Integrated Corridor Management
ICMS	Integrated Corridor Management System
IDA	Infocomm Development Authority
IDTO	Integrated Dynamic Transit Operations
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEPS	Integrated Electronic Payment System
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
KPI	Key Performance Indicator
LADOT	Los Angeles Department of Transportation
LTA	Land Transport Authority
MaaS	Mobility as a Service
MDS	Mobility Data Standard
MMTE	Multimodal Trip Engine
MOD	Mobility on Demand
MPO	Metropolitan Planning Organizations
MTC	Metropolitan Transportation Commission
MTA	Metropolitan Transportation Authority
NFC	Near-Field Communication
NoSQL	Non-SQL/Not only SQL
OCTA	Orange County Transportation Authority
OD	Origin/Destination
OEM	Original Equipment Manufacturers
OMF	Open Mobility Foundation
OSM	OpenStreetMap
OTP	OpenTripPlanner
P2P-GDM	Peer-to-Peer Goods Delivery Marketplace
P2P-MM	Peer-to-Peer Mobility Marketplace
PII	Personally Identifiable Information
PMT	Person Miles Traveled
POI	Point of Interest
POS	Point of Sale

Acronym/ Abbreviation	Definition
RDBMS	Relational Database Management System
REST	Representational State Transfer
RFID	Radio-Frequency Identification
ROI	Return on Investment
RRRR	Rapid Real-time Routing
RTD	Regional Transportation District
SDK	Software Development Kit
SEPTA	Southeastern Pennsylvania Transportation Authority
SQL	Structured Query Language
STM	Société de transport de Montréal
SUMC	Shared-Use Mobility Center
TDM	Transportation Demand Management
TLC	Taxi and Limousine Commission
TLS	Transport Layer Security
TMC	Traffic Message Channel
TMCC	Travel Management Coordination Center
TNC	Transportation Network Company
TSMO	Transportation Systems Management and Operations
TSP	Transportation Service Provider
UI	User Interface
UJM	User Journey Map
USDOT	United States Department of Transportation
USPS	United States Postal Service
UX	User Experience
Vtrans	Vermont Agency of Transportation
XML	Extensible Markup Language

Appendix B. Available Multimodal Trip engines

Some of the current trip engines available in the marketplace can be taken into consideration in the deployment of a MOD multimodal trip engine subsystem and include:

OpenTripPlanner

OpenTripPlanner (OTP) (https://www.opentripplanner.org/) is an open source trip engine that provides passenger information and transportation network analysis services. The core server-side Java component finds itineraries combining transit, pedestrian, bicycle, and car segments through networks built from widely available, open standard OpenStreetMap, GTFS, GTFS Flex and GBFS data. This service can be accessed directly via its web API or using a range of JavaScript client libraries, including modern reactive modular components targeting mobile platforms. Relevant features include:

- OTP supports open specifications GTFS, GTFS-Flex, GBFS and KML (https://developers.google.com/kml/documentation/kmlreference)
- OTP supports various base maps including ArcGIS, Open Street Maps, Google Maps
- Ability to consider mobility services extensions and other options available in the marketplace (rideshare, carsharing, microtransit).
- Intermodal routing engine
- Trip engine can dynamically adjust to new data updates, connecting times and change requests.
- Options to including on-demand scheduling in the multimodal trip engine
- Adequate and seamless multimodal and multi-agency transfers

Sample deployments include:

- TriMet - transit, bikeshare (Biketown), ridesourcing (Lyft, Uber), carsharing (car2go) and walking
- Santa Clara Valley Transit Authority - transit, bus, Park & Ride, biking and walking
- New York State Department of Transportation - transit (Bee-Line Bus, Amtrak, Metro-North Railroad, MTA New York City transit bus and subway), Park & Ride and driving.
- Arlington County Commuter Services – transit (Metro, bus), driving, biking, bikeshare (Capital Bikeshare) and walking
- Adelaide Metro – transit (bus, train, tram), school services, biking, walking
- University of Florida (USF) Maps – USF Bus, walking, biking, bikeshare (Share-A-Bull Bikes), carshare (USF Enterprise Carshare), drive, parking and electrical vehicles charging stations.
- Regional Transportation District – Transit (bus, rail), biking, driving, walking and Park & Ride locations.
- Cherriots Salem-Keizer Transit and paratransit (bus, Dial-a-Ride, shopper service), driving and walking.
- Sound Transit – Transit (Link light rail, TT Express bus, Sounder train, Tacoma Link light rail), walking and driving.

HAFAS Trip engine

HAFAS (HACON, 2020) is multimodal door-to-door trip engine. The engine supports the integration of GTFS data from transit agencies, real-time traffic and transit data. The trip engine is available as a web app and native apps for iOS and Android. The trip engine also has the ability to generate a trip based on grouped modes (walk and train), (bike and bus) but does not allow for the combination of all modes. Sample deployments include:

- Capital Metro (Austin Texas) (https://capmetro.org/)
- Southeastern Pennsylvania Transportation Authority (SEPTA) (http://www.septa.org/service/trip-planner.html)
- Bay Area Rapid Transit (BART) (https://www.bart.gov/planner)

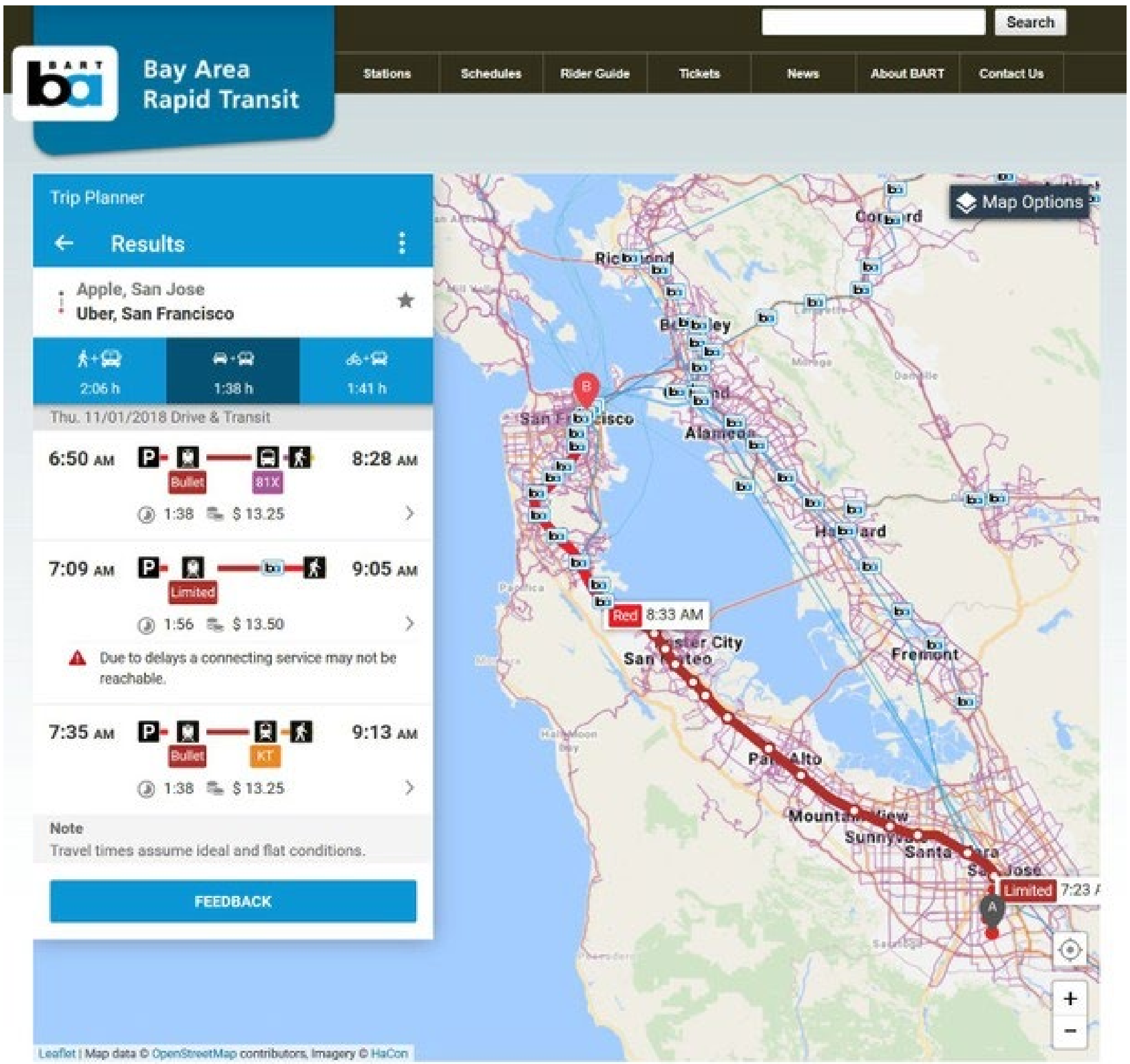


Figure 15 - HAFAS Trip planner: BART Deployment

Google Trip engine

The Google trip engine (https://developers.google.com/maps/documentation/) provides the ability to generate trips including transit agencies publishing their data in GTFS and GTFS

Realtime extension. The engine also allows for linkage with ridesharing and carsharing services. The Google trip engine takes into account all data collected and published to Google, such as GTFS, GTFS Realtime, real-time traffic, weather alerts, travel trends and service disruption. The Google trip engine requests can only be submitted through the API. The implementation of this trip engine provides very little flexibility for MOD stakeholders to alter and expand functionality based on implementation needs. Google API allows for standard functionality and does not support customized implementations. Some examples of transit agencies using the Google trip engine for their ATIS include:

- DART GoPass App and 511DFW (http://www.511dfw.org)
- Metropolitan Transportation Commission (MTC) (https://511.org/)
- Orange County Transportation Authority (OCTA) (http://octa.net/Bus/Trip-Planner/)

RRRR Journey Planner

Bliksem Labs' Rapid Real-time Routing (RRRR or R4) (https://www.transitwiki.org/TransitWiki/index.php/Rrrr) is an open source multimodal routing engine. The engine supports GTFS as an input, and compiles it to an intermediate timetable format. GTFS-Realtime is also supported to update the trip engine results based on real-time conditions. The output of the engine complies with the JSON format found in OpenTripPlanner. The application supports advanced routing features such as wait-time compression. Additionally, the trip engine was designed to run on smartphones with the ability to buffer the data and operate with no cell coverage. This trip engine has been deployed in various transportation consortia in the Netherlands.