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Mobility Performance Metrics (MPM) for Integrated Mobility and Beyond

February 2020

FTA Report No. 0152
Federal Transit Administration

PREPARED BY
TransitCenter
Applied Predictive Technologies (a Mastercard Company)
Texas A&M Transportation Institute

U.S. Department of Transportation
Federal Transit Administration

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Metric Conversion Table

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

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Abstract

This report presents traveler-centric mobility performance strategies and metrics and the approach for the development of those metrics for use as supplemental measures to assess how well an integrated public/private mobility system meets the needs of individual travelers, how well the system performs while meeting overall travel demand, and what the system's impact is locally and nationally. By measuring transportation performance from the traveler's perspective, agencies and operators can be incentivized to improve service based on what matters most to travelers. The report identifies a large set of potential measures that align with Federal Transit Administration (FTA) goals as well as goals of the Mobility on Demand (MOD) Sandbox Projects. It then presents a comprehensive evaluation process using applicability and feasibility criteria that were used to cull the potential performance measures to a smaller more appropriate set of performance measures. The report discusses possible data sources and data integration strategies for the application of the new mobility performance measures.

EXECUTIVE SUMMARY

This report presents supplemental mobility performance metrics (MPMs) and the process used to develop them. New metrics are desirable given movements in the transportation industry toward integrating the operations of mostly public-sector fixed-route and specialized public transportation services with private-sector on-demand mobility services. The progression towards individualized, integrated, and seamless mobility is occurring through the Federal Transit Administration's (FTA's) Mobility on Demand (MOD) Sandbox and Integrated Mobility Innovation (IMI) programs, as well as other industry activities. The motivation for such movements is the aspiration to better serve the traveling public. With greater involvement of private companies and better coordination between jurisdictions in "public transportation," travelers expect the transition between modes to be as seamless as possible.

Traveler expectations of integrated and seamless mobility options are also based on their experiences and interaction with other technological advancements outside the transportation and mobility realms, such as smart phones becoming an integral part of daily lives, use of apps for planning, scheduling, purchasing, etc., availability and speed of digital communication, availability of and access to real-time data and information, and many other integrative technologies/platforms. This creates the need for public and private entities providing mobility services to coordinate schedules, services, planning, and payment systems. This integration of services makes it difficult to capture and measure a complete picture of American mobility today, especially by using traditional transit and transportation performance measurement techniques. It also makes it difficult to answer the question of whether the public is being best served by a changing transportation system. There is a need to define what an effective mobility system looks like for travelers and a need to measure performance against a traveler-centric mobility vision. Thus, the goal of developing and using new performance metrics is to measure how well an integrated public-private mobility system meets the needs of individual travelers, how well the system performs while meeting overall travel demand, and what the system's impact is locally and nationally.

Research Approach

A structured approach was used to address the layers of complexities described above. The approach includes two phases—a Development Phase and a Testing Phase (see Figure ES-1). The first two parts of the Development Phase have been completed. Research activities included:

- Evaluating current performance measurement requirements and practices
- Identifying challenges and gaps
- Determining potential performance measures to bridge those gaps
- Identifying the data sources to functionalize those performance metrics

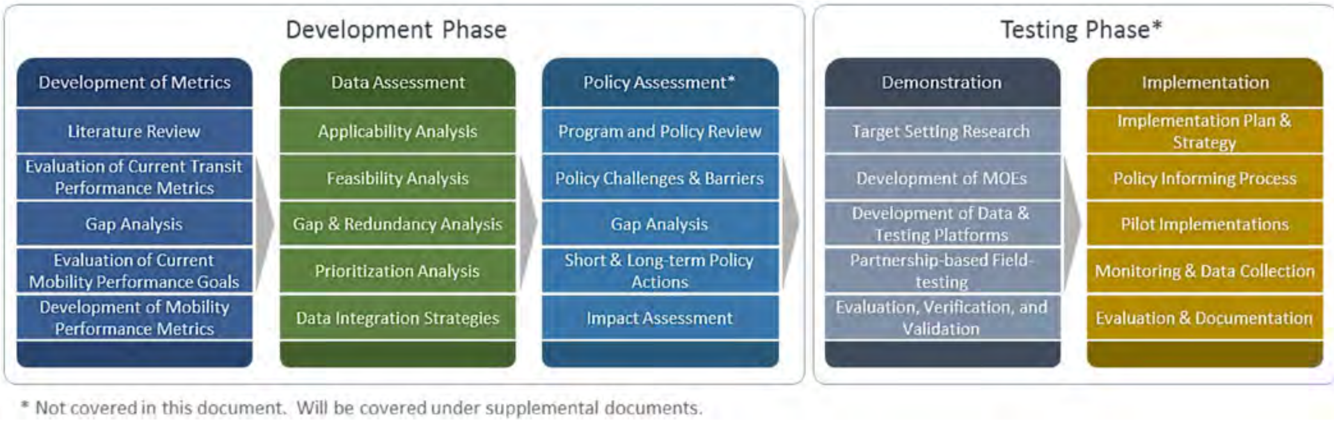


Figure ES-1 *MPM Development and Testing Phase Activities*

In the Testing Phase, research will be conducted to develop a roadmap to operationalize the metrics for measuring the performance of the mobility system. This report covers the first two activities in the Development Phase—Development of Metrics and Data Assessment. Subsequent companion reports will cover Policy Assessment and Demonstration and Implementation activities in the Testing Phase.

MPM Development

Based on information gathered from a literature review, interviews, and analyses as part of the MPM Development Phase, a tiered framework was developed (see Figure ES-2) and candidate metrics were identified for the core and each tier. The core of the framework focuses on performance as it impacts individual travelers—specifically, how individual travelers view their trip experience through five factors that affect transportation efficiency, effectiveness, and experience: time, budget, reliability, safety, and availability. This core is followed by three tiers designed to measure performance of a given mobility system (Tier 1), a city and/or region (Tier 2), and national-level performance (Tier 3). Candidate metrics for the different tiers were identified:

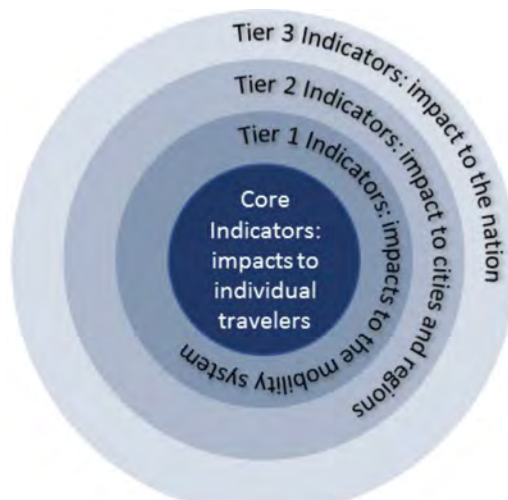


Figure ES-2
MPM Tiered Framework

- **Core** – Metrics measuring how well the integrated mobility system meets the needs of individual travelers
- **Tier 1** – Metrics measuring how effectively and efficiently the integrated mobility system performs while meeting the needs of individual travelers
- **Tier 2** – Metrics measuring how the integrated mobility system impacts the region in terms of sustainability, accessibility, environment, workforce, etc.
- **Tier 3** – Metrics measuring how the integrated mobility system impacts national goals for societal benefits, economic benefits, return on infrastructure investment, etc.

An additional dimension to the MPM framework was aligning it with FTA's Complete Trip concept; within the tiers, metrics were identified to measure performance in three stages—pre-trip, trip, and post-trip. In addition to tiers and trip stages, candidate metrics were sorted into five categories of traveler experience (Time, Budget, Reliability, Availability, and Safety), and potential data that would be required to measure each metric were identified.

In total, 65 candidate metrics were identified—25 metrics for the core of the framework, 25 metrics for Tier 1, 8 metrics for Tier 2, and 7 metrics for Tier 3.

MPM Assessment

The second stage in the Development Phase was Data Assessment. It was necessary to identify potential data required for the analyses and measurement of the metrics and to assess data availability and potential constraints associated with that data. Data assessment was conducted as five activities, as follows:

1. **Applicability Assessment** – The relevance of the candidate mobility performance metrics for evaluating MOD and similar projects was assessed. The MOD Sandbox projects, selected based on their context and closeness to FTA's integrated mobility vision, were used as starting use cases for assessing applicability, with the assumption that findings could be extrapolated to future MOD use cases. MOD Sandbox projects were analyzed to understand current evaluation criteria and current measures of performance, and then candidate MPMs were scored based on how well they were applicable to these items. The applicability scores ranged from 1 to 4, where 1= metric aligns with goals of MOD Sandbox projects and is currently widely measured; 2 = metric aligns with goals of MOD Sandbox projects but metric is captured across some but not all MOD projects; 3 = metric aligns with goals of MOD Sandbox projects but is not currently measured; and 4 = metric does not align with current goals of MOD Sandbox projects. No candidate metrics were rated a 4; the most common score was a 3, followed by 1 and then 2.
2. **Feasibility Analysis** – After determining the applicability of the MPMs to the goals of MOD projects, it was necessary to assess the feasibility of

collecting or obtaining the data required to compute the candidate MPMs. The following questions were answered under the feasibility assessments:

- Do the data exist?
- Are the data available?
- What is the feasibility of obtaining the data?
- What are the constraints associated with available data?
- What would be the format and unit of a given data element?
- What are the data sets that are currently unavailable, but in development phases by the agencies or stakeholders?
- What are the data that are not available?
- What are the reasons that the data are not available?
- Are the constraints removable?
- What are the required actions to remove such constraints and by whom?

Feasibility scores were computed that ranged from “high” to “infeasible”—“high” = currently measurable by transit agencies or private partners; “moderate” = currently measurable with external data; “low” = currently not measurable but would be measurable in the future with insignificant to moderate additional effort; “infeasible” = currently not measurable and would be measurable in the future with significant additional effort that would require policy and regulatory actions. Overall, although all agencies will not be able to measure every candidate metric covered under the MPMs, they should be able to measure many of the metrics without additional policy, technology, regulatory, or organizational changes. Of the candidate measures, only four were rated as “infeasible”; about half received a feasibility score of “high” or “moderate.”

3. **Gap Analysis and Redundancy Analysis** – The candidate metrics were mapped to nine goals for MOD projects to ensure coverage in measuring the goal. The goals are customer satisfaction, time effectiveness, cost effectiveness, reliability, availability, safety, accessibility, demand for MOD, knowledge transfer, and enhancing transit industry preparedness for MOD. Overall, the candidate MPMs aligned well with the goals. For goals with low metric coverage, 27 additional metrics were proposed to close the coverage gap. Metrics with unique MOD goal coverage were scored more favorably than those for which many metrics were available to cover the goal. Required data to compute the metric was also assessed. The investigation found that for a handful of MOD goals, there were several key data elements with high counts of dependent metrics, meaning that the data could be used to computer multiple metrics. *Data for higher counts of dependent metrics will be most important to collect and were prioritized over data elements with few dependent metrics.*

4. **Prioritization Analysis** – After the identification of the additional metrics in the preceding exercise, there were nearly 100 candidate metrics. The prioritization assessment identified how the metrics should be prioritized within each of the nine MOD goals, the order in which the data feeds and metrics should be obtained, the ways to integrate various data elements, and how to use the metrics to inform decisions. The prioritization scheme was based on the applicability scores, feasibility buckets, and gap analysis and redundancy findings associated with each metric. In total, 14 high priority metrics were identified: Wait Time, Standard Deviation of Wait Time, Median Wait Time, Total Journey Time, Trip Cost, Median Trip Cost, Budget Spent on Transportation, Trip Price, Passenger Revenue Miles per Year or Passenger Revenue Hours per Year, Option Availability, Crime Rate, Crash Rate, and Injury Rate.
5. **Data Integration Strategies** – The research developed an approach for determining how to facilitate performance measurement through data integration strategies—that is, creating many of the metrics from the same, often easily-accessible data sources. By recommending a prioritization of metrics, the analysis provides a framework for entities to begin to collect data sources to create the mobility performance measures. Ideally, policy changes will make it easier for entities to obtain additional MPMs, which will enable collection, measurement, and analysis of a wider range of metrics than currently available today.

Conclusion

The goal the new supplemental mobility performance measures is to improve decision-making. The objective of the performance metrics is to measure the performance of "integrativeness" of the mobility system, primarily focusing on the effectiveness on the traveler-centric performance. This means investing in the effort to collect the data elements necessary to calculate them. Since the mobility performance measures are well aligned with the goals of MOD and other types of integrative mobility projects, if leveraged correctly, the mobility performance measures can provide the necessary insight into the true impact of programs across MOD project goals. Reporting and sharing metric values is an important undertaking—why use new mobility performance measures if they are not transparently shared with and understandable by all key stakeholders? By establishing systems to report and share mobility performance measures, bringing understanding of the true impact of a program on the given metric, projects will be able to make the best and most informed go-forward decisions.

SECTION 1

Introduction

Research Objective

The objective of this research is to develop new mobility performance metrics (MPM) to supplement existing, traditional public transit-oriented ones. New MPM are needed because emerging mobility services such as bikeshare, carshare, ridesourcing, ridesharing, and on-demand transit, coupled with trip planning, scheduling, transfer, and navigation platforms, are changing the way people get around. These new mobility services have important implications for public transportation, such as serving as first/last-mile solutions or shifting demand to other modes of mobility services, especially in urban areas and cities. For example, facilitating trips between residences and transit stations in lower-density areas is a challenge for some transit agencies. Traditional solutions such as expanding park-and-ride facilities have land use and cost implications. New mobility services such as ridesourcing can fill in the first/last-mile connections for many travelers. But at the same time, ridesourcing trips have been known to substitute for public transit trips that might otherwise have been taken. Because each public transportation service area is unique, the implications will play out differently among them. Moving into the future, the prospect of automated vehicles and their application to transit add complexities to these potential implications. As a result, integrating the operations of mostly public-sector-provided fixed route/specialized public transportation services and private-sector-provided on-demand mobility services becomes an important operating strategy for the transportation industry, where the focus remains on how to best serve the traveling public.

The goal of developing and using a new set of performance metrics is to measure how well an integrated public/private mobility system meets the needs of individual travelers, how well the system performs while meeting overall travel demand, and what the system's impact is locally and nationally. By measuring transportation performance from the traveler's perspective, agencies and operators can be incentivized to improve service based on what matters most to travelers. In addition, performance metrics should be selected and designed to evaluate progress toward an agency's overall goals and objectives. As such, it is important to reassess public transportation's goals, how progress toward those goals can be measured comprehensively from traveler and system perspectives, what the federal government's role is in setting national transportation goals, and facilitating progress toward the achievement of national goals. The Federal Transit Administration's (FTA's) Integrated Mobility Innovation (IMI) Program is leading this research effort to develop new MPM and align them with transportation agency goals. This report presents the findings of the research.

Background

Historically, public transportation in North America has been provided by transit agencies that operate fixed-route bus and rail lines. Agencies measure their performance using metrics that focus on public transportation exclusively as a system, reflecting factors such as costs per traveler trip or mile, on-time performance, and ridership. These performance metrics, particularly ridership, will continue to be key to tracking how cities and agencies are doing. However, they inadequately capture the performance and benefits of the mobility ecosystem as a whole, including transportation modes such as walking and biking that existed long before mass transit—let alone the emerging mobility services that increasingly serve similar trips to conventional public transportation—and mobility service providers (MSPs) that offer various options. Furthermore, existing transit performance metrics often fail to reflect important existing goals such as accessibility, safety, and sustainability.

Mobility-on-Demand (MOD) is as an integrated and connected multimodal network of safe, affordable, equitable, and reliable options for personal mobility and goods delivery that are available and accessible to all. According to the U.S. Department of Transportation's (USDOT's) vision, MOD is achieved by leveraging innovative technologies and facilitating public-private partnerships to allow for a user-centric approach that improves personal mobility options and delivery of goods and services. The guiding principles of MOD are:

- *User-centric* – promotes choice in personal mobility and uses universal design principles to satisfy the needs of all users
- *Mode-agnostic* – supports connectivity and interoperability where all modes of transportation work together to achieve the complete trip vision and efficient delivery of goods and services
- *Multimodal* – where personal mobility and goods delivery services can be discovered, preferred options can be selected, and travel can be managed via an integrated digital marketplace
- *Technology-enabled* – leverages emerging and innovative use of technologies to enable and incentivize smart decision-making by all users and operators in the mobility ecosystem
- *Partnership-driven* – encourages partnerships, both public and private, to accelerate innovation and deployment of proven mobility solutions to benefit all

Furthermore, MOD and associated integrative enablers also support FTA's Complete Trip for All concept. USDOT's vision of a MOD is as a transformative transportation system that will make all the essential/necessary linkages that make up the trip fully accessible and connected. This transformative transportation system will also allow individuals to go from any origin to any destination without physical, modal, system, or access barriers along their path and overall trip. As an objective of this integrated system, if one link is not accessible, then access to a subsequent link is unattainable and the trip cannot be completed.

To examine what the future public transportation system would look like, FTA launched the MOD Sandbox Program and funded 11 projects in 2016. The program provides a mechanism through which MOD concepts and solutions are demonstrated in real-world settings, thus facilitating an evaluation of the MOD vision, which recently transformed to become several strategic objectives under FTA's IMI program. Both MOD and IMI support a vision of an individual traveler-focus, integrated and seamless operations, and value-based options for traveler mode choice decisions, which can vary greatly depending on traveler mobility and temporal needs. In 2019, FTA's IMI released a funding opportunity for additional demonstration projects relating to MOD, Strategic Transit Automation Research, and Mobility Payment Integration.

Context: Transformational Era of Mobility and Transportation Experience

Innovations in information, communications, and transportation technologies are supporting the societal, technological, economic trends that continue transforming personal mobility. As recently as a decade ago, mobility options were limited to private vehicles, public transit, and limited for-hire services such as taxis. Today, a diverse mobility ecosystem exists that provides unprecedented flexibility and modal choices, including public transit, bikeshare, ridesourcing services, and flex-route microtransit. Private companies are providing many of these new mobility services, bringing competitive dynamism to transportation. At the same time, public transportation agencies around the country continue to adopt innovation—taking on new roles as regional mobility managers within the transportation ecosystem while simultaneously transforming their business models to offer better service and improved integration with other modes. Some of the more influential trends are as follows:

- **Societal Trends**
  - *Population growth and aging* – By 2045, the U.S. population is expected to grow by 70 million and the number of Americans over age 65 will increase by 77% [1].
  - *Mobility impairments* – In 2014, persons with disabilities comprised nearly 27% of the U.S. population; nearly 14% had a mobility impairment [2].
  - *Digital natives* – Millennials are the first generation to have access to the internet during their formative years and are often early adopters of technology solutions including shared-use mobility services [3].

  - *Transportation costs* – The majority of American households have three major expenditures—housing, transportation, and food. In 2017, transportation was the second highest spending category after housing and ahead of food, healthcare, and clothing. Low-income Americans spend a disproportionate share of their annual income on transportation [4].
- **Technological Trends**
  - *Diffusion of smart phones* – A total of 81% of Americans own a smart phone, allowing them to access to traffic and transit information on schedules, options, and travel choices [5].
  - *Vehicle connectivity* – The percentage of new cars shipped with internet connectivity will rise to 75% in 2020, and cars with internet connectivity could account for 22% of all vehicles on the road by 2020, enabling unprecedented opportunities for real-time, demand-responsive mobility solutions [6].
  - *Vehicle automation* – Major automaker companies, technology giants, and specialist start-ups have invested more than $50 billion over the past five years to develop higher levels of automated vehicle technology. Currently, 93% of new vehicles had at least one advanced driver assistance system feature available [7].
- **Environmental Trends**
  - *Congestion costs* – In 2017, congestion caused urban Americans to travel an extra 8.8 billion hours and purchase an extra 3.3 billion gallons of fuel [8].
  - *Shared use mobility* – Demand for bikesharing, carsharing, ridesharing, ridesourcing, and scooters is growing [9].
  - *Increase in greenhouse gases (GHGs)* – Cities generate 67% of GHGs released into the atmosphere, which is expected to rise to 74% by 2030. The transportation sector is the second-biggest source of GHGs, responsible for 28% of GHGs [10].

Many Americans rely on buses and trains to get around, but travelers now can know when they will arrive and can pay their fare on their smart phone. Taxi service is complemented by ridesourcing, and transit service is complemented by microtransit and ridesharing services, which allow vehicles to arrive more quickly, serve more places, and take advantage of mobile phones for payment and real-time location tracking. Bike ridership has increased, and travelers now can rent bikes off the street and drop them off within a few blocks of their destination. A fundamental change is that it is far easier for round trips to and from destinations to use different modes in different directions [11]. Furthermore, travelers now can afford to spontaneously change their mode choice depending on the ideal match of temporal availability of mobility options and their need-based choices, rather than arranging their plans and needs around the fixed schedules of the public transportation systems.

With greater involvement of private companies and jurisdictions in public transportation, travelers want the transition between modes to be as seamless as possible. This creates the need for these entities to coordinate schedules, services, planning, and payment systems. There is also a need for a new way of looking at how our transportation system serves users, our cities, regions, and the country that reflects these changes. This modal integration of services, which often are owned and operated by different entities, makes it difficult to draw a complete picture of how Americans get around today. It also makes it difficult to answer the question of whether the public is being best served by the transportation system. Along with looming changes to those operating these services brought by automation of driving, there is an urgent need to evaluate and define what a successful transportation system looks like for travelers.

The progression toward individualized, integrated, and seamless mobility is occurring through the MOD Sandbox Program, IMI Program, and other industry activities. Considering this, it is necessary to assess the feasibility of new metrics that are supplemental to existing public transit performance measures and capture the impacts and outcomes of integrated operations of transit and new mobility services. This is necessary to ensure that this transformative mobility environment provides optimal effectiveness, efficiency, and value-based affordability aligned with the traveling public's needs and the objectives of the other participants in this mobility environment.

Research Approach

Developing metrics from conceptualization to operationalization, testing them in real-world conditions through validation and verification processes, and measuring performance of personal and regional mobility by using new MPM is a complex undertaking. It requires assessments from several perspectives to validate that the outcomes and the levels of practicality for the metrics to be implemented are aligned with FTA's objectives and the broader goals of the USDOT. Another complexity layer is added by the ever-evolving transportation/mobility options, constantly evolving technological advancements, and associated user needs/demands as a response to those (rapid) changes in technology and options.

A structured approach was developed to address the layers of complexities identified in the prior sentences. The approach includes two phases—a Development Phase and a Testing Phase (Figure 1-1). The first two parts of the Development Phase have been completed. Research activities included:

- Evaluating current performance measurement requirements and practices
- Identifying challenges and gaps
- Determining potential performance measures to bridge those gaps
- Identifying the data sources to functionalize those performance metrics

In the Testing Phase, research will be conducted to develop a roadmap to operationalize the metrics for measuring the performance of the mobility systems from the perspectives of the individual traveler and entire system.

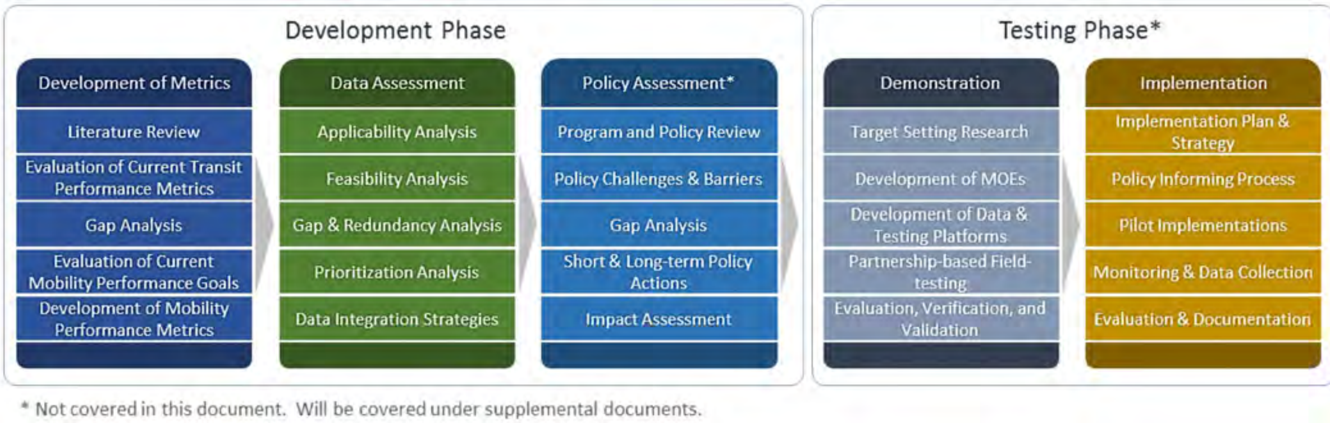


Figure 1-1 *Research Phases of MPM Development and Testing*

Report Purpose

This report covers the findings of Development of Metrics and Data Assessment activities in the Development Phase, shown in Figure 1-1. Subsequent companion reports will cover Policy Assessment and Demonstration and Implementation activities in the Testing Phase.

SECTION 2

Development of Metrics

Five research activities were conducted to develop the new MPM. These activities are discussed in this section:

- Literature Review
- Evaluation of Current Transit Performance Metrics
- Gap Analysis
- Evaluation of Current Mobility Performance Goals.
- Development of Mobility Performance Metrics

Literature Review

Performance metrics should be selected and designed to evaluate progress toward an agency's overall goals and objectives. As a result, for this effort, it was important to begin with an understanding of agency and community strategic transportation goals. A literature review of existing transit and adjacent transportation performance metrics was conducted to fulfill this objective; the full document is included as Appendix A. The literature review explored goals and their associated performance metrics from 42 agencies and governing bodies around the world; this included 13 departments of transportation, 14 local transit agencies, 8 metropolitan planning organizations (MPOs), and 2 city governments from across the U.S., as well as 4 transit agencies and 1 city government from foreign countries. USDOT's goals were also included, as this project intends to inform Federal goals.

Evaluation of Current Transit Performance Metrics

The literature review provided an understanding of the current (and traditional) performance measurement metrics used in the public transportation agencies in the U.S. The primary purpose of the evaluation of current metrics was to establish the concepts, rationale, and requirements behind the current metrics and how they map into the emerging concepts of mobility and services. This evaluation covered USDOT strategic goals and objectives, FTA's National Transit Database (NTD)-required metrics for urban areas, the perspectives of key stakeholders, and transit agency goals.

USDOT Strategic Goals and Objectives

USDOT sets a national policy agenda, provides funding, and creates incentives for agencies operating at the local, regional, and state levels. The relevant performance metrics to the MOD project are not those USDOT uses to evaluate its own performance, but rather those for which it requires reporting at the local and regional levels. Under USDOT, FTA's mission is to "improve public transportation for America's communities." FTA's efforts are guided by the goals stated in USDOT's most recent strategic plan, *U.S. Department of Transportation Strategic Plan for FY 2018–2022* [12]. Table 2-1 summarizes USDOT's most recent goals and the underlying strategic objectives.

Table 2-1
USDOT Strategic Goals and Objectives

Goal	Description	Strategic Objectives
Safety	Reduce transportation-related fatalities and serious injuries across the transportation system.	Systemic Safety Approach
Infrastructure	Invest in infrastructure to ensure safety, mobility, and accessibility and to stimulate economic growth, productivity, and competitiveness for American workers and businesses.	• Project Delivery, Planning, Environment, Funding, and Finance • Life Cycle and Preventive Maintenance • System Operations and Performance • Economic Competitiveness and Workforce
Innovation	Lead in development and deployment of innovative practices and technologies that improve safety and performance of nation's transportation system.	• Development of Innovation • Deployment of Innovation
Accountability	Serve nation with reduced regulatory burden and greater efficiency, effectiveness, and accountability.	• Regulatory Reform • Mission Efficiency and Support

USDOT goals and strategic objectives have underlying strategies to ensure that the objectives are measured and the goals are met. Several of those strategies involve performance, reliability, data, and partnerships/collaborations, which are directly or closely related to development of MPM development strategies.

FTA's NTD-Required Metrics

Each urban area transit agency uses a different but similar methodology to measure the performance for its generalized goals (several examples are provided in the full literature review in Appendix A). At a bare minimum, transit agencies use the performance metrics that are required for NTD reporting to qualify for FTA grant funding. Some key service measurements required by FTA include ridership counts (unlinked trips), passenger miles, vehicle revenue miles, vehicle revenue hours, and vehicles available for maximum service, among others [13]. Agencies also report their operating expenses by mode per vehicle mile, per vehicle hour, per passenger mile, and per unlinked passenger trip.

For large urbanized areas with populations over 200,000, FTA funding is apportioned based on population, population density, operating costs, revenue miles, and passenger miles. For Small Transit-Intensive Cities—where the population is smaller than 200,000 but that have transit service levels that are comparable with larger cities—funding is based on metrics such as passenger miles traveled per vehicle revenue mile, passenger miles traveled per vehicle revenue hour, vehicle revenue miles per capita, vehicle revenue hours per capita, passenger miles traveled per capita, and passengers per capita [13, 14]. Some key service measurements required by FTA include ridership counts (unlinked trips), traveler miles, vehicle revenue miles, vehicle revenue hours, and vehicles available for maximum service, among others. Agencies also report their operating expenses by mode per vehicle mile, per vehicle hour, per traveler mile, and per unlinked traveler trip. Table 2-2 summarizes the NTD-required performance metrics for urbanized areas.

Table 2-2

Summary of NTD-Required Metrics for Urbanized Areas

Annual Reporting Metrics	Monthly Reporting Metrics	Safety and Security Reporting Metrics
• Demographic data • Service area • Types of service (directly operated or purchased transportation) • Modes • Financial data (operating expenses, capital expenses, full cost of operations) • Funding sources	• Unlinked passenger trips • Passenger miles traveled (PMT) • Vehicle revenue miles • Vehicle revenue hours • Vehicles operated in maximum service • Regular service days for each month	• Fatalities • Injuries • Collisions • Derailments • Fires • Hazardous material spills • Evacuations • Arrests • Significant security events

Stakeholder Perspectives on Performance

In addition to basic NTD reporting data, transit agencies "collect other measures to help identify how well service is being provided to their customers, the areas where improvement may be needed, and the effects of actions previously taken to improve performance" [15]. To this end, agencies frequently measure key operational data focused on understanding system reliability and schedule adherence (e.g., on-time performance), cleanliness, and customer satisfaction [16, 17, 18]. For example, the Massachusetts Bay Transportation Authority demonstrates this approach with an accessible and understandable website that reports on performance on reliability, ridership, financial, and customer satisfaction [19]. The San Francisco Municipal Transportation Agency also provides customers with an online performance dashboard that organizes its metrics by the agency's strategic goals [20]. Supporting this perspective, in its report, *A Guidebook for Developing a Transit Performance-Measurement System*, the Transit Cooperative Research Program (TCRP) points out the four key perspectives that come into play when considering performance. These are summarized in Table 2-3, along with their corresponding performance metrics [15].

Table 2-3

Stakeholder Points of View on Performance

Perspective	Areas of Focus	
Customer	• Spatial availability • Temporal availability • Information availability • Capacity availability • Comfort	• Service delivery • Travel time • Safety and security • Maintenance • Customer satisfaction
Community	• Provision of transportation to persons without ready access to private automobile • Reduction of air pollution • Travel when an automobile is not available • Parking congestion mitigation • Reduction of traffic congestion	• Job accessibility • Taxes directly or indirectly paid for transit service • Visual attractiveness of public facilities • Loud noise or diesel fumes from buses • Perception of waste or inefficiency of bus service • Empty buses
Agency	• Operating efficiency • Operating effectiveness • Organizational performance	• How well the service is working • Customer and community concerns
Vehicle/driver (vehicle-oriented)	• Vehicle capacity • Roadway capacity • Presence of transit signal priority	• Traffic congestion • System speed • Delay

Transit Agency Goals

Nine high-level agency goals emerged from the scan of literature, transit agencies, MPOs, and municipalities. These goals provided a generalized framework in which to consider performance metrics for transportation agencies in general. MOD partnership values can be evaluated to the degree that those partnerships support these goals. Table 2-4 summarizes the nine goals/goal areas and their definition.

Table 2-4

High-Level Transit Agency Goals

Goals Area	Definition
Connectivity	Usefulness, quality, and accessibility of service
Financial Management	Financial sustainability of agency and effective allocation of resources
Planning	Community engagement, economic development, land use decisions, and system planning
Environmental Sustainability	Environmental footprint of agency
Equity	Availability and usefulness of system for all people
Safety and Security	Ability to protect system, riders, and employees from harm
Customer Satisfaction	Rider happiness with system
Organizational Excellence	Capacity of agency to deliver transportation services
State of Good Repair	Maintenance of transportation system to protect long-term investment of infrastructure

Gap Analysis

Gap analyses were conducted to identify the challenges and opportunities that exist between measuring the performance of transit systems as a stand-alone system versus the performance of transit systems as part of an integrated system with other mobility services. Primary foci were capturing the emphasis of traveler-centric concepts of new mobility services and the constantly evolving expectations of travelers in terms of time, reliability, cost, and availability of options.

Gaps in Achieving USDOT Goals and Strategic Objectives

As included in the *U.S. Department of Transportation Strategic Plan for FY 2018–2022*, each USDOT goal has strategic objectives, and each strategic objective has multiple strategies to contribute to achieving the specific strategic objective and its overlying goal. System performance strategies are included under the Safety and Infrastructure goals, and a programmatic performance strategy is included under the Accountability goal. Furthermore, partnerships and collaborations are also part of the USDOT strategies under the Safety, Infrastructure, and Innovation goals. This is particularly important because public- and private-partnership-based performance metrics are not very common. Mobility and provision of mobility services are often products of public/public partnerships and collaborations, so development of performance metrics and performance measurement in integrated mobility systems become essential. Table 2-5 summarizes the strategies associated with performance and partnerships/collaborations.

Table 2-5 *Performance and Related Strategies to Reach USDOT Goals and Strategic Objectives*

Goal	Strategic Objectives	Strategy(ies)
Safety	Systemic Safety Approach	*Performance* – Promote the use of performance-based safety standards and measures
Infrastructure	Project Delivery, Planning, Environment, Funding and Finance	*Partnerships* – Build partnerships with stakeholders to facilitate financing, development, and implementation of multimodal transportation projects that improve connectivity, accessibility, safety, and convenience for all users
Infrastructure	System Operations and Performance	• *System Reliability* – Improve reliability and efficiency of passenger travel and freight movement on nation's transportation systems by working with state departments of transportation and other stakeholders to identify, collect, and analyze data sources and models to assess overall system reliability and implement strategies that target sources of unreliable travel and freight movement • *Performance* – Measure performance of transportation systems and support targeted investments to improve experience of traveling public

Goal	Strategic Objectives	Strategy(ies)
Innovation	Development of Innovation	• *Partnerships* – Partner with private sector, state, tribal, and local governments, and research organizations to encourage technology innovation • *Data* – Facilitate development of data systems to support data-driven technologies, decision-making in real time, and data sharing
Innovation	Deployment of Innovation	*Collaboration* – Facilitate private sector and multimodal stakeholder collaboration to improve transportation safety and performance

Gaps in Incentivizing Integrated Mobility Services

Similar to the gaps identified in the USDOT goals and strategic objectives, FTA or transit agency efforts to measure performance are not comprehensive enough to cover the mobility partnerships, especially when multiple providers from the private sector are involved in the partnerships. For many regions, provision of first/last mile services by the private-sector MSPs is an integral part of regional mobility performance, especially from the traveler perspective because it involves availability of options, which are not reflected in the overall performance of the regional system. Furthermore, there are instances in which the transit-only performance measurement goals and objectives could contradict regional mobility goals. For example, ridership metrics can disincentivize agencies from partnering with private providers because trips made with private services are not counted in current FTA funding formulas. A stronger connection between FTA goals and mobility performance measurement and the connection between mobility performance and funding could effectively influence how transit agencies form partnerships and how they approach service provision and delivery. However, measurement of multi-provider and multi-agency mobility is somewhat restricted given the availability of data and the metrics that would set the goals for mobility performance measurement.

Some integrated transit–department of transportation agencies, such as the San Francisco Municipal Transportation Agency and London's Transport for London, use more comprehensive, multimodal performance metrics, in part because both agencies govern their local streets, transit, taxis, bicycles, and the pedestrian environment. This multimodal approach presents a good starting point from which to measure performance from an integrated mobility perspective. Although these agencies collect traditional data, such as bunching and gaps in bus service, they are also well-situated to consider all measurements together to provide a more comprehensive evaluation of overall transportation system performance. This would ideally include an understanding of complete, door-to-door trips and customer perceptions across multiple modes.

Gaps in Equity and Access

The novelty of integrated mobility ensures that there is much left to learn. Several gaps remain to be filled with a better understanding of multimodal performance metrics. In some cases, existing metrics are still relevant and may even be ideal; in others, a more radical change may be required to understand performance in a meaningful way. In addition to operational, efficiency, financial, and effectiveness of systems, *equity* is one of the areas in which performance metrics are inconsistent, and a critical gap remains when performance is measured from traveler perspectives. The few existing metrics used by agencies to measure accessibility in compliance with the Americans with Disabilities Act (ADA) have to do primarily with paratransit availability, usage, and ADA complaints. Specific Federal reporting requirements for accessibility for people with disabilities in transit merits more detailed exploration, given the ADA's requirement for non-discrimination or equivalent service. The most recent version of FTA Circular C4702.1B [21] describes requirements that all FTA recipients must follow to ensure that their programs, policies, and activities comply with FTA's Title VI requirements. However, accessibility of vehicles or services provided by MSPs is not within FTA's domain of policies, requirements, or regulations, because MSPs typically are not FTA funding recipients.

Gaps in Land Use, Economic Opportunities, and Mobility Options

Due to its close dependency and interdependency relationship with transportation and mobility, land use provides a significant challenge to measuring performance. Evaluations have focused mainly on planning outcomes that are process-oriented and focus less on empirical observable impacts for performance measurement. Researchers and agencies have recommended some paths forward, encouraging agencies to look at the number of job opportunities and commercial services within 30-minute travel distance of residents. This 30-minute metric can be expanded or retracted based on the availability of mobility options in a region. For example, the availability of private-sector mobility services, such as ridesourcing and bikesharing, and the walkability of pedestrian paths that lead to transit and mobility services also play a role in the overall mobility performance measurement. Some metrics of pedestrian and bicycle performance have been challenging to measure but are becoming increasingly feasible with the support of new data (e.g., cell phone and GPS tracking data).

Evaluation of Current Mobility Performance Goals

In addition to traditional single-system transit performance objectives, current measures of success across current MOD Sandbox projects were evaluated. MOD projects were selected based on their context and closeness to FTA's integrated mobility vision. The data assessment efforts also document the performance metrics that track those success measures, both as measured currently and how they would ideally be measured in the future.

During this phase, stakeholder interviews were conducted with persons from USDOT, contractors involved in the independent evaluation of MOD projects, and selected transit agencies to understand the drivers of success for MOD programs. A literature review of transit agency measures of success also was conducted. Based on the interviews and literature review, nine categories emerged as elements of current evaluation criteria and measures of success, as shown in Figure 2-1.

Figure 2-1

Current Performance Measurement Categories

During the evaluation process, many transit agencies and partnerships emphasized that there was room for improvement to capture the ideal state of the performance under several of the performance objectives, such as the customer satisfaction, time and cost effectiveness, reliability, availability, and accessibility. These performance metrics and their objectives are well-aligned with the considerations summarized in Tables 2-3 and 2-4 as well as the overall strategic objectives of the USDOT, as included in Table 2-5.

Development of MPM

A trend in the transportation industry is use of traveler-centric performance metrics to measure outcomes such as customer satisfaction, reliability, time and cost effectiveness, similar to those shown previously in Table 2-3. Joseph S. Sussman captured this perspective in his book *Perspectives on Intelligent Transportation Systems (ITS)* by saying "performance metrics should matter to the customer of the system, and further, should be something the manager is convinced matters to the customer" [22]. Ultimately, more complete knowledge of how customers plan and experience their trip in the context of their personal needs and preferences will allow the system to evolve to provide better, more desirable service to customers.

> Performance metrics should matter to the customer of the system, and further, should be something the manager is convinced matters to the customer.
>
> *– Joseph S. Sussman*
> *Perspectives on Intelligent Transportation Systems (ITS)*

Most existing metrics focus on measuring the operations of each mode or segment of a traveler's trip. Many of these metrics are created and used by agencies to measure their own performance but lack the focus necessary to capture the performance from the traveler's perspective. The MPM developed in this research were developed to capture the performance of an integrated mobility system. Under composite trip environments in which the segments of a trip are composed of modes from multiple providers, such as FTA's Complete Trips for All concept, the prevailing performance metrics are most likely to fail at fully capturing the performance of "integrativeness" of multimodal, cross-modal, and multi-provider on-demand trips. New higher-level metrics that capture the full impacts of a transportation system on those who use it—and on the larger community—will result in more informed decision-making by elected officials and transportation agency leadership.

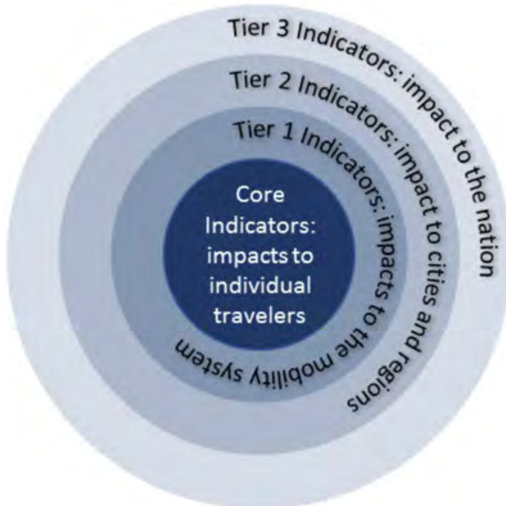
MPM Structure, Goals, and Objectives

The goal of developing and using a new set of performance metrics is to measure how well integrated transit and mobility meets the needs of individual travelers, how well the system performs while meeting travel demand, and what the system's impact is regionally and nationally. By measuring transportation performance from the traveler perspective, agencies and operators can be incentivized to improve service based on what matters most to travelers. Governments at all levels can also understand what impacts integrated mobility may have on issues important to their constituents, be it the economy, the environment, or another area that transportation may influence.

Based on the information gathered during the literature review, interviews, analyses, and evaluations previously noted, a-tiered structure was developed to address interfused objectives of public transportation, mobility, travelers, and national interests. The MPM were developed with a core section that was designed to measure performance as it impacts individual travelers. This core is followed by three tiers designed to measure performance of a given mobility system (Tier 1), a city and/or region (Tier 2), and national-level performance (Tier 3). A mobility system, in this context, is an integrated system of multimodal, cross-modal, and multi-provider multimodal, cross-modal, and multi-provider (i.e., public and private providers) on-demand trips. Figure 2-3 illustrates this concept. The following paragraphs explain the performance measurement goals and objectives for each tier.

Figure 2-2

Multi-tiered Structure of MPM



Core – Traveler-Centric Measures

According to FTA's published documents, the primary goals of the MOD concept are to improve transportation efficiency, increase transportation effectiveness, and enhance the customer experience. Core performance metrics were designed to measure these goals from the traveler-centric perspective, specifically how an individual traveler views his/her trip experience through five factors that affect transportation efficiency and effectiveness and the overall experience—time, budget, reliability, safety, and availability. By using these traveler-centric core performance metrics, government agencies, MSPs, and other stakeholders can begin to evaluate how MOD compares to prior service models and how different projects are succeeding in meeting the goals of their travelers. Once implementation of integrated mobility has increased, a different set of core performance metrics will also be developed to track the maturation of MOD, rather than compare MOD to prior service models.

Transportation has a much broader impact than just the immediate trip experience of individual travelers as measured by the core performance metrics. To measure those broader impacts, Tier 1, Tier 2, and Tier 3 performance metrics were developed.

Tier 1 – System-Centric Measures

Tier 1 metrics measure the impact MOD has on the transportation system and how well the system serves travelers. Categories include System Capacity, Utilization, and Effectiveness. Tier 1 also measures the geographic accessibility of neighborhoods and how easy or difficult it may be for specific populations to access their community.

Core and Tier 1 MOD performance metrics capture the transportation system at the individual traveler and local system levels. The Core metrics aim to measure how well the transportation system is performing from the traveler perspective against the criteria that matter most to individuals. For systems that seek to meet the needs of individual travelers, these performance metrics should be the primary means of measuring service quality. Tier 1 metrics measure system performance in categories such as Capacity and Utilization. These metrics can give insight into how efficient a transportation system is running, and if there is any excess capacity or need for adjustments.

Tier 2 – Regional Perspective Measures

Tier 2 metrics aim to measure the impacts of the transportation system at the regional level. Whereas meeting the needs of the individual traveler may be the primary function of a transportation system, this system also leaves a footprint that can impact a region's economy, accessibility, environment, or safety. This footprint can be measured through Tier 2 performance metrics, which measure the secondary impacts of transportation. The primary performance measures attempt to capture the impact or contribution of the integrated mobility system to the overall regional mobility while also evaluating those impacts/contributions from multiple perspectives such as sustainability, reliability, accessibility, programmatic effectiveness and efficiency, access to employment/healthcare/educational opportunities, economic development opportunities, and land use/transportation connections. Furthermore, this tier includes impacts to the regional economy, environment, safety, and social equity.

Tier 3 – National Perspective Measures

Tier 3 metrics evaluate the impacts of all jurisdictions and regions collectively. This will give a national picture of the impact of MOD and should be applied by Federal agencies to capture a national perspective. Ultimately, Tier 3 presents an opportunity to qualitatively and quantitatively measure the impact of integrated mobility on the nation based on a series of econometric and transportation forecasting models. These macro-level impacts include categories such as Economic Growth, Socioeconomic Impacts, Accessibility, Service to Transit-Dependent Population Groups, Impacts or Contributions to Meeting USDOT/National Goals and Associated USDOT Investments, Long-Term Sustainability Goals, Effectiveness of Social Programs, Environmental Goals, and Nationwide Workforce/Employment Impacts.

To illustrate the different levels of performance measurement, Figure 2-3 lists the overall goals of the MPM classified into Traveler, System, Regional, and National categories to align with the tiered structure, and Figure 2-4 summarizes the key objectives of MPM.

Figure 2-3

Goals of MPM

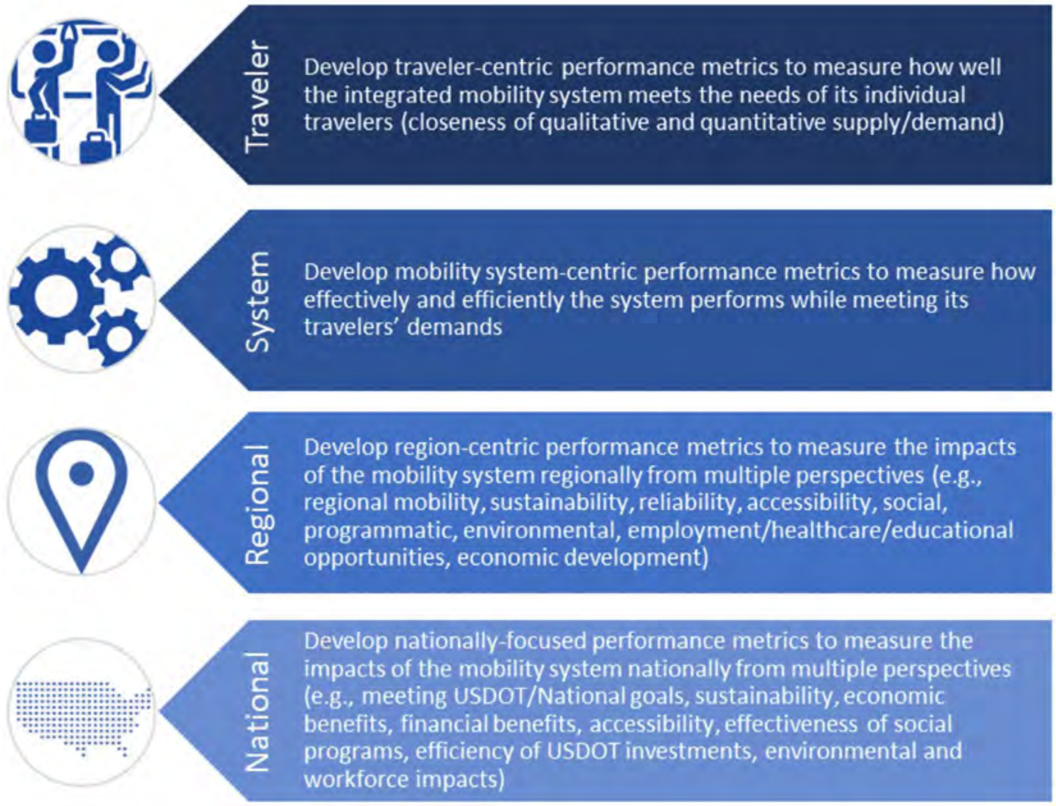


Figure 2-4 *Objectives of MPM*

Trip Stages

To be aligned with FTA's current complete trip concept, each metric within the tiers was placed into a trip stage bin to measure the performance at pre-trip (planning), trip (operations), and post-trip (feedback/experience). Figure 2-5 illustrates these three different trip stages along with the possible steps within each stage considering today's contemporary trip planning, execution, and feedback environments such as using real-time information and mobile devices.

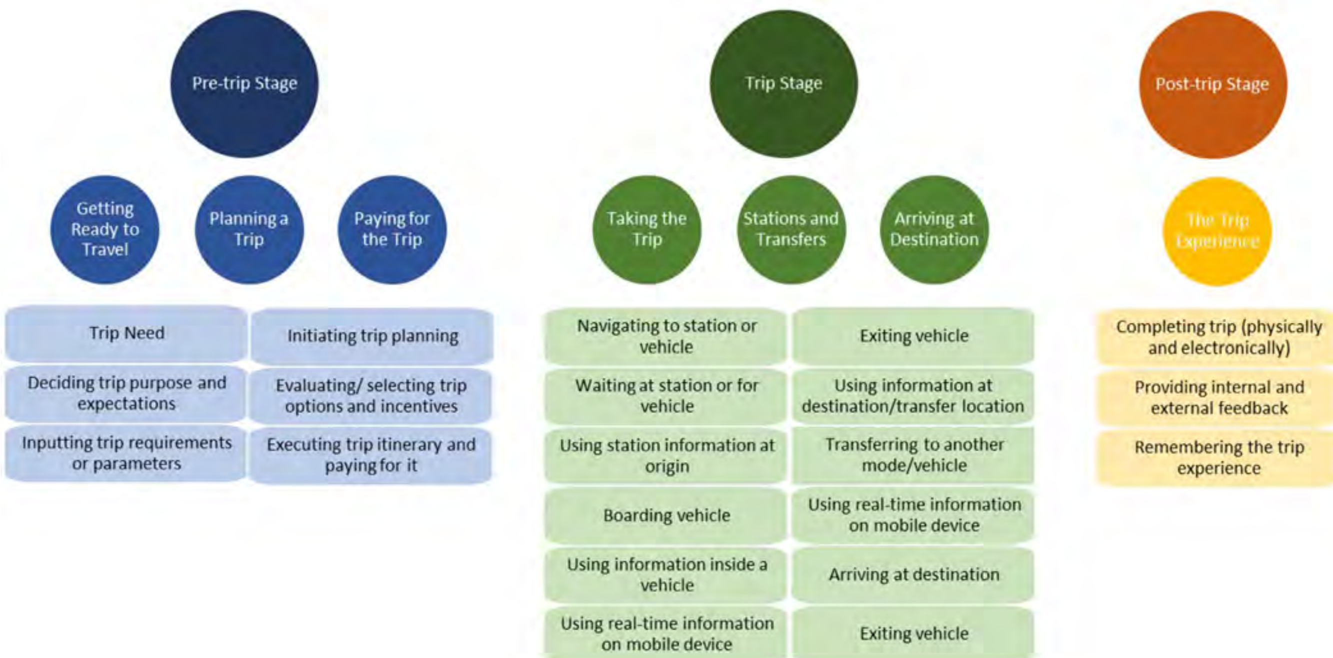


Figure 2-5 *Stages and Steps in a Contemporary Trip (Using a Single Transfer Example)*

Pre-trip Stage (Planning-Level Data for Planning and Predictive Analytics)

Before travelers leave their front door, their trip is already shaped by the transit agency or MSP pre-trip planning process. This is called the pre-trip phase. This phase encompasses decisions regarding the trip purpose; time constraints such as arrival time requirements; special needs requirements such as accessible vehicles, price, and itinerary discovery; comparing options (and incentives, if any); and deciding on which trip itinerary to accept. Data used to inform performance metrics at this phase can be captured by the user's trip planning habits (e.g., phone apps, surveys to uncover habits of those who do not use apps). There are few existing metrics that capture the decisions in this phase. Understanding the factors of how travelers choose to make a trip is essential to improving an on-demand transportation system such as the ones being tested under MOD.

Trip Stage (Operational-Level Data for Real-time and Predictive Analytics)

Once travelers embark on their trip, measurements for this segment are captured in the trip phase. This phase covers the period from when travelers leave their origin, through any connections or changes to their trip, until they reach their destination. Most existing transportation metrics focus on the different trip segments or modes that travelers take in this phase. The metrics presented here evaluate the operations of all segments of the trip together.

Post-trip Stage (Feedback/Experience Data for Planning and Predictive Analytics)

When travelers reach their destination, they enter the post-trip phase until they start to plan their next trip. Measures in this trip phase focus on the traveler experience with the trip and how that feedback will shape the planning for the next trip.

MPM

In addition to tiers and trip stages, the metrics were also sorted into five categories of traveler experience (Time, Budget, Reliability, Availability, and Safety). Each metric was related to an associated traveler question that the metric is attempting to measure. The unit of measurement was shown along with a description of the performance metric and the potential external and internal factors that would affect it, such as weather, peak demand, and day-of- week. The final element in the development of the metrics was a list of the potential data that would be required to measure each metric. Availability of and constraints associated with the required data were assessed during the Data Assessment activity in the Development Phase. Tables 2-6 through 2-9 show the MPM, along with details such as the traveler question that each metric aims to answer, unit of measurement, external factors potentially effecting the measure, the type of data that would be required to functionalize the metric and its measurement, and the brief justification regarding the reason about the inclusion of that metric.

After the performance metrics were developed, an assessment was done of the applicability of those metrics to the current mobility performance measurement goals of agencies involved in MOD and similar mobility integration projects, as well as the feasibility of measurement of those goals from a data availability and constraints perspective. Based on data availability and constraints, a map was developed to chart the data gaps (challenges) and redundancies (opportunities). Leveraging the findings of the above process, a set of data tables and elements was developed. During the redundancy evaluation stages, these data elements were used to display any mathematical equations required to compute the desired performance metrics. Based on the above analyses and findings, a prioritization list was developed to collect, sanitize, format, and analyze data and compute the metrics developed under the MPM. This process was necessary to functionalize the MPM.

Table 2-6 *Core (Traveler-Centric) Performance Metrics*

Category Code	Category of Performance Metric	Trip Stage	Traveler Question	Performance Metric	Unit of Measurement	Metric Description	Factors Affecting Metric	Data Required	Justification
C1	Time	Pre-Trip	Can I depart within the times I want to so I can arrive within the time window I want to?	Offset time	Minutes	Difference in the time between preferred departure/arrival time window and actual departure/ arrival time	Pricing, mode availability, congestion, traveler's schedule, and flexibility	Trip planning inputs, actual departure, and arrival date and time	Determines whether the mobility system can physically complete the trip the user wants to make
C2	Time	Pre-Trip	How long in advance do I need to know that I want to travel?	Spontaneity time	Minutes	Difference in time between being ready to travel and earliest departure time	Reservation lead time, wait time, mode choice, trip preference, time of day	Trip planning inputs, reservation policies, reservation date and time, actual departure date and time	Determines how responsive the mobility system is to the travel the user wants to take
C3	Time	Pre-Trip	How easy is it to plan my trip?	Trip planning and booking experience	Survey rating	Traveler satisfaction with trip planning and booking process	Quality and design of app, speed and reliability of network connection provided to traveler, website, call center, real-time data availability	Booking time, availability and accuracy of real-time information, survey of travelers	Determines how effective trip planning is and whether travelers can do it during their trip
C4	Time	Pre-Trip	How easy is it for me to plan and book my trip?	Trip planning and booking experience	Survey rating	Traveler satisfaction with trip planning and booking process	Quality and design of app, speed and reliability of network connection provided to traveler, website, call center, real-time data availability	Booking time, availability and accuracy of real-time information, survey of travelers	Determines how efficient trip planning is and whether travelers can do it during their trip
C5	Time	Trip	How long do I have to wait until my trip begins if requested immediately?	Wait time	Minutes, seconds	Amount of time between end of trip planning and beginning of trip	Supply of transportation, modal capacity, temporal demand based on time-of-day and day-of-week, reliability of service	Reservation date and time, actual departure date and time	Determines the amount of time for the mobility system to meet the demand of a traveler

Category Code	Category of Performance Metric	Trip Stage	Traveler Question	Performance Metric	Unit of Measurement	Metric Description	Factors Affecting Metric	Data Required	Justification
C6	Time	Trip	How long will my trip take until I am at my destination?	Travel time	Minutes, seconds	Amount of time walking to access and in-vehicle	Access distance, capacity, congestion, mode choices, weather, incidents, system delay (due to maintenance, events, or incidents), time-of-day, day-of-week, pricing	Actual departure and arrival date and time, origin, destination, pickup point, drop off point	Determines how long the operations portion of the trip phase will take
C7	Time	Trip	How long does my connection take before my next leg of my trip begins?	Connecting time	Minutes, seconds	Difference between alighting from first vehicle/mode and getting back on the trip on second vehicle/mode	Supply of transportation, reliability of service, accuracy of real-time algorithms, accuracy of real-time information	Actual wait time(s) at connection points	Determines how much of the trip phase will be taken up by connecting between two services in the same trip
C8	Time	Trip	How long will my total journey time be?	Total journey time	Minutes, seconds	Wait time plus trip time plus connecting time	Supply of transportation, reliability of service, access distance, congestion, mode choices, weather, incidents, system delay (due to events or incidents), time-of-day, day-of-week, modal pricing	Reservation date and time, actual arrival date and time	Determines the total time the trip phase took
C9	Budget	Pre-Trip	Are trip options offered at a reasonable price as determined reasonable by the traveler?	Trip prices	Dollars, cents	Price of each trip available	Supply of transportation, demand, subsidy available, policies, traveler price preference	Trip planning inputs, prices of offered trips before booking, traveler survey	Captures the user-acceptability of the price of the trips provided by the mobility system
C10	Budget	Pre-Trip	Are the trip options I want at prices I am willing to pay?	Trip prices	Dollars, cents	Price of each trip that is within traveler's travel time and mode preference (potentially to be determined by clustering user preferences and schedule flexibility)	Supply of transportation, demand, subsidy available, policies, traveler preferences	Trip planning inputs, prices of offered trips before booking, trip options offered before booking	Determines how many of those trips fall within the range considered reasonable by the traveler

Category Code	Category of Performance Metric	Trip Stage	Traveler Question	Performance Metric	Unit of Measurement	Metric Description	Factors Affecting Metric	Data Required	Justification
C11	Budget	Pre-Trip	How much value can I derive from each trip option?	Trip value	Index of dollar per travel speed, or dollar per value item	Price of trip component that is important to traveler	Supply of transportation, demand, subsidy available, policies, traveler preferences	Trip planning inputs, prices of offered trips before booking, trip options offered before booking	Determines which trips the traveler will take at certain price points
C12	Budget	Pre-Trip	Are trip prices predictable?	Trip price predictability	Percentage	Variability of trip price for similar [ ] itineraries for the same traveler	Surge pricing, supply of transportation, demand	Prices offered for each option available per trip (pre-trip estimate and actual cost), origin, destination, time and date stamp	Determines whether a trip is predictably priced across time
C13	Budget	Pre-Trip	Are trip prices consistent?	Trip price consistency	Percentage	Variability of trip price for similar [23] itineraries between different travelers; variability of trip price for similar [23] itineraries for the same traveler	Surge pricing, supply of transportation, demand	Prices offered for each option available per trip, origin, destination, time and date stamp	Determines whether a trip is predictable priced across different travelers
C14	Budget	Post-Trip	Is the price I was quoted the actual price I paid?	Price accuracy	Percentage	Difference between quoted and actual trip price	Congestion, policies, trip planning data quality	Price of booked trip before booking, actual price paid of booked trip	Determines the difference in the price paid by the traveler at the end of the trip, compared to the estimate they were shown during the pre-trip phase

Category Code	Category of Performance Metric	Trip Stage	Traveler Question	Performance Metric	Unit of Measurement	Metric Description	Factors Affecting Metric	Data Required	Justification
C15	Reliability	Pre-Trip	Can I plan on my preferred trip options being available every day?	Option availability	Percentage	Percent of times when planning a trip that there is at least one trip option available that fits within traveler time, cost, and mode preferences (potentially to be determined by clustering user preferences and schedule flexibility)	Traveler preferences, supply of transportation, demand, congestion, surge pricing, policies	Trip planning inputs, trip options offered before booking	Determines whether the service will be physically available at the cost determined reasonable by the traveler
C16	Reliability	Pre-Trip	Will the same trip options always be available to me for recurring trips?	Option reliability	Percentage	Percent of recurring trips that offer the same menu of trip options	Traveler preferences, supply of transportation, demand, congestion, surge pricing, policies	Trip planning inputs, trip options offered before booking, actual itinerary of booked trip	Determines whether the same selection of trip options will be available
C17	Reliability	Post-Trip	Did my trip take as long as I was told it would take?	Travel time prediction accuracy	Percentage/ minutes, seconds	Percent and absolute difference between predictions and actual travel time	Supply of transportation, demand, congestion, quality of trip planning tools	Predicted journey time immediately before booking, actual journey time of booked trip	Determines the difference between the trip time compared to the estimated trip time
C18	Reliability	Post-Trip	Did my trip cost me as much as I was told it would?	Travel cost prediction accuracy	Percentage/ dollars, cents	Percent and absolute difference between predictions and actual trip cost	Supply of transportation, demand, congestion, surge pricing, policies, quality of trip planning tools	Price of booked trip before booking, actual price paid of booked trip	Determines the reliability of the trip cost estimate
C19	Reliability	Post-Trip	Was my total journey time consistent for similar trips?	Travel time reliability	Minutes, seconds/ index number	Standard deviation of actual total journey time/95th percentile travel time divided by mean travel time	Supply of transportation, demand, reliability of service, access distance, congestion, mode choices, traveler preferences	Actual journey time, actual itinerary of booked trip	Determines whether the traveler's trip time is consistent across time and across users
C20	Availability	Pre-Trip	Are multiple travel options that fit my time, budget, and mode constraints available to me?	Travel option availability, cluster analysis	Number of traveler options	Number of travel options available that fit traveler constraints	Supply of transportation, demand, surge pricing, congestion, traveler preference, policies	Trip planning inputs, trip options offered before booking	Determines how many options the traveler has for these trips that fall within the traveler's stated preferences

Category Code	Category of Performance Metric	Trip Stage	Traveler Question	Performance Metric	Unit of Measurement	Metric Description	Factors Affecting Metric	Data Required	Justification
C21	Availability	Pre-Trip	How many trips were not taken, had to be deferred, or had to be taken in a way that was not preferred?	Trip deferments, cluster analysis	Number of trips deferred/ 100 trips	Number of trips planned but not taken, deferred, or taken in a way outside of traveler preferences	Traveler preferences, supply of transportation, demand, congestion, surge pricing, policies	Trip planning inputs, actual departure and arrival date and arrival time, actual price paid of booked trip, actual itinerary of booked trip, survey	Determines how many trips the traveler planned but did not take
C22	Availability	Trip	Are there redundancies along my trip in case something happens?	Connection redundancy	Number of trip branches available in real-time per trip taken	Number of trip branches providing a similar travel time and cost available in real-time to travelers	Supply of transportation, demand, surge pricing, congestion, traveler preference, policies	Number of comparable trip options immediately available to travelers while they are on their trip	Determines whether the traveler can change to a different service midway through their trip to reach their destination
C23	Safety	Trip	Do I feel safe on my trip?	Safety perception (personal security)	Survey rating	Level of safety felt during all parts of a trip	Design of waiting areas, level of security presence, driver and traveler screening policies, local and regional crime trends	Survey results	Determines travelers' perception of safety on their trip
C24	Safety	Trip	Will I be physically safe on my trip?	Crime rate, crash rate, injury rate	Number of reported crimes, crashes, and severe injuries per 100,000 trips	Crime rate, crash rate, injury rate	Design of waiting areas, level of security presence, driver and traveler screening policies, local and regional crime trends	Number of reported crimes, number of crashes, number of severe injuries	Determines whether the travelers are physically safe on their trip
C25	Safety	Trip	Does the privacy of my trip and my data meet my preferences?	Met Privacy Preference (y/n)	Survey rating	Level of privacy felt during all parts of the trip	Traveler preferences, data practices of the providers	Trip planning inputs, data sharing policies of transportation providers, actual itinerary of booked trip, survey	Determines whether the travelers' trip data meet their privacy preferences

Table 2-7 *Tier I (System-Centric) Performance Metrics*

Category Code	Category of Performance Metric	Trip Stage	Mobility System Question	Performance Metric	Unit of Measurement	Justification
T1.1	Capacity, Effectiveness	Trip	What is the maximum number of trips that can be served by the system? How well is supply meeting demand?	Maximum number of trips per hour	Trips taken	The mobility ecosystem's capacity and ability to provide the appropriate supply affects traveler departure and arrival times, wait times, and booking experience. Capacity is measured in maximum number of trips per hour. Effectiveness captures how well supply meets demand. Lower wait times and travel times would indicate supply is meeting demand. Increases in deadheading or hours of the day with surge pricing reveal excess or tight supply, respectively.
T1.2	Capacity, Effectiveness			Median wait time	Minutes, seconds	
T1.3	Capacity, Effectiveness			Number of deadheading (no travelers in the vehicle) miles per day	Miles/24 hours	
T1.4	Capacity, Effectiveness			Number of deadheading (no travelers in the vehicle) hours per day	Hours/24 hours	
T1.5	Capacity, Effectiveness			Median hours per day with surge pricing	Hours with surge pricing	
T1.6	Cost, Effectiveness, Efficiency	Post-Trip	What is the cost of the system to the owner (government) and to the user?	Annual system subsidy	Dollars, cents	One of the primary inputs of any transportation system, including the mobility ecosystem, is funding. These metrics capture how much input is required to operate the mobility ecosystem, and how much of it comes from the owner (most likely the public via the state) or user. Effectiveness and efficiency metrics also play a role. If supply does not meet demand, it is expected that costs would rise.
T1.7	Cost, Effectiveness, Efficiency			Subsidy ratio	Ratio of what the user pays/cost of providing the service	
T1.8	Cost, Effectiveness, Efficiency			Median trip fare	Dollars, cents	
T1.9	Cost, Effectiveness, Efficiency			Median trip cost	Dollars, cents	
T1.10	Cost, Effectiveness, Efficiency			System cost per revenue mile	Dollars/revenue mile	
T1.11	Cost, Effectiveness, Efficiency			System cost per revenue hour	Dollars/revenue hour	
T1.12	Effectiveness, Efficiency	Trip	How well is supply meeting demand? Does supply reliably meet demand?	Median wait time	Minutes, seconds	Traveler wait time, journey time, and ability to travel on their preferred option are dependent on the mobility ecosystem's ability to match supply to demand. Day to day reliability is perceived by travelers as the system's ability to consistently match supply to demand. Otherwise wait time will fluctuate, as will pricing.
T1.13	Effectiveness, Efficiency			Standard deviation of wait time	Standard deviation	
T1.14	Effectiveness, Efficiency			Number of deadheading miles per day	Miles/24 hours	
T1.15	Effectiveness, Efficiency			Number of deadheading hours per day	Hours/24 hours	
T1.16	Effectiveness, Efficiency			Median hours per day with surge pricing	Hours/24	
T1.17	Effectiveness, Efficiency			Standard deviation hours per day with surge pricing	Standard deviation	

Category Code	Category of Performance Metric	Trip Stage	Mobility System Question	Performance Metric	Unit of Measurement	Justification
T1.18	Utilization	Trip	How many people are using the system? How intensely are people using the system?	Number of planned trips per hour	Trips planned/hour	These metrics will determine the actual number of how many travelers are using the mobility system that is provided, when, and where they are using it.
T1.19	Utilization			Number of linked trips per hour	Linked trips/hour	
T1.20	Utilization			Passenger revenue miles per year	Revenue miles/365 days	
T1.21	Utilization			Passenger revenue hours per year	Revenue hours/365 days	
T1.22	Utilization			Number of linked trips per vehicle revenue mile	Linked trips/vehicle revenue mile	
T1.23	Utilization			Number of linked trips per vehicle revenue hour	Linked trips/vehicle revenue hour	
T1.24	Safety	Trip, Post-Trip	How safe is the system?	Fatality or serious injury per 100,000 trips	Killed or seriously injured rate (ksi)/ 100,000 trips	The success of the mobility system will be determined by whether it makes travelers safe. These metrics will measure that.
T1.25	Security			Incidence of crime per 100,000 trips	Crime reported/ 100,000 trips	

Table 2-8 *Tier 2 (Region-Centric) Performance Metrics*

Category Code	Category of Performance Metric	Impact Stages	Performance Metric	Unit of Measurement	Justification
T2.1	Economic	Regional (MPO Level)	Number of jobs and other destinations in the region that can be reached in 15, 30, and 45 minutes from a person's origin (potentially, ZIP code)	• Number of jobs accessible • Off-peak access to jobs by public transportation	Determines whether the mobility system is increasing access to jobs and increasing the gross domestic product of each region
T2.2	Economic	Local (County/City/ Municipality)	Economic development	Annual percentage of growth in GDP that can be attributable to mobility integration and improved mobility to access opportunities	
T2.3	Mobility	Regional (MPO Level)	Effective service area/coverage	• Square miles of area provided service • Public transportation travel time reliability (based on day-to-day variation) • Number of high-quality transportation options available	Determines the physical area covered by the mobility system and the jobs and residents to which it provides access
T2.5	Mobility	Local (County/City/ Municipality)	Reduction of trip times	Median journey time	

Category Code	Category of Performance Metric	Impact Stages	Performance Metric	Unit of Measurement	Justification
T2.6	Accessibility	Local (County/City/ Municipality)	Impact on accessibility	Difference journey time between jobs and residences reached by those with different physical abilities	Determines the accessibility of the mobility system by each jurisdiction
T2.7	Financial	Local (County/City/ Municipality)	Budget spent on transportation	Monthly cost of public transportation as a share of local census tract median monthly income	Determines the cost of the mobility system to each jurisdiction
T2.8	Safety/Public Health	Local (County/City/ Municipality)	Incidence of fatalities or serious injuries per capita	Fatalities and disabling injuries per capita	Determines the safety of the mobility system within each jurisdiction

Table 2-9 *Tier 3 (National) Performance Metrics*

Category Code	Category of Performance Metric	Impact Stages	Performance Metric	Unit of Measurement	Justification
T3.1	Economic	National	Increased access to jobs and other destinations	Median number of jobs that can be accessed in 45 minutes	Determines whether the mobility system is increasing access to jobs.
T3.2	Economic	National	Reduced transportation and living costs	Monthly cost of transportation as a share of local Census tract median monthly income	Determines the cost burden the mobility system places on travelers.
T3.3	Economic	National	Economic development	Growth in National GDP	Determines the impact of the mobility system in supporting GDP growth.
T3.4	Social	National	Alignment with national goals	Qualitative measures	Determines whether the mobility system is supporting the nation's qualitative goals.
T3.5	Accessibility	National	Impact on accessibility	Difference between jobs and residences reached by those with different physical abilities	Determines whether the mobility system is increasing the access of those with disabilities.
T3.6	Accessibility	National	Amount spent on transportation that increases access	Dollars, cents	Determines the cost per unit of increased access to jobs and residences.
T3.7	Safety/Public Health	National	Incidence of fatalities or serious injuries	Fatalities and disabling injuries per capita	Determines how safe the mobility system is at a national level.

Future Metrics

Table 2-10 shows the MPM that are for the future in which a system is developed to allow the methods to capture the required data and MOEs to measure such metrics.

Table 2-10 *Future Performance Metrics for Consideration*

Category Code	Category of Performance Metric	Trip Stage	Traveler or System Question	Performance Metric	Unit of Measurement	Indicator Description	Factors Affecting Indicator
F1	Future	Pre-Trip	[Traveler question]: Am I unable to take this trip due to options not matching my trip preferences and cancel the trip?	Trips not taken	• Number of trips not taken • Reason/factors that contributed to the traveler's decision	Measures how travelers respond to the travel options they are presented and measures the impact of the travelers' decision of not taking a trip on their travel experience	Supply of transportation, demand, pricing, congestion, traveler preferences, incentives (if present)
F2	Future	Pre-Trip	[Traveler question]: Am I unable to take this trip due to options not matching my trip preferences and postpone it for another time?	Trips postponed	• Number of trips postponed • Reason/factors that contributed to the traveler's decision	Measures how travelers respond to the travel options they are presented and measures the impact of the travelers' decision of postponing a trip on their travel experience	Supply of transportation, demand, pricing, congestion, traveler preferences, incentives (if present)
F3	Future	Pre-Trip	[System question]: How do we measure the effect of a trip not taken and the decision is associated with the options not being suitable—negative or positive (cost, schedule, station location, accessibility, trip duration, etc.)?	Effect of trips not taken	Number of trips not taken and temporal distribution of those trips along the supply/ demand curve	Measures the impact of the travelers' decision of not taking a trip on the system from supply/demand management and capacity perspectives	Supply of transportation, demand, pricing, congestion, traveler preferences, incentives (if present)
F4	Future	Pre-Trip	[System question]: How do we measure the effect of a trip that is postponed to another time and the decision is associated with the options not being suitable—negative or positive (cost, schedule, station location, accessibility, trip duration, etc.)?	Effect of trips postponed	Number of trips postponed and temporal distribution of those trips along the supply/ demand curve	Measures the impact of the travelers' decision of postponing a trip on the system from supply/demand management and capacity perspectives	Supply of transportation, demand, pricing, congestion, traveler preferences, incentives (if present)
F5	Future	Pre-trip	• [System question]: Can and how dynamically can the system assess the adequacy of optimal supply for the temporal demand throughout the day? • Can the system self-optimize to balance the supply and demand to an equilibrium? • Can the system do that with minimal surplus or shortage?	Mobility dynamicity	Dynamic temporal delta between supply and demand	Real-time balancing of the supply and demand based on optimal efficiency and effectiveness criteria set as localized and temporal equilibriums and desired dynamic balancing and/or tolerance levels	Supply, demand, time-of-day, day-of-week, availability and pricing of modal options, weather, special events

Category Code	Category of Performance Metric	Trip Stage	Traveler or System Question	Performance Metric	Unit of Measurement	Indicator Description	Factors Affecting Indicator
F6	Future	Pre-trip, Trip, and Post-trip (System Level)	[System question]: Can the system place a trip on the system predictively (actively by the pre-trip actions of the traveler and passively by the travelers' known travel patterns)?	Ability and accuracy of the system's predictive demand forecasting (passive and active)	Number of predictive trips and number of actual trips taken that are associated with each predictive trip	Through apps, the system can develop a pattern for specific travelers and use that for predictive demand simulations, or the system can recognize the trip request at the pre-trip stages and burden the system predictively by simulating it as if the trip is taking place	Availability and pricing of options, availability and time constraints for transfers, environmental conditions (weather, congestion, time-of-day, day-of-week) and travelers' decision (plus travelers' decision-making process)
F7	Future	Pre-trip, Trip, and Post-trip (System Level)	[System Question]: Can the system present optimized options based on the predictive analytics results to the traveler for his/her decision-making process (i.e., feedback loop)?	Accuracy of predictive demand	Number of travelers' trip decisions affected by the system's feedback	When the system analyzes the predictive trip demand and simulates the mobility network conditions, it can also optimize the supply/demand based on the forecasted modal congestion levels and present the results of the real-time or predictive analyses as more viable temporal options specific for the travelers' location and preferences	Availability and pricing of options, availability and time constraints for transfers, environmental conditions (weather, congestion, time-of-day, day-of-week) and travelers' decision (plus travelers' decision-making process)

Iterative Performance Measurement Strategy

Although the preferences of individual travelers will likely remain the same—high reliability, fast travel times, on-demand availability (or, at a minimum, faster headways), easy to use, low cost, and safe—the transportation system will continue to evolve to better serve these preferences as technology develops and becomes more widely adopted. New technology may not only change how a transportation system operates; it can also change the availability and quality of data that the system produces, influence ownership and governance structures, and affect other areas as well.

With these potential changes in mind, and with the possibility that traveler preferences may also change, it is important for agencies to periodically re-evaluate their suite of transportation performance metrics. Depending on the changes, some performance metrics may rise in importance while others fall, or new data sources may make a sought after but previously impossible-to-measure performance metrics are now feasible.

The frequency of performance metric re-evaluations should be based on a set of time or event triggers depending on the resources available for any agency to do so. A significant change in technology or in transportation governance would present a good opportunity to make sure that current performance metrics are still fully relevant. Absent an event, a regular FTA review every five years would allow an agency to stay current with traveler preferences and transportation technology without being over burdensome. This review period can be shortened or lengthened depending on agency resources, and the following could be some of the potential review triggers:

- Time-based review (e.g., every 5 years)
- Critical technology change (e.g., fully-automated vehicles replacing manual vehicles)
- Governance change (e.g., significant participation of private sector in delivery of public transportation)

SECTION 3

Data Assessment

Introduction

The second stage in the Development Phase was Data Assessment. It was necessary to identify potential data required for the analyses and measurement of the metrics, as well as to assess data availability and potential constraints associated with that data. This section discusses how the MPM support current goals and objectives of MOD and future integrated mobility projects holistically. It highlights areas in which the new metrics align as measures of performance for the current MOD projects and FTA's objectives for integrated seamless public-private operations, identifies areas where metrics do not capture these objectives, and analyzes challenges in collecting individual metrics. In brief, this effort was undertaken to understand the opportunities, challenges, and gaps to functionalize the MPM.

Data Assessment Approach

Data assessment was conducted as five activities. Brief description of each module is provided below:

1. **Applicability Assessment** – To assess the relevance of the MPM to evaluate MOD and similar projects' efficacy, using the MOD Sandbox projects as tangible starting use cases and extrapolating to future potential use cases. MOD Sandbox projects were selected based on their context and closeness to FTA's integrated mobility vision. During this phase, stakeholder interviews were conducted with persons from the USDOT and contractors who are involved in the independent evaluation of MOD Sandbox projects and development of performance metrics, and a select number of transit agencies to understand the drivers of success for MOD programs.

2. **Feasibility Analysis** – To analyze the identified data elements through research and industry knowledge to determine:
   - If they existed
   - The feasibility of obtaining the data elements
   - How potential providers should be asked for a given data element, also highlighting data sets that are currently unavailable, but in development phases by the agencies or stakeholders

3. **Gap Analysis and Redundancy Analysis** – To compare success criteria and available data sets to identify redundancies and gaps. During this phase, the draft logic was refined, and the metrics were defined combining the relevant data sources.

4. **Prioritization Analysis** – To develop a priority list given applicability, feasibility, and gaps.
5. **Data Integration Strategies** – To outline considerations for data integration and management strategies to achieve the objectives of the performance measurement metrics and how MOD Sandbox projects can be evaluated with the proposed metrics.

Applicability Assessment

To assess the applicability of the MPM, measures of success across current MOD Sandbox projects were determined. The data assessment efforts also documented the performance metrics that track those success measures, both as measured currently and ideally to be measured in the future. Furthermore, the MPM were also mapped to the current success measures and objectives. The applicability assessment was done in three stages:

- Current Evaluation Criteria of MOD Sandbox Projects
- Current Measures of Performance
- Mapping of Current Measures to Proposed MPM

Based on the interviews and literature review, the elements of current evaluation criteria and measures of success were defined and documented across nine goals of MOD projects:

- Customer satisfaction
- Time effectiveness
- Cost effectiveness
- Reliability
- Availability
- Safety
- Accessibility
- Demand for MOD and MOD-like integrated mobility systems
- Knowledge transfer

The proceeding sections present the findings of the applicability assessment for each category of current measurements from the perspectives of the three-stage approach elements and considerations for additional metrics that were uncovered during the applicability assessment process.

Customer Satisfaction

Current Evaluation Criteria

MOD Sandbox projects placed a heavy emphasis on the satisfaction of the traveler. Several agencies' objectives were to improve the quality of service across modes of transportation through their MOD projects. One priority of the agencies was building a high-quality technology platform to enable MOD. Likewise, customer service, especially for disadvantaged populations, was another important factor [24, 25]. Measures ranging from surveys to customer service instances were used to assess customer satisfaction with new MOD systems.

Current Measures of Performance

The following were the key metrics that the agencies used for measuring the level of customer satisfaction. The method of data collection was various survey instruments because surveys provided the voice of the customers in transportation issues. All five projects analyzed used various forms of customer surveys, including app-based surveys and in-person questionnaires for transit users [26, 27, 28].

Table 3-1

Current Measures of Performance for Customer Satisfaction

Metric	Definition/Measure	Importance
Return users	Percent of customers who returned to their service after their first trip	Used as an indication that these customers had a positive initial interaction with the new flex system
Response to customer complaints	Measure of a timely response to customers who have complaints [29]	If customer complaints not addressed in a timely manner, the MOD system may develop a poor reputation in the community

Additional Customer Satisfaction Metrics for Consideration

Among MOD Sandbox initiatives, there was a desire for deeper customer satisfaction metrics to more holistically understand a customer's experience and anticipate the needs of future travelers. The following are the two noteworthy focus areas drawn from the MOD Sandbox use cases:

- **Deeper Customer Satisfaction Survey Measurements/Stronger Feedback Mechanism** – Mobility projects would like to capture additional survey data to better understand how travelers feel about the initiatives themselves. However, agencies involved in the MOD Sandbox projects feel they have an opportunity to interact directly with customers but have had difficulty leveraging feedback across different channels such as through an app or via a customer survey given a greater focus on overall execution of the initiative. One strategy to capture additional feedback would be to develop and implement mechanisms for additional questions on various customer surveys (e.g., app-based real-time feedback, intercept, interviews).

- **Trip Quality Data by Time of Day and Date of Trip** – Operational trip metrics such as wait times, complaints, disruptions to service, etc. at temporal or day-of-the-week level granularity are important to have according to the MOD Sandbox use cases. Mobility initiatives would like to split trip metrics across various times of day or days of trips to understand the performance of an initiative or a service among different populations, transit conditions, and operators. However, the challenge is that granularity of data is not always easily available and data structures are not readily query-able across different mobility systems.

Time Effectiveness

Current Evaluation Criteria

One of the main aspirations of the MOD concept has been to improve the effectiveness of getting travelers where they want to go. For several MOD Sandbox projects, time effectiveness included lowering time spent waiting for various transportation methods. Many agencies also hoped to reduce journey times overall, and it was the aspiration of one of the platforms to allow travelers to make better informed decisions about multimodal transportation methods by providing real-time information on timing of trips. By reducing wait and journey times at the traveler level, transportation agencies and MOD projects can improve time effectiveness across their respective transportation systems [30, 31, 32].

Current Measures of Performance

Given that a key goal of MOD Sandbox projects was to improve the effectiveness of a traveler's trip from origin to destination (final or interim), it is unsurprising that a plethora of metrics exist to assess integrated mobility and MOD's impact on time effectiveness.

Table 3-2

Current Measures of Performance for Time Effectiveness

Metric	Definition/Measure	Importance
Wait time	Time spent waiting for various transit options used during a trip. In the case of on-demand transit, this is the time between scheduling and pick-up. In the case of traditional transit, this is the time between arrival at a stop and being picked up by the vehicle [33,34].	One of the aims of MOD is to be able to provide transportation to passengers on their schedule, thus lowering wait times for various means of transportation.
On-time performance	Percent of time a transportation option arrived within an acceptable window of its scheduled arrival time. For example, the percent of buses that arrived between 1 minute before and 4 minutes after their scheduled arrival time [35].	MOD transport projects aim to provide a reliable and efficient means of transportation, and this is not possible if transportation methods do not run on schedule.

Metric	Definition/Measure	Importance
Dwell times	Time between a vehicle's arrival at a stop and its departure from this stop [36].	Dwell time factors into a transportation vehicle's on-time performance and customers' journey times.
Journey time	Time between departure from original transit location and arrival at final transit destination [37, 38].	Especially for multimodal MOD projects, one of the primary end goals is to reduce journey time by directing passengers to the most efficient routes.

Additional Time Effectiveness Metrics for Consideration

Agency planners are working on leveraging additional data sets to develop a greater understanding of performance across time effectiveness metrics. Table 3-3 summarizes potential metrics that agencies expect to explore further, along with potential challenges associated with them.

Table 3-3

Additional Time Effectiveness Metrics for Consideration

Metric	Definition/Measure	Importance
Wait time data	A measure of customers' wait time for a transportation option, a measure of deviations in wait time across a day, and a calculation of variation in wait time across a system.	Help project planners capture system specific performance and compare performance across transportation options.
	Challenge: Certain mobility projects have had difficulty capturing wait time data. When measuring wait times for public transit, it can be difficulty to accurately link together door open and close times, particularly in relation to transit vehicles servicing the same route. When trying to obtain wait time data from Transportation Network Companies (TNCs), mobility projects have had difficulty with the level of detail that certain TNCs are willing to share.	
Travel time data	Time taken to complete a route (particularly on public transportation).	Measure speed of trip help network planners better understand routes.
	Challenge: Speed and reliability data are often provided through infrequent quarterly reports internal to agency. Furthermore, travel time data, particularly when measured for public transit, capture more variables than just operational performance. For example, it factors in traffic, schedule changes, route extensions, and netting out all these different variables to measure performance is difficult.	
Traffic and O/D data	Traffic data that capture the origin and destination of non-public transportation trips.	Help network planners understand the flow of traffic.
	Challenge: Data are not readily available to all transit agencies.	
Operational data	Count of different operational metrics such as complaints, missed stops, tracked issues.	Measure the operational performance of a system.
	Challenge: Data are not always readily available or aggregated across a system or a network. Data might exist but are difficult to leverage because they could be logged incorrectly.	
Customer pickup and drop-off location data	Exact location a customer was picked up and dropped off.	Measure the way that curb space is used.
	Challenge: TNC providers are hesitant to share pickup and drop-off data with mobility initiatives given concerns over the privacy of their pricing, ride matching, and routing algorithms. A data commons provided by a third party such as SharedStreets may address in the future [39].	

Cost Effectiveness

Current Evaluation Criteria

Cost effectiveness was also an important factor in developing MOD Sandbox projects. Most projects hoped to remain cost neutral or even reduce costs for the transportation agencies involved. Furthermore, cost neutrality for private partners was also important [40, 41].

Current Measures of Performance

As cost effectiveness was another goal of several of the MOD Sandbox projects, several measures of cost effectiveness existed in the performance measurement approach of many agencies.

Table 3-4

Current Measures of Performance for Cost Effectiveness

Metric	Definition/Measure	Importance
Operating cost per revenue hour	Cost of operating the service per hour that it is operational.	Provides a sense of the fixed hourly cost of operating the transit service.
Cost per trip (agency)	For private-public partnerships, particularly with TNCs, another way of measuring this is the amount the private partner charges the agency per trip. For projects that were not private-public partnerships, the calculation of cost per trip was not clearly defined [42].	Gives a sense of how efficiently the transit system transports customers.
Price per trip (traveler)	Average amount paid by a customer per trip.	Price per trip provides a metric for how economically accessible the MOD system is and how MOD has influenced the cost of mobility for riders.
Number of operators in service	Average number of operators in service at the MOD service fleet at a given time.	Number of operators in service is a good proxy for the marginal cost per revenue hour.

Additional Cost Effectiveness Metrics for Consideration

The scan of the industry did not yield to any additional metrics associated with cost effectiveness.

Reliability

Current Evaluation Criteria

While MOD is an innovative, new style of transportation, MOD Sandbox projects recognized the need for it to also be reliable. MOD Sandbox project participants all acknowledged that ease of use was a key factor in developing a MOD system on which travelers could rely. Several agencies involved also stressed that their systems must be reliably available, highlighting that if promised trips were not delivered this would be unacceptable for travelers. Likewise, another agency placed a heavy emphasis on the need for reliable data in its system [43, 44, 45].

Current Measures of Performance

Having a reliable and easy to use system was paramount for maintaining and generating demand for MOD systems; therefore, many of the MOD projects used key metrics to assess reliability.

Table 3-5

Current Measures of Performance for Reliability

Metric	Definition/Measure	Importance
Ease of use	Several agencies referenced surveys, shadowing, or user interface studies to assess how accessible and understandable their system was for the user [46, 47].	A means of transportation will not be used if passengers find it too complicated or confusing.
Accuracy of predicted wait time	Average difference between the wait times predicted for a trip and the actual wait times [48].	MOD transport projects aim to provide a reliable and efficient means of transportation, and this is not possible if transportation methods do not run on schedule.
Accuracy of predicted journey time	Average difference between the time predicted for a trip and the actual time the trip takes [49, 50].	MOD transport projects aim to provide a reliable and efficient means of transportation, and this is not possible if transportation methods do not run on schedule.
Purchase transactions not completed	For MOD projects using an application, this is the percent of purchase transactions completed compared to those initiated [51].	Comparing initiated versus completed transactions provides an indication of how useable the interface is for purchase transactions.
Missed trips	Number of trips booked but not fulfilled by the transportation agency [52].	Especially for those transit options that must be scheduled in advance, when a service has been booked but is not actually provided, this is a metric of an unreliable system.

Additional Reliability Metrics for Consideration

The scan of the industry did not yield to any additional metrics associated with cost effectiveness.

Availability

Current Evaluation Criteria

Augmenting the availability of transportation was a key goal in the implementation of MOD projects. Several projects stressed that improving mobility of residents was a key goal of their projects. Furthermore, it was hypothesized that multimodal trip planning tools would help increase mobility by informing travelers of their available options for getting from one point to another [53, 54, 55].

Current Measures of Performance

Being available to meet demand was critical for sustaining an effective transportation system, as was the availability of multiple options for travelers.

Table 3-6

Current Measures of Performance for Availability

Metric	Definition/Measure	Importance
Number of trip options presented	For trip planning tools, especially multimodal MOD platforms, this is the average number of routes offered to users [56, 57].	Increasing the number of options available was one of the intentions of many MOD pilots, especially those concerning multimodal transportation.
Percent of demand met	Number of trips requested versus the number of trips the mobility program can complete given availability of vehicles or other means of transportation.	If a MOD program is not able to meet demand, it may be important to either allocate more funding or, if costs are already too high, rethink the project altogether. Note initial mobility programs are measuring this metric at the mobility program and not the total system level.

Additional Availability Metrics for Consideration

MOD initiatives have faced difficulty capturing measures of success particularly around equity. Wait times for wheelchair travelers was a measure that was agreed to have substantial benefits when analyzed; however, data are not always easily available. Furthermore, in some cases, the data were found not to be tracked at all.

Safety

Current Evaluation Criteria

Traveler safety continued to be a priority for MOD Sandbox projects. Several projects stressed the need to maintain low crash rates and to comply with safety regulations [58, 59].

Current Measures of Performance

In addition to compliance with local regulations, monitoring the safety of transportation options was critical.

Table 3-7

Current Measures of Performance for Safety

Metric	Definition/Measure	Importance
Number of incidents (crashes) reported	Number of safety incidents reported to transit authorities by passengers or operators [60, 61].	Safety for the public is a high priority.

Additional Safety Metrics for Consideration

It is challenging to measure the changes in safety due to integrativeness of a system; however, as mobility integration demonstrations and subsequent deployments reach certain maturities in their development cycle, additional metrics will surface to measure the safety factors attributable to the integrativeness of systems.

Accessibility

Current Evaluation Criteria

Accessibility to all travelers was critical to the creation of MOD Sandbox projects. Within accessibility, equity of service across travelers with different demographic, location, and economic backgrounds was another priority among MOD Sandbox projects. Most projects included enhancements to accommodate travelers of all abilities, including travelers using wheelchairs. Furthermore, many initiatives included systems for subsidized or low-income travelers, and one project created a phone line to accommodate non-English speaking travelers. MOD Sandbox projects worked to address accessibility of service, accessibility to travelers with disabilities and older travelers, and equity of service among travelers with various backgrounds [62, 63, 64].

Current Measures of Performance

For MOD projects to succeed, it was critical that they be accessible to all passengers. Furthermore, FTA's Complete Trips concept depends on the accessibility of each link along the trip chain of a person.

Table 3-8

Current Measures of Performance for Accessibility

Metric	Definition/Measure	Importance
Satisfaction of transportation disadvantaged travelers	Several agencies conducted surveys specifically of their transportation-disadvantaged travelers, including travelers with disabilities and travelers whose rides required subsidies [65, 66].	These surveys were helpful to compare their satisfaction with the broader traveler pool.
Third party evaluation of WCAG 2.0 rating	One agency planned to hire an independent third party to ensure WCAG 2.0 standards were being met [67].	Compliance with local and federal regulations is important, especially concerning access to public systems.
Trips booked on pre-paid debit cards	Percentage of trips paid for on pre-paid debit cards.	Unbanked travelers have limited options for online transactions, so to see how they were interacting with MOD systems; one agency used this metric to gauge their reach among unbanked travelers.
Wait times for ADA transportation options	Time between a request for a wheelchair-accessible vehicle or transportation option and the arrival of this vehicle or transportation option.	Equity in wait times is just as important as lowering wait times altogether.

Metric	Definition/Measure	Importance
Availability of accurate accessibility data	Percentage of accessible options or obstacles listed compared to the number of accessible options or obstacles shown [68].	Data on accessibility are critical for transportation disadvantaged travelers to make informed travel decisions.

Additional Accessibility Metrics for Consideration

The scan of the industry did not yield to any additional metrics associated with Accessibility.

Demand for MOD

Current Evaluation Criteria

Given that MOD is an emerging form of transportation, most MOD Sandbox projects also emphasized the importance of creating and understanding demand for MOD systems. Several teams explicitly stated creating and assessing demand for their systems as a main goal of their projects. Many agencies interviewed emphasized that increasing ridership and transportation resource utilization were high priorities. Likewise, it was expected that multimodal transportation would increase ridership of public transportation where it had previously been prohibited by first and last mile constraints [69, 70].

Current Measures of Performance

Without sufficient demand, MOD will not be a viable transportation concept. Therefore, monitoring demand for MOD and MOD's impact on demand for transportation resources was important for most projects. Assessing demand was also important for planning purposes to understand how this demand could be met in the future.

Table 3-9

Current Measures of Performance for Demand for MOD

Metric	Definition/Measure	Importance
Number of trips requested or planned	Number of times users interacted with a MOD system interface to either plan or request a trip shows general interest in MOD as an option for transportation [71, 72].	Number of trips planned or requested provides insight into demand for the MOD system.
Number of trips ordered/ purchased	Number of trips booked, and if applicable paid for, through the MOD system [73, 74].	Provides a sense of how effectively MOD systems' offerings match the demands of the users.
Number of trips completed	Number of trips completed by users of the MOD system, especially compared to the number of trips ordered or purchased [75, 76].	Shows how effectively the MOD system gets users from one destination to another.
Number of trips canceled	Number of trips scheduled then subsequently canceled [77].	Provides for useful planning data, especially if rides that are booked in advance are frequently canceled.

Metric	Definition/Measure	Importance
Number of multimodal trips planned/ completed	For those systems that combine multiple means of transportation, this is the number of trips completed using two or more transportation methods (e.g., Light rail + bikeshare + TNC) [78].	Multimodality is part of the core concept of MOD transportation. This is a critical metric to monitor to understand how customers interact with multimodal transit options.
Utilization of vehicles in the fleet	Number of customers in a vehicle divided by capacity of the vehicle.	Provides agencies with a sense of how effectively and efficiently demand is being met.
Perceived utility of the Interface	Can be measured using a survey about how useful customers find the new MOD systems compared to traditional transit systems.	Customer demand is based in part on how useful they find the system.
App-Related Metrics	Several metrics can be used for measuring demand for an app, including the number of downloads, the number of users who interact with the app in a week, and the percent of users who create an account compared to those who log in as a guest [79, 80].	For app-based projects, demand for the app is a good proxy for demand for MOD transit options itself.

Additional Demand for MOD Metrics for Consideration

The scan of the industry did not yield to any additional metrics associated with demand for MOD.

Knowledge Transfer

Current Evaluation Criteria

Since MOD is a relatively new concept in the sphere of public transportation, creating a set of best practices and key insights was a focus of the MOD Sandbox projects. Given MOD Sandbox projects are innovative, they tend to capture new and unique data; projects understand that it is important to differentiate the newer data sets that measure success from the less relevant new data. Projects underscored the importance of documenting lessons learned from private-public partnerships. Many agencies recognized the importance of data generation, and it was hoped that this data collection process and information sharing would allow future metropolitan areas to adapt to changes in mobility [81, 82, 83].

Current Measures of Performance

In order to measure their progress in achieving their goals, the MOD Sandbox projects tracked various measures of success. While the varied nature of the projects and the freedom they were given in determining their own key performance indicators (KPIs) led to a wide range of metrics of success among the projects, the metrics fell within the common goals of the projects.

Table 3-10

Current Measures of Performance for Knowledge Transfer Projects

Metric	Definition/Measure	Importance
Types of data generated	Amount of different types of data is generated by the project. Some examples of data types include location data, route data for buses, financial data, and traveler demographic data.	Various data on the projects provide further insight into the project's success [84].
Feedback (through stakeholder interviews)	One of the most effective ways to gain insight into the process of developing and implementing MOD programs is through interviewing those involved in their creation [85].	Interviews can provide qualitative insight into challenges, successes, and other key information.

Additional Knowledge Transfer Metrics for Consideration

Several metrics were identified for future considerations. Table 3-11 summarizes those metrics, along with potential challenges associated with them.

Table 3-11

Additional Knowledge Transfer Metrics for Consideration

<table>
<tr><th>Metric</th><th>Definition/ Measure</th><th>Importance</th></tr>
<tr><td rowspan="2">Out of network customer journey data</td><td>Customer pickup and drop off data, travel pattern data for out of network customers.</td><td>Out of network customer journey data can help project planners understand the flow of traffic outside of a transportation system or network. The data can be used to influence future network planning and design to enhance mobility more broadly particularly within populations that do not traditionally interact with transportation systems.</td></tr>
<tr><td colspan="2">Challenge: Obtaining data on out of network passengers is challenging. For example, it is difficult to find and survey potential passengers who travel outside of the transit system.</td></tr>
<tr><td rowspan="2">Accuracy and usefulness of data generated</td><td>Accuracy of wait time, journey time prediction data, and qualitative assessment of usefulness of data captured.</td><td>Improve predictions and estimates within mobility programs.</td></tr>
<tr><td colspan="2">Challenge: There are multiple data elements necessary to complete this measurement and coordinating with TNCs to obtain these data can be difficult.</td></tr>
</table>

Mapping of Current Measures to MPM

The MPM were mapped onto current and ideal mobility performance measurements and challenges in obtaining data to measure each metric are highlighted. The mapping emphasized the MPM that are currently applicable to MOD initiatives and those that are ideal goals for future measurements. Additionally, the mapping documents challenges that mobility initiatives face when capturing data to measure each metric. The analysis here focuses on the applicability of the MPM highlighting how the new metrics support current or ideal measurements for MOD Sandbox projects. Finally, the analysis categorized each MPM by an applicability score that highlights the current and future applicability along the following scale.

Table 3-12

Metric Applicability Score and Criter

Applicability Score	Criteria	Definition
1	Aligned with MOD goals under the Performance Measurement Objective categories and widely measured	Metric aligns with goals of MOD Sandbox projects and is currently widely measured
2	Aligned with MOD goals under the Performance Measurement Objective categories and measured	Metric aligns with goals of MOD Sandbox projects but there is difficulty measuring, metric is captured across some but not all MOD projects
3	Aligned with MOD goals under the Performance Measurement Objective categories and not currently measured, ideal future metric	Metric aligns with goals of MOD Sandbox projects but is not currently measured
4	Not aligned with MOD goals under the Performance Measurement Objective categories	Metric does not align with current goals of MOD Sandbox projects

Based on the above criteria, each metric was assessed and assigned an applicability score. The scores and rationale behind the assessments are summarized in Table 3-13 (Core), Table 3-14 (Tier 1), Table 3-15 (Tier 2), and Table 3-16 (Tier 3).

Table 3-13 *Applicability Scores – Core (Traveler-centric) Performance Metrics*

Metric	Metric Description	Is this part of current or ideal measurement of MOD Sandbox projects?	Challenges	Applicability Score
Offset time	Difference in time between preferred departure time window and actual departure time	This is not an explicit metric used by MOD Sandbox projects; however, projects leveraging flex transit and ride sharing systems did mention that meeting riders' desired departure time as closely as possible was an important factor in the effectiveness of MOD.	For transportation options that are scheduled by the agency (e.g., trains and buses), it is difficult to assess when riders would like to have left compared to the scheduled time of departure.	3
Spontaneity time	Difference in time between being ready to travel and earliest departure time	This metric was not explicitly mentioned but would support the availability goal defined by almost all the projects. If a ride is not available within a reasonable amount of time of a passenger being ready to depart, the system is not meeting a customer's desire for available transit services.	Perhaps this metric is not used because it is difficult to gauge the actual time when a customer will be ready to depart.	3
Trip planning and booking experience	Traveler satisfaction with trip planning and booking process	This metric was explicitly cited by most of the MOD Sandbox projects. Variations of this metric included surveys on ease of use of a technology interface, return users, and purchase transactions not completed.	Many projects measured this through surveys and there were noted challenges around designing surveys. For example, there is a fine balance between a survey long enough to be informative and a survey too long for customers to answer.	1
Wait time	Amount of time between end of trip planning and beginning of trip	This was a metric used explicitly by almost all the MOD Sandbox projects. Another variation of this metric was the amount of time between a scheduled trip beginning and the actual trip beginning.	When transportation vehicles do not have GPS tracking, it can be difficult to measure when passengers are picked up.	1
Travel time	Amount of time walking to access and in-vehicle	This was mentioned indirectly by several MOD Sandbox projects. One project cited the desire to know the difference between the planned and actual pick up of a passenger by a ridesourcing vehicle, while another described the distance walked to flex transit stops as an ideal measurement.	Because many MOD systems were unable to track the actual movements of passengers, it is difficult to measure the travel time.	3
Connecting time	Difference between alighting from first vehicle/mode and getting back on the trip on second vehicle/mode	This was not explicitly mentioned by the projects; however, it ties into trip time. Furthermore, for multimodal projects, behavioral barriers to connecting between transit types were mentioned, and the time taken to make the connection was one of the suspected barriers.	Inaccuracies between actual and reported pick up and drop off can make this measure difficult, especially between multiple modes of transit.	3
Total journey time	Wait time plus trip time plus connecting time	Many of the MOD Sandbox projects used or hoped to use this metric.	When transportation vehicles do not have GPS tracking or the vehicles are equipped with GPS devices, providers do not necessarily want to release these data, or requests couldn't be tied to specific vehicle pickups to get full journey time.	1
Trip price Availability	Price of each trip available	This was mentioned by several of the MOD Sandbox projects.	Proprietary algorithms by TNCs make it difficult to offer trip prices in advance without incorporating data from TNCs. TNCs are hesitant to provide data to mobility projects due to concerns in protecting the privacy of their pricing algorithms.	2

Metric	Metric Description	Is this part of current or ideal measurement of MOD Sandbox projects?	Challenges	Applicability Score
Trip prices and mode preferences	Price of each trip that is within traveler's travel time and mode preference	This was mentioned by several of the MOD Sandbox projects.	Proprietary algorithms by TNCs make it difficult to offer trip prices in advance without incorporating data from TNCs. TNCs are hesitant to provide data to mobility projects due to concerns in protecting the privacy of their pricing algorithms.	2
Trip value	Price of trip component that is important to traveler	This was not explicitly mentioned by any of the MOD Sandbox projects, but one of the projects had hoped to gather information on whether subsidized passengers would choose more expensive options.	We did not hear explicit challenges around capturing this metric.	3
Trip price predictability	Variability of trip price for similar itineraries for the same traveler	This was mentioned indirectly, particularly by MOD Sandbox projects that collaborated with TNCs, because TNC algorithms made trip pricing less consistent.	Proprietary algorithms by TNCs make it difficult to predict trip prices in advance without incorporating data from TNCs. TNCs are hesitant to provide data to mobility projects due to concerns in protecting the privacy of their pricing algorithms.	3
Trip price consistency	Variability of trip price for similar itineraries between different travelers. Variability of trip price for similar itineraries for the same traveler	MOD Sandbox projects mentioned monitoring the variability of trip prices for TNCs was mentioned.	Proprietary algorithms by TNCs make it difficult to predict trip prices in advance without incorporating data from TNCs. TNCs are hesitant to provide data to mobility projects due to concerns in protecting the privacy of their pricing algorithms.	3
Trip price accuracy	Difference between quoted and actual trip price	Inaccuracy of pricing was mentioned as a potential problem for several MOD Sandbox projects, especially those working with TNCs.	Proprietary algorithms by TNCs make it difficult to predict trip prices in advance without incorporating data from TNCs. TNCs are hesitant to provide data to mobility projects due to concerns in protecting the privacy of their pricing algorithms.	3
Option availability	Percent of times when planning a trip that there is at least one trip option available that fits within traveler time, cost, and mode preferences	Several of the MOD Sandbox projects measured this indirectly through methods including trip availability and number of trips planned but not requested (likely because the trips offered did not fit what a potential rider was looking for). One project also hoped to track reason for trip cancellation, which would likely include trips not meeting preferences.	Many of the MOD Sandbox projects did not provide the optionality of stating specific trip preferences before trip planning. Instead, customers were provided options and then could choose whether to take these options. However, knowing why a customer did not take the options for trips would be useful information if it were available.	1
Option reliability	Percent of recurring trips that offer the same menu of trip options	This was not explicitly mentioned; however, several MOD Sandbox projects did describe plans for scheduling recurring trips, so consistency of recurring trip options is likely something that will become top of mind. Furthermore, reliability overall was an important goal for most of the projects, so reliable availability of options is definitely important.	MOD Sandbox projects do not currently know which trips will be consistently planned, so cannot ensure reliability of the options existing.	2
Travel time prediction accuracy	Percent and absolute difference between predictions and actual travel time	This was explicitly mentioned by several MOD Sandbox projects. Attempts to measure predicted versus actual journey time and wait time were made by most of the agencies.	Because many transportation vehicles were not equipped with GPS, and because tracking customers' movements on multimodal trips was a challenge, gauging the actual travel and wait times were challenging.	3

Metric	Metric Description	Is this part of current or ideal measurement of MOD Sandbox projects?	Challenges	Applicability Score
Travel cost prediction accuracy	Percent and absolute difference between predictions and actual trip cost	MOD Sandbox projects ideally looks to measure the accuracy of cost prediction to ensure that data presented to customers is accurate.	Proprietary algorithms by TNCs make it difficult to predict trip prices in advance without incorporating data from TNCs. TNCs are hesitant to provide data to mobility projects due to concerns in protecting the privacy of their pricing algorithms.	3
Travel time reliability	Standard deviation of actual total journey time/95th percentile travel time divided by mean travel time	Many of the MOD Sandbox projects did have an emphasis on reliability, and many explicitly mentioned the importance of repeat customers. One of the biggest factors likely to drive customers to return to a MOD system is a guarantee that they will arrive at their destination in a predictably timely manner.	Because many transportation vehicles were not equipped with GPS, and because tracking customer movements on multimodal trips was a challenge, gauging the actual travel and wait times were challenging.	3
Travel option availability, cluster analysis	Number of travel options available that fit traveler constraints	Several MOD Sandbox projects focus on aggregating travel options within a mobile application emphasizing different route, modes, and prices for journeys within a network.	Proprietary algorithms by TNCs make it difficult to predict trip prices in advance without incorporating data from TNCs. TNCs are hesitant to provide data to mobility projects due to concerns in protecting the privacy of their pricing algorithms.	2
Trip deferments	Number of trips planned but not taken, deferred, or taken in a way outside of traveler preferences	Several MOD Sandbox projects mentioned measuring the number of trips planned but not taken.	Measuring trips outside of customer preferences may be challenging because these preferences were not monitored by many of the MOD Sandbox projects.	2
Connection redundancy	Number of trip branches providing a similar travel time and cost available in real-time to travelers	This was not explicitly used as a metric by the MOD projects; however, this was because the multimodal projects were still working to get all travel optionality onto one platform.	Another of the challenges faced by a project was that TNCs did not want to agree to appear in a side-by-side comparison.	3
Personal security	Level of personal security felt during all parts of a trip	Personal security was a high priority for many of the projects we reviewed. Several projects measured personal security through compliance with regulations as well as the number of incidents reported	Measuring perception can be challenging without surveys, and especially in instances such as safety, surveys are likely to have response bias.	1
Crime rate	Crime rate	"Crime rate" was a measure used by several of the MOD Sandbox projects.	None identified.	1
Crash rate, injury rate	Crash rate, injury rate	Not sure if this was captured in MOD Sandbox projects.	MSPs are reluctant to share data on crash, injury rates. Police and hospital records (if obtainable) do not capture the full extent of the issue.	1
Met Privacy Preference (y/n)	Data privacy preference met while on all parts of a trip	While privacy of passengers was not explicitly mentioned, the ability of the government to handle private information was mentioned in several cases.	Some states, such as Arizona, have open book laws, which means that data shared with public agencies is often legally required to be accessible by all citizens. Furthermore, data privacy and intellectual property came up as a concern among private TNC partners.	3

Table 3-14 *Applicability Scores – Tier I (System-Centric) Performance Metrics*

Metric	Measures of Performance for MOD Projects	Challenges	Applicability Score
Maximum number of trips per hour	System performance is an overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	None identified.	3
Number of deadheading (no passengers in the vehicle) miles per day	Transportation demand and system cost efficiencies are overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	None identified.	3
Annual system subsidy	Cost efficiencies is an overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	None identified.	3
Subsidy ratio	Cost efficiencies is an overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	None identified.	3
Median trip fare	Passenger price sensitivities and cost efficiencies are overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	None identified.	2
Median trip cost (subsidy related)	Passenger price sensitivities and cost efficiencies are overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	None identified.	2
System cost per revenue mile	This was mentioned by several MOD Sandbox projects.	None identified.	2
Median wait time	This was mentioned by several MOD Sandbox projects.	When transportation vehicles do not have GPS tracking, it can be difficult to measure when passengers are picked up.	1
Standard deviation of wait time	This was mentioned by several MOD Sandbox projects.	When transportation vehicles do not have GPS tracking, it can be difficult to measure when passengers are picked up.	1
Median hours per day with surge pricing	Cost effectiveness is an overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	Proprietary algorithms by TNCs make it difficult to predict trip prices in advance without incorporating data from TNCs. This would require post hoc customer session specific data from TNCs. TNCs are hesitant to provide data to mobility projects due to concerns in protecting the privacy of their pricing algorithms.	3
Fatality or serious injury per 100,000 trips	Safety is an overarching goal of multiple MOD initiatives. Stakeholders did not explicitly mention this metric.	None identified.	1
Incidence of crime per 100,000 trips	Security is an overarching goal of multiple MOD initiatives. Stakeholders did not explicitly mention this metric.	None identified.	1
Number of planned trips per hour	Enabling trip planning is an overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	None identified.	3
Number of linked trips per hour	Enabling trip planning is an overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	Collecting data to measure planned trips and trip linkages.	3
Passenger revenue miles per year	Cost effectiveness is an overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	None identified.	2
Number of linked trips per vehicle revenue mile	Broadening transit options is an overarching goal of multiple MOD Sandbox projects. Stakeholders did not explicitly measure this metric.	None identified.	3

Table 3-15 *Applicability Scores – Tier 2 (Region-Centric) Performance Metrics*

Metric	Measures of Performance for MOD Projects	Challenges	Applicability Score
Number of jobs and other destinations in the region that can be reached in 15, 30, and 45 minutes	Increasing accessibility to public transportation was a primary goal of many MOD Sandbox projects, especially those focusing on first/last mile constraints.	None identified.	3
Net job growth	MOD Sandbox projects aim to allow cities to adapt to changes in mobility that will be instrumental in the future economic success of the area.	None identified.	3
Effective service area/coverage	Increasing accessibility to public transportation was a primary goal of many MOD Sandbox projects, especially those focusing on first/last mile constraints.	It is difficult to figure out where passengers who do not use public transportation are going and what their journey is like.	2
New access – increase access to essential amenities by public transportation	Increasing accessibility to public transportation was a primary goal of many MOD Sandbox projects, especially those focusing on first/last mile constraints.	It is difficult to figure out where passengers who do not use public transportation are going and what their journey is like.	2
Reduction of trip times	This was a goal for many of the MOD Sandbox projects, and many projects monitored journey times.	None identified.	2
Impact on accessibility	Almost all MOD Sandbox projects placed a heavy emphasis on accessibility for transportation-disadvantaged passengers.	None identified.	1
Budget spent on transportation	Cost neutrality was mentioned by several MOD Sandbox projects.	None identified.	1
Incidence of fatalities or serious injuries per capita	Safety was a concern for many MOD Sandbox projects.	None identified.	1

Table 3-16 *Applicability Scores – Tier 3 (National) Performance Metrics*

Metric	Measures of Performance for MOD Projects	Challenges	Applicability Score
Increased access to jobs and other destinations	Increasing accessibility to public transportation was a primary goal of many MOD Sandbox projects, especially those focusing on first/last mile constraints.	It is difficult to figure out where passengers who do not use public transportation are going and what their journey is like.	3
Reduced transportation and living costs	Transportation costs were certainly monitored by many projects, and reduced living costs were an important goal.	None identified.	3
GDP per capita	MOD Sandbox projects aim to allow cities to adapt to changes in mobility that will be instrumental in the future economic success of the area.	None identified.	3
Alignment with national goals	Many projects referenced the MOD Sandbox goals put forward by FTA.	None identified.	3
Impact on accessibility	Almost all MOD Sandbox projects placed a heavy emphasis on accessibility for transportation-disadvantaged passengers.	None identified.	1
Amount spent on transportation that increases access to opportunities	Cost and access were both KPIs for MOD Sandbox projects.	None identified.	1
Incidence of fatalities or serious injuries	Safety was a concern for many MOD Sandbox projects.	None identified.	1

Findings of the Applicability Assessment

Overall, the MPM support the broad goals of MOD Sandbox projects that were included in this assessment. As these projects are in their early stages, the specific metrics highlighted in the new MPM were not necessarily included as key performance metrics in current MOD Sandbox projects. However, they should be included in evaluation of future MOD projects because they have been shown in preceding sections of this report to support the broad goals of the MOD Sandbox projects. The relevancy of the MPM in measuring MOD Sandbox project success is further augmented by the inclusion of many of the proposed metrics in stated ideal measurements by MOD Sandbox project coordinators.

Feasibility Analysis

After determining the applicability of the MPM to the goals of MOD projects, it was necessary to assess the feasibility of collecting or obtaining the data that would be required to ensure that the identified performance metrics can be measured as the next factor to consider in the prioritization of metrics. Although the capabilities and ability of an agency to collect data may differ, the following assessment summarizes the overall capabilities of agencies to collect required data.

Through research and industry knowledge, the identified data elements were assessed to determine their feasibility for functionalizing the MPM. The following questions were answered under the feasibility assessments:

- Do the data exist?
- Are the data available?
- What is the feasibility of obtaining the data?
- What are the constraints and the level of those constraints associated with available data?
- What would be the format and unit of a given data element?
- What are the data sets that are currently unavailable, but in development phases by the agencies or stakeholders?
- What are the data that are not available?

Feasibility Criteria

In evaluating feasibility of collecting metrics, the following three criteria were considered as the important factors for grouping:

- **Currently collected in MOD Sandbox projects** – The research sought to answer the question “Could the data currently collected in MOD Sandbox projects be sufficient for the metric?” If yes, the metrics could be more feasible to measure in future MOD projects than metrics. (Data under this category are typically considered as being feasible.)

- **Potential future measurement in MOD projects** – Can the metric be measured through existing data methods within the agency? Additionally, can the metric be measured by data collected from external sources (i.e., data sets external to the agency such as national databases, private-sector organizations)? The easier the data for a metric is to collect and measure, the more feasible it is to use to measure in future MOD projects. Certain metrics take data inputs from multiple sources, or involve data manipulations making them complicated, more difficult to measure and thus less feasible for future measurement. When developing this score, the team accounted for both internal agency data and external data sources that could be leveraged by the agency. (Data under this category are typically considered as being feasible.)
- **Existence of data concerns** – Do any known privacy or third-party concerns exist in including or obtaining the data for a given metric? Metrics with data concerns such as privacy or cost are less feasible than metrics that are readily available. (Data under this category are typically considered as being less feasible.)

Data Sources

Data availability, quality, and relevancy from the following sources were evaluated for incorporation in this feasibility assessment:

- **Shared-Use Mobility Center (SUMC) Policy Database** – The research efforts identified and analyzed 136 projects and policies within the MOD Partnership of the SUMC Policy Database. Wherever possible, source policy documentation was referenced to inform the feasibility of metrics across various programs. For policies with limited documentation, additional research efforts were undertaken to understand the MOD program and evaluate the success for different projects.
- **MOD Sandbox Independent Evaluation Criteria** – The research efforts incorporated learnings from conversations with the USDOT team regarding work pertaining to the MOD Sandbox evaluations, and the findings informed the development of the MPM and proposed evaluation their feasibility.
- **Additional External Data Sources** – The following data sources and the data within those sources were analyzed for consistency, relevancy, applicability, quality, and granularity to assess their usefulness and feasibility for incorporation in the required analyses:
  - NTD
  - Bureau of Transportation Statistics
  - Bureau of Labor Statistics
  - US Census Data

- National Highway Traffic Safety Administration
- Mobile phone location data
- Center for Neighborhood Technology's All Transit
- Data from transit agency databases, including route shape files, station information, fare information, and other data sets
- Incident and fatality data from USDOT database

Feasibility Score Rubric

The feasibility analysis was done to accomplish the following:

- Establish if data currently collected by MOD Sandbox projects could be used for metric.
- Assess how difficult it would be to the required data for the metric in future MOD projects (e.g., through customer surveys, GPS systems, external data sets).
- Determine if data for metric is potentially inaccessible due to privacy or cost concerns.

To accomplish this goal, each metric was assigned a subscore of 0 (low), 0.5 (medium), or 1 (high) across the three feasibility criteria discussed above. An overall Feasibility Score was then calculated by summing the subscores to total a range between 0 and 3. Scores from each feasibility category were then weighted equally. Table 3-17 shows the feasibility score rubric used for the feasibility analysis.

Table 3-17 *Feasibility Score Rubric*

Overall Feasibility Score*	Category		
	Current Measurement in MOD and Integrated Mobility Projects (Current State)	Difficulty of Future Measurement in MOD and Integrated Mobility Projects (Future Potential)	Data Concerns (e.g., Privacy, Cost) (Data Concerns)
	Criteria		
3.0	Data are currently captured and are sufficient to measure the metric.	There are noted data concerns with this metric that historic MOD projects were able to overcome, (e.g., private partners may be reluctant to share data or survey responses).	There are no privacy/cost concerns of collecting or sharing the metric data.
2.0–2.5	Current data exist but are not sufficient to measure the metric in all cases, for example: • Some elements of the necessary data are captured by MOD projects. • Data are captured for specific types of MOD projects (e.g., can be collected! for apps, but not flex transit programs).	*Agency Data*: Data do exist and can be collected, but there are noted difficulties in collecting or measuring the data (e.g., data require additional transformation from primary state, aggregation of multiple data sources necessary to calculate the metric). *External Data*: External data sources do not capture the full definition of the metric or there are notable difficulties in collecting and or measuring the external data source (e.g., a proxy for these data exists in an identifiable external data source, data are published on a lag making real time measurement difficult).	*Agency Data*: Data exist and can be easily collected to create a future metric. *External Data*: External data sources that measure this metric exist, are clearly identified, and are easily accessible.
0.0–1.5	Data are not currently captured by MOD projects.	*Agency Data*: Data do not currently exist and cannot be captured without extensive resource or time investment. *External Data*: Data cannot exist because they are system/project specific.	There are significant cost and/or privacy concerns that are currently prohibitive to obtaining these data.

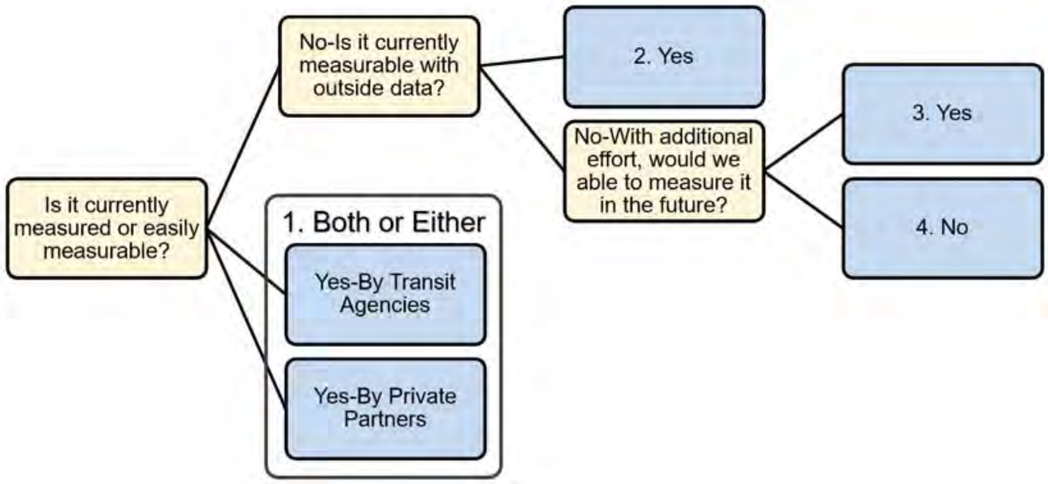
** Overall feasibility score: Scores from each category are weighted equally and aggregated to create an overall feasibility score for each metric.*

Categorization Process (Buckets)

Whereas the feasibility score provides insight into how challenging a metric is to measure overall, it does not provide clear insight into the roadmap for making the metric a reality. To provide a better heuristic for the necessary next steps for measuring a metric, four buckets were developed, determined using a decision tree that mapped the process of developing the metric, as shown in Figure 3-1.

Figure 3-1

Decision Tree Used in Categorization Process



Those metrics that were already measured internally by several agencies or private partners of MOD projects were bucketed into **Bucket 1 = High**. Metrics that could not be easily measured internally by agencies, but for which clear external data sources existed were assigned **Bucket 2 = Moderate**. Metrics that are feasible but require relatively high-cost or time-intensive investments (e.g., policy considerations, partnership agreements, incentivization) by transit agencies to either measure internally or obtain external data sets are in **Bucket 3 = Low**. Metrics that are not likely to be feasible due to unreliable data and privacy concerns, and thus require significant efforts such as policy changes and regulatory considerations are in **Bucket 4 = Infeasible**. Table 3-18 shows the summary of the buckets and their descriptions.

Table 3-18

Categorization of Feasibility Criteria into Buckets

Feasibility Bucket	Criteria
High	Currently measurable by transit agencies or private partners
Moderate	Currently measurable with external data
Low	Currently not measurable, but would be measurable in the future with insignificant to moderate additional effort
Infeasible	Currently not measurable and would be measurable in the future with significant additional effort that would require policy and regulatory actions

Feasibility Evaluation for Proposed MPM

Individual feasibility scores were assigned and summed to compute an overall feasibility score using the rubric in Table 3-17, and the categorization (bucketing) criteria shown in Table 3-18 were applied to each metric to categorize them under the four buckets. Tables 3-19, 3-20, 3-21, and 3-22 show the feasibility scores and categorical buckets for each proposed metric within Core, Tier 1, Tier 2, and Tier 3, respectively.

Table 3-19 *Feasibility Scores and Buckets – Core (Traveler-Centric) Performance Metrics*

			Feasibility Score	Feasibility Bucket
Metric: Offset time			**1.5**	**Low**
Current State		This metric is not explicitly captured in this exact form across MOD Sandbox projects researched.		
Measurability	Internal Data Sources	This metric could be measured in any MOD project that involves an app or other system where trips are scheduled by asking customers for their desired departure time (e.g., Valley Transportation Authority (VTA) Flex, Pinellas Suncoast Transit Authority (PSTA), or Valley Metro), or less optimally, it can be measured through surveys [86, 87].		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	Surveys are not precise, as participants could suffer from recall bias for extreme outliers (e.g., if offset time is usually 5 minutes, but one day trains were delayed and it was 30 minutes, they may report offset time as 30 minutes because that is the most memorable event).		
Metric: Spontaneity time			**1.0**	**Infeasible**
Current State		This metric is not explicitly captured in this exact form across MOD Sandbox projects researched.		
Measurability	Internal Data Sources	This metric is not measurable for programs that must be scheduled in advance, as the passenger knows in advance when they will depart, so they will be ready to travel according to that time (e.g., PSTA). The metric could, however, be measured in customer surveys for MOD projects such as trip planning apps where transportation schedules or rideshare arrival times are displayed (e.g., LA Metro) or for bikeshare programs where bike availability is a limiting factor for when a person is able to depart [88].		
	External Data Sources	This metric focuses on a measurement that is only measurable within the MOD service, so it is not likely to exist in third-party data.		
Challenges	Privacy	If the app is a private partner app, it might be difficult to obtain data due to privacy concerns.		
	Cost	Could be significant (if a method was developed to measure it).		
	Other	Surveys are not precise, as participants are likely to suffer from recall bias for extreme outliers (e.g., if spontaneity time is usually 5 minutes, but one day the next available option was in 30 minutes of when they were ready to travel, they may report spontaneity time is 30 minutes because that is the event that comes to mind).		
Metric: Trip planning and booking experience			**2.5**	**High**
Current State		This metric is currently measured in many MOD Sandbox Projects (ex: LA Metro, PSTA, Valley Metro, Centennial; City of Arlington & Via partnership) and is also being measured in several Independent Evaluation analyses. Most projects measured it through surveys [89].		
Measurability	Internal Data Sources	If not already measured, this metric can be measure directly through customer surveys, which were taken by many MOD Sandbox projects. Furthermore, beyond surveys, this metric can be measured indirectly by number of repeat customers, and for application-based MOD where a purchase is involved; the metric can be measured indirectly by incomplete purchases (e.g., Valley Metro).		
	External Data Sources	Projects could potentially use social media data to measure customer satisfaction with planning/booking experience (e.g., DART Independent Evaluation analysis).		

			Feasibility Score	Feasibility Bucket
Challenges	Privacy	None.		
	Cost	None.		
	Other	Surveys can be unreliable due to selection bias (e.g., only dissatisfied customers may answer a survey). Furthermore, private partners may be reluctant to share survey responses (e.g., NY Metro North's RFP does not indicate whether provider offers data on final contract).		
Metric: Wait time			**2.5**	**High**
Current State		This metric is currently measured in many MOD Projects (e.g., You Drink, We Drive Partnership with Lyft; PSTA, Valley Metro, CARE On-Demand (arrival within a window of scheduled time); Centennial; City of Arlington and Via partnership;) This metric was also measured by some Independent Evaluation analyses through TNC data and through surveys [90].		
Measurability	Internal Data Sources	Any app-based project that involves booking a rideshare or traditional transportation (buses, trains, etc.) can measure predicted wait time (e.g., drive time to pickup location or next scheduled bus), but predicted wait time is not always accurate. On-time performance measures can be used to deduce actual wait-time for customers. Some projects planned to track wait times or on-time performance with GPS trackers on vehicles (e.g., AC Transit).		
	External Data Sources	Data are likely to be held by third-party data.		
Challenges	Privacy	If app is a private partner app, might be difficult to obtain data.		
	Cost	Moderate (e.g., equipment cost; in interviews (e.g., With AC transit), difficulty in measuring actual wait times for public transportation options were highlighted, often as the result of a lack of GPS systems in vehicles system-wide, largely due to expenses)		
	Other	Surveys can be unreliable, as customers may not keep track of how long they spend waiting for a trip.		
Metric: Travel time			**2.0**	**Low**
Current State		Some projects mentioned trying to measure this metric (e.g., VTA Flex). Bridj KC had access to vehicle-level data including locations and timestamps for all RideKC Bridj vehicles. Additionally, Bridj KC surveyed riders to understand on average how long customers walked to get to a Bridj stop [91]. Several Independent Evaluation analyses measured travel time through survey data; others measured it through origin and destination data, and for DART also through app data [92]. Bikeshare programs can measure the distance and time between when the bike was undocked and when/where it was docked again [93].		
Measurability	Internal Data Sources	Any app-based MOD project with access to location data could theoretically measure this by tracking a customer's location. It is also easy to predict this (distance traveled × estimated speed of walking/vehicle travel), but predictions are not always accurate. For the in-vehicle component of travel time, GPS devices on transportation vehicles or undocked time on bikeshare projects could be used.		
	External Data Sources	There is the potential to collaborate with geolocation advertising companies that have access to location data from cell phones [94].		
Challenges	Privacy	If app is a private partner app, might be difficult to obtain data.		
	Cost	Moderate.		
	Other	Surveys can be unreliable, as customers may not keep track of how long they spend on the different aspects of their journey.		
Metric: Connecting time			**2.0**	**Low**
Current State		This metric was not measured currently by any MOD Sandbox project; however, Bridj KC surveyed riders to understand on average how long customers walked to get to a Bridj stop [95].		
Measurability	Internal Data Sources	This metric could be estimated in an app with multiple modes as the difference between arrival time of mode 1 and departure time of mode 2 (e.g., Vermont Statewide Transit Trip Planner). Measuring actual connection time through this method would probably require GPS devices on transportation vehicles. It may also be possible to use location-tracking data from an app to measure connecting time, especially if walking is involved.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		

			Feasibility Score	Feasibility Bucket
Challenges	Privacy	There may be concerns about the government using apps to track the locations of private citizens. If partners are a component of the multiple mode app, it might be difficult to obtain data on arrival/departure time due to data protection concerns.		
	Cost	Significant (purchasing location data are expensive).		
	Other	None.		
Metric: Total journey time			**2.5**	**High**
Current State		This metric was measured by bikeshare companies as time between pick up and drop off. This metric was also measured or estimated in some apps (e.g., You Drink we Drive Partnership with Lyft or multiple mode app: Vermont Statewide Transit Trip Planner). Bridj KC had access to vehicle-level data, including locations and timestamps for all RideKC Bridj vehicles [96]. Some Independent Evaluation analyses measured this metric through either app data, TNC data, or survey data [97].		
Measurability	Internal Data Sources	This metric could be measured or estimated in apps that allow you to request rides or an app with multiple modes in it (ex: Vermont Statewide Transit Trip Planner). Surveys could be used to estimate full journey time.		
	External Data Sources	There is the potential to collaborate with geolocation advertising companies that have access to location data from cell phones [98].		
Challenges	Privacy	If a MOD project involved public private partnership, it might be difficult to obtain data. There may be privacy concerns about the government using apps to track the locations of private citizens.		
	Cost	Significant (purchasing location data is expensive).		
	Other	None.		
Metric: Trip prices availability			**2.5**	**High**
Current State		This metric was measured in many apps/systems (ex: Vermont Statewide Transit Trip Planner, PSTA) [99].		
Measurability	Internal Data Sources	This metric can be measured (or at least estimated) in any app where trip is planned and where customers provide their travel time and mode preferences. The metric may also be measured through surveys where customers state their travel preferences.		
	External Data Sources	Third party TNC data, if not already a private partner in the MOD Project, would provide insight into the cost of this trip option.		
Challenges	Privacy	MOD projects may struggle to get pricing information from TNCs, which view their pricing algorithms as proprietary.		
	Cost	None.		
	Other	None.		
Metric: Trip prices and mode preferences			**2.5**	**High**
Current State		While trip prices are available for many MOD Sandbox projects, the travel time and mode preferences of riders are not always measured. Nevertheless, this metric was still measured in many apps or systems with multiple modes of transit (e.g., Vermont Statewide Transit Trip Planner, PSTA). [100]		
Measurability	Internal Data Sources	This metric can be measured (or at least estimated) in any app where trip is planned and where customers provide their travel time and mode preferences. The metric may also be measured through surveys where customers state their travel preferences. For single-mode transportation projects, however, this metric may not be relevant.		
	External Data Sources	Third party TNC data, if not already a private partner in the MOD Project, would provide insight into the cost of this trip option.		

			Feasibility Score	Feasibility Bucket
Challenges	Privacy	MOD projects may struggle to get pricing information from TNCs, which view their pricing algorithms as proprietary.		
	Cost	None.		
	Other	Tying a customer's mode preference to trip prices adds a layer of difficulty to the measurement process. If measured through surveys, surveys are not always reliable, especially given that a customer's trip preferences may vary over time or depending on the situation.		
Metric: Trip value			**2.0**	**Low**
Current State		This metric was not directly measured by anyone, but Bridj KC surveyed riders to understand on average how much riders were willing to pay for a trip [101].		
Measurability	Internal Data Sources	This metric could be measured through surveys.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	Surveys are not always reliable, especially given that a customer's trip preferences may vary over time or depending on the situation.		
Metric: Trip price predictability			**1.5**	**Low**
Current State		This metric was measured by some of MOD Sandbox projects (e.g., UberHop Partnership), but it was not widely measured [102].		
Measurability	Internal Data Sources	Many MOD projects kept track of price per trip; however, if a trip is a single-price trip (e.g., $2 fare for a bus), then this metric would not be as relevant.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	MOD projects may struggle to get pricing information from TNCs, which view their pricing algorithms as proprietary.		
	Cost	None.		
	Other	None.		
Metric: Trip price consistency			**1.5**	**Low**
Current State		This metric was measured by several of the MOD Sandbox projects surveyed (e.g., UberHop Partnership) [103].		
Measurability	Internal Data Sources	Many MOD projects kept track of price per trip; however, if a trip is a single-price trip (e.g., $2 fare for a bus), then this metric would not be relevant.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	May have issues getting this info from TNCs, which view their pricing algorithms as proprietary.		
	Cost	Unknown. Cost of data exchange would be more predictable if data exchange markets were established or sharing agreements were formed. TCRP J11-31 is evaluating the value of transportation data and can be used as a resource going forward.		
	Other	None.		
Metric: Price accuracy			**1.5**	**Low**
Current State		This metric was measured by ride providers (e.g., UberHop Partnership).		
Measurability	Internal Data Sources	Many MOD projects kept track of price per trip; however, if a trip is a single-price trip (e.g., $2 fare for a bus), then this metric would not be relevant.		
	External Data Sources	This metric focuses on a measurement only measurable within the specific transit system, so it is not likely to exist in third-party data.		

			Feasibility Score	Feasibility Bucket
Challenges	Privacy	May have issues getting this info from TNCs, which view their pricing algorithms as proprietary.		
	Cost	None.		
	Other	None.		
Metric: Option availability			**3.0**	**High**
Current State		This metric was measured by most multimodal projects or projects with multiple private partners (e.g., Valley Metro, PSTA Vermont Statewide Transit Trip Planner). The Independent Evaluation analyses of DART, Valley Metro, and PSTA measured users' reported perception of options available to them as a result of the app though a survey. The Independent Evaluation analysis of TriMet and Vermont Agency of Transportation leveraged survey data to measure if riders felt they were more connected to transit or had a greater ability to overcome first mile/last mile (FMLM) issues [104].		
Measurability	Internal Data Sources	For any multimodal trip planning system, this metric can easily be tracked and measured. This metric could be also measured by bikeshare or other shared mobility based on number of hours a dock/vehicle location is empty or completely full. Some projects (e.g., PSTA) were capped by vehicles at maximum utilization, in which case this metric could be measured as a% of the time when vehicles were at full utilization. For all other types of MOD project, this can be measured through a survey.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	Surveys may not always be reliable, so they would not be the preferred method.		
Metric: Option reliability			**2.0**	**Low**
Current State		This metric was measured in some apps that allow you to request rides with multiple modes in it and which keeps track of recurring trips (e.g., Vermont Statewide Transit Trip Planner) [105].		
Measurability	Internal Data Sources	This metric requires a project to keep track of recurring users, which is not always the case. However, many programs did keep track of recurring users, so this would be possible for those programs (e.g., Valley Metro, Centennial, and AC Transit). For all other MOD projects, this can be measured through a survey.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	Surveys may not always be reliable, so they would not be the preferred method.		
Metric: Travel time prediction accuracy			**1.0**	**3** **4**
Current State		This metric was measured by ride providers (e.g., UberHop Partnership, City of Arlington, and Via partnership) [106].		
Measurability	Internal Data Sources	Not all programs predict a journey time, but a lot of the trip planning programs do. Actual journey time can be challenging to measure but could potentially be done through GPS tracking of transport vehicles, location tracking for apps, or undocked times for bikeshare projects.		
	External Data Sources	There is the potential to collaborate with geolocation advertising companies that have access to location data from cell phones [107].		

			Feasibility Score	Feasibility Bucket
Challenges	Privacy	If a MOD project involved a public private partnership, it might be difficult to obtain data. There may be privacy concerns about the government using apps to track the locations of private citizens.		
	Cost	Purchasing location data is expensive.		
	Other	None		
Metric: Travel cost prediction accuracy			**2.5**	**Low**
Current State		This metric was measured by MOD projects involving ride providers (e.g., UberHop Partnership) [108].		
Measurability	Internal Data Sources	This metric can be measured by difference between projected and actual operating cost of the transit agencies involved.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Travel time reliability			**1.5**	**Low**
Current State		This metric was not explicitly measured by any MOD Sandbox project; however, it was measured in the Independent Evaluation analysis of LA/Puget Sound project through "TNC Data, Surveys, and "Wait Time Data" [109].		
Measurability	Internal Data Sources	Any app-based MOD project with access to location data could theoretically measure total journey times by tracking a customer's location. Travel time can also be measured by GPS tracking of vehicle location or bikeshare undocked/docked time.		
	External Data Sources	There is the potential to collaborate with geolocation advertising companies that have access to location data from cell phones [110].		
Challenges	Privacy	If a MOD project involved a public private partnership, it might be difficult to obtain data. There may be privacy concerns about the government using apps to track the locations of private citizens.		
	Cost	Purchasing location data are expensive.		
	Other	None.		
Metric: Travel option availability			**1.5**	**Low**
Current State		This metric was measured by most multimodal projects or projects with multiple private partners (e.g., Valley Metro, PSTA Vermont Statewide Transit Trip Planner [VT-STTP]).		
Measurability	Internal Data Sources	Projects that only concern one mode of transit mostly cannot measure this metric. This metric could feasibly be measured by any multimodal project, and it could also be measured by bikeshare or other shared mobility based on number of hours a dock/vehicle location is empty. Furthermore, it may be possible to use a survey.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	If not explicitly asked, may be difficult to know a traveler's constraints.		

			Feasibility Score	Feasibility Bucket
Metric: Trip deferments			**2.0**	**High**
Current State		This metric was measured by most multimodal projects or projects with multiple private partners (e.g., Valley Metro, PSTA VT-STTP).		
Measurability	Internal Data Sources	Projects concerning one mode of transit mostly cannot measure this metric. This metric could feasibly be measured by any multimodal project, and it could also be measured by bikeshare or other shared mobility based on number of hours a dock/vehicle location is empty. Furthermore, it may be possible to use a survey.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	If not explicitly asked, may be difficult to know a traveler's constraints.		
Metric: Connection redundancy			**2.5**	**High**
Current State		This metric was indirectly measured by most multimodal projects or projects with multiple private partners (e.g., Valley Metro, PSTA Vermont Statewide Transit Trip Planner).		
Measurability	Internal Data Sources	Measured by most multimodal projects or projects with multiple private partners. Could be measured by bikeshare or other shared mobility based on number of hours a dock/vehicle location is empty. Another option could be to use a survey.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Personal security			**2.5**	**Low**
Current State		This metric was measured by Independent Evaluation through surveys in their analysis of the LA/Puget sound MOD Sandbox project [111].		
Measurability	Internal Data Sources	This metric can be measured through customer satisfaction surveys.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Crime rate, cash rate, injury rate - Need to split into two different metrics			**2.5**	**High**
Current State		This metric was measured in some form by many MOD Sandbox projects (e.g., PSTA, Valley Metro, Centennial, and Bridj KC surveyed riders to understand if customers felt that Bridj was reliable/safe/comfortable/fast [112, 113]).		
Measurability	Internal Data Sources	Could be measured by several different methods (incidents reported, surveys, police reports, etc.).		
	External Data Sources	Crime data and traffic fatality data are available to the public in most states [114].		

			Feasibility Score	Feasibility Bucket
Challenges	Privacy	None.		
	Cost	None.		
	Other	San Clemente "SC Ride" FMLM ride subsidy program highlighted contracting difficulties with TNCs that were not able to offer crash rate data in a timely manner. In particular, the program cited that Uber did not offer the data [115].		
Metric: Privacy Preference			**2.0**	**Low**
Current State		This metric is not explicitly captured in this exact form across MOD projects researched.		
Measurability	Internal Data Sources	This metric could be measured through customer satisfaction surveys.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		

Table 3-20 *Feasibility Scores and Buckets – Tier 1 (System-Centric) Performance Metrics*

			Feasibility Score	Feasibility Bucket
Metric: Maximum number of trips per hour			**2.0**	**Low**
Current State		System capacity constraints are captured by carsharing services and in distinct MOD Sandbox initiatives, though are not currently widely captured across projects. Current metrics are both captured through survey and through counting current capacity and utilization. (e.g., RTA, PIMA, and BART Independent Evaluation analyses, Zipcar partnerships and NY Metro North's carsharing RFP) [116, 117].		
Measurability	Internal Data Sources	Capacity constraints can be measured for paratransit MOD projects and for MOD projects that leverage public/private partnerships with TNC [118, 119].		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	Negotiating data sharing agreements with private partners is difficult; system capacity constraints might fall within the privacy or competitive concerns of private partners.		
	Cost	None.		
	Other	None.		
Metric: Number of deadheading miles per day			**2.0**	**Low**
Current State		Vehicle utilization was tracked within a subset of MOD Sandbox partnerships, but not widely across all projects (e.g., City of Arlington and VIA) [120].		
Measurability	Internal Data Sources	Vehicle utilization could be tracked by MOD projects that leverage web or mobile applications by tracking driver miles and vehicle utilization data; furthermore, vehicle utilization can be measured by surveying drivers.		
	External Data Sources	This metric focuses on a measurement only measurable within the specific transit system, so it is not likely to exist in third-party data.		

			Feasibility Score	Feasibility Bucket
Challenges	Privacy	Negotiating data sharing agreements with private partners is difficult; vehicle utilization might fall within privacy or competitive concerns of private partners.		
	Cost	None.		
	Other	Furthermore, if the data are obtained through surveys, these methods can be biased, which may caveat measurement.		
Metric: Annual system subsidy			**3.0**	**High**
Current State		System subsidy is currently measured in MOD Sandbox projects that participate in the Sandbox program and projects that did not receive Sandbox grants (e.g., PSTA, Marin Transit and Centennial) [121, 122, 123].		
Measurability	Internal Data Sources	System subsidy is measurable within a profit and loss or system performance statement [124, 125, 126].		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Subsidy ratio			**3.0**	**High**
Current State		Subsidy ratio is currently measured for a handful of MOD Sandbox program projects. (e.g., LA/Puget Sound and Palo Alto analyses by Independent Evaluation) [127].		
Measurability	Internal Data Sources	Subsidy ratio should be measurable by future projects given that the elements necessary to calculate a system subsidy should currently be tracked and available to MOD projects.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Median trip fare			**2.0**	**High**
Current State		While trip prices are available for many MOD Sandbox projects, the travel time and mode preferences of riders are not always measured. Nevertheless, this metric was still measured in many apps or systems with multiple modes of transit (e.g., VT-STTP, PSTA) [128].		
Measurability	Internal Data Sources	Can be measured (or at least estimated) in any app where trip is planned and where customers provide their travel time and mode preferences. The metric may also be measured through surveys where customers state their travel preferences. For single-mode transportation projects, however, this metric may not be relevant.		
	External Data Sources	Third party TNC data, if not already a private partner in the MOD Project, would provide insight into the cost of this trip option.		
Challenges	Privacy	MOD projects may struggle to get pricing information from TNCs, which view their pricing algorithms as proprietary.		
	Cost	None.		
	Other	None.		

			Feasibility Score	Feasibility Bucket
Metric: Median trip cost			2.5	High
Current State		System subsidy data are currently tracked across multiple MOD Sandbox projects; additional trip cost is currently tracked by a handful of MOD projects (e.g., UberHob Partnership, PSTA, Valley Metro, DART, Marin Transit and Centennial MOD projects) [129, 130, 131, 132].		
Measurability	Internal Data Sources	This can be measured in future MOD projects using trip specific cost data or overall program subsidy data.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	Private partners might be unwilling to share trip fare data particularly for trip planning apps; however, MOD projects that provide ride services generally report this data [133, 134, 135, 136].		
	Cost	None.		
	Other	None.		
Metric: System cost per revenue mile			2.0	High
Current State		This metric is currently measured in a handful of MOD Sandbox program projects. When it is captured, it has captured using cost, origin and destination data from the MOD program's application. (e.g., Independent Evaluation analysis of RTA and PIMA project measured this metric in comparison to single occupancy vehicle trips) [137, 138, 139, 140, 141].		
Measurability	Internal Data Sources	This could be captured by MOD projects with access to cost and trip distance data; however, there might be difficulty accurately and rapidly piecing together multiple data elements necessary for the data calculation.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	System cost data should be available to all MOD projects; however, revenue miles might be more difficult to measure and was noted as a difficult metric to track in certain MOD projects.		
Metric: System cost per revenue hour			2.0	High
Current State		Some form of this metric is currently measured across Independent Evaluations of MOD Sandbox projects. When it is captured, this metric is measured through TNC cost data, customer surveys, and origin and destination data (e.g., Independent Evaluation analysis of LA/Puget Sound MOD project measured minutes of travel from a user perspective using origin and destination data) [142].		
Measurability	Internal Data Sources	This metric could be captured by projects with access to cost and operating time data, though there may be difficulties piecing together multiple data elements.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Median wait time			2.5	High
Current State		This metric is currently measured in many MOD Sandbox projects (e.g., You Drink we Drive Partnership with Lyft; PSTA, Valley Metro, CARE On-Demand [arrival within a window of scheduled time]; Centennial; City of Arlington and Via partnership;) This metric was also measured by some independent evaluation analyses through TNC data and through surveys [143].		

			Feasibility Score	Feasibility Bucket
Measurability	Internal Data Sources	Any app-based project that involves booking a rideshare or traditional transportation (buses, trains, etc.) can measure predicted wait time (e.g., drive time to pick-up location or next scheduled bus), but predicted wait time is not always accurate. On-time performance measures can be used to deduce actual wait-time for customers. Some projects planned to track wait times or on-time performance with GPS trackers on vehicles (e.g., AC Transit).		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	If the app is a private partner app, might be difficult to obtain data.		
	Cost	In interviews (e.g., with AC transit), difficulties in measuring actual wait times for public transportation options were highlighted, often as the result of a lack of GPS systems in vehicles system-wide, largely due to expenses.		
	Other	Surveys can be unreliable, as customers may not keep track of how long they spend waiting for a trip.		
Metric: Standard deviation of wait time			**2.5**	**High**
Current State		This metric is currently measured in many MOD Sandbox Projects (e.g., You Drink we Drive Partnership with Lyft; PSTA, Valley Metro, CARE On-Demand [arrival within a window of scheduled time]; Centennial; City of Arlington and Via partnership). This metric was also measured by some independent evaluation analyses through TNC data and through surveys [144].		
Measurability	Internal Data Sources	Any app-based project that involves booking a rideshare or traditional transportation (buses, trains, etc.) can measure predicted wait time (e.g., drive time to pick-up location or next scheduled bus), but predicted wait time is not always accurate. On-time performance measures can be used to deduce actual wait-time for customers. Some projects planned to track wait times or on-time performance with GPS trackers on vehicles (e.g., AC Transit).		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	If the app is a private partner app, might be difficult to obtain data.		
	Cost	In interviews (e.g., with AC transit), difficulty in measuring actual wait times for public transportation options were highlighted, often as the result of a lack of GPS systems in vehicles system-wide, largely due to expenses.		
	Other	Surveys can be unreliable, as customers may not keep track of how long they spend waiting for a trip.		
Metric: Median hours per day with surge pricing change to percent of daily customer sessions with surge pricing?			**2.0**	**Low**
Current State		This metric was not explicitly stated as a measured across any reviewed MOD projects.		
Measurability	Internal Data Sources	This metric could be captured by web or mobile-based transportation providing MOD projects.		
	External Data Sources	Outside data sources on pricing exist and include surge pricing information, specifically at “Geospatial at the Bureau of Transportation Statistics” [ ]. However, these are only applicable to public transportation agencies.		
Challenges	Privacy	MOD projects may struggle to get pricing information from TNCs, which view their pricing algorithms as proprietary.		
	Cost	None.		
	Other	None.		
Metric: Fatality or serious injury per 100,000 trips			**3.0**	**Moderate**
Current State		Safety and injury data are currently captured by MOD Sandbox projects (e.g., PSTA, Centennial, Bridj KC) [146, 147, 148].		
Measurability	Internal Data Sources	Safety and injury data could be captured by future MOD projects.		
	External Data Sources	Local safety and crash data could be leveraged to measure this metric.		

			Feasibility Score	Feasibility Bucket
Challenges	Privacy	None.		
	Cost	None.		
	Other	These data should generally be available; however certain MOD projects had difficulties in negotiating that this be available as part of a contract with a TNC [149].		
Metric: Incidence of crime per 100,000 trips			**3.0**	**Moderate**
Current State		Crime data are currently captured by MOD Sandbox projects (e.g., PSTA, Centennial, Bridj KC) [150, 151, 152].		
Measurability	Internal Data Sources	Crime data could be captured by additional MOD projects.		
	External Data Sources	Local crime data could be leveraged to measure this metric.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	These data should generally be available; however certain MOD projects had difficulties in negotiating that this be available as part of a contract with a TNC [153].		
Metric: Number of planned trips per hour			**2.0**	**High**
Current State		Trip planning is currently captured by a wide variety of MOD Sandbox projects. In some cases, this metric is measured using survey data (e.g., PSTA, Valley Metro, DART, Vermont Statewide Transit Trip Planner; additionally, Independent Evaluation analysis of Valley Metro is specifically looking at the number of FMLM planned trips) [154, 155].		
Measurability	Internal Data Sources	Trip planning metrics can be captured across MOD projects that involve trip planning.		
	External Data Sources	This metric is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	MOD projects that offer trip-planning services should have no issue querying the trip planning counts; however, projects that leverage TNC apps might have difficulty negotiating data sharing agreements with TNCs.		
Metric: Number of linked trips per hour			**2.0**	**Low**
Current State		This metric is currently captured by MOD Sandbox projects through survey data (Valley Metro) [156].		
Measurability	Internal Data Sources	Additional MOD projects with access to multimodal trip planning data through web or mobile applications should be able to track these data. Additional other projects can measure this through surveys.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system. It is not likely to exist in third-party data.		
Challenges	Privacy	If these data are not currently tracked, negotiating data sharing with third parties for this metric might be difficult to track.		
	Cost	None.		
	Other	None.		
Metric: Passenger revenue miles per year			**2.5**	**High**
Current State		This metric is currently captured across several different MOD Sandbox projects (e.g., Bike New Haven, DART, Carpool in Mateo County, Bike Walk Tompkins, Bridj KC, NY Metro North Car Sharing) [157, 158, 159, 160, 161].		

			Feasibility Score	Feasibility Bucket
Measurability	Internal Data Sources	This metric could be captured by future MOD projects with access to trip distance data.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	Revenue miles might be difficult to measure and was noted as a difficult metric to track in certain MOD projects.		
Metric: Passenger revenue hours per year			**3.0**	**High**
Current State		This metric is currently captured across several different MOD Sandbox projects. This metric is easily available to projects that offer rides on State-owned vehicles (e.g., Marin Transit, Bridj KC) [162, 163, 164, 165, 166].		
Measurability	Internal Data Sources	This metric could be collected by future MOD projects with access to trip time data.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system. It is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Number of linked trips per vehicle revenue mile			**1.0**	**Infeasible**
Current State		This metric is not explicitly captured in this exact form across MOD projects researched.		
Measurability	Internal Data Sources	Aggregating the necessary data elements to calculate this metric could prove challenging, particularly if certain data elements are unavailable to a future MOD project.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	If elements of these data are not currently tracked, negotiating data sharing with third parties for this metric might be difficult to track.		
Metric: Number of linked trips per vehicle revenue hour not in applicability table			**1**	**Infeasible**
Current State		This metric is not explicitly captured in this exact form across MOD projects researched.		
Measurability	Internal Data Sources	Aggregating the necessary data elements to calculate this metric could prove challenging, particularly if certain data elements are unavailable to a future MOD project.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system. It is not likely to exist in third-party data.		
Challenges	Privacy	None		
	Cost	None		
	Other	If elements of these data are not currently tracked, negotiating data sharing with third parties for this metric might be difficult to track.		

Table 3-21 *Feasibility Scores and Buckets – Tier 2 (Region-Centric) Performance Metrics*

			Feasibility Score	Feasibility Bucket
Metric: Number of jobs and other destinations in the region that can be reached in 15, 30, and 45 minutes			**3.0**	**Moderate**
Current State		This metric is currently captured by MOD Sandbox projects. This metric is measured using General Transit Feed Specification data, QGIS and supporting base maps, surveys, and employer partnership data. Other projects collect this using origin and destination data before and after system deployment to measure the special diversity of locations that users travel (e.g., VTA Flex, PSTA) [,].		
Measurability	Internal Data Sources	This metric could be captured by future MOD projects with access to any of the above data sets and the ability to accurately evaluate them.		
	External Data Sources	All Transit data by the Center for Neighborhood Technology provide an index that incorporates jobs accessible by public transportation [ ]. Furthermore, numerous transit data sets provide information on geolocation of transit accessibility [,].		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Economic development Net Job Growth?			**2.0**	**Moderate**
Current State		This metric is not explicitly captured in this exact form across MOD Sandbox projects researched.		
Measurability	Internal Data Sources	This metric could be measured through outside data sets, or potentially through survey data, but as a concept, economic development is difficult to measure broadly. MOD projects will need to be explicit in their definitions of success for Economic Development metrics to meaningfully track progress.		
	External Data Sources	Economic development can be measured through inflation, housing starts, and unemployment data available through Bureau of Labor Statistics, and US Census [ ]. All Transit data by the Center for Neighborhood Technology provide an index that incorporates jobs accessible by public transportation [ ]. Furthermore, numerous transit data sets provide information on geolocation of transit accessibility [ ].		
Challenges	Privacy	None.		
	Cost	None.		
	Other	There should be few data privacy or cost concerns. The most difficult part of measuring this metric will be aligning on what specifically economic development means to each MOD project.		
Metric: Effective service area/coverage			**2.5**	**Moderate**
Current State		This metric is currently captured by MOD Sandbox projects. In particular, this metric is measured using General Transit Feed Specification data, QGIS and supporting base maps, surveys, and employer partnership data. Other projects collect these using origin and destination data before and after system deployment to measure the special diversity of locations that users travel [,].		
Measurability	Internal Data Sources	This metric could be captured by future MOD projects through customer surveys or could be explicitly defined in the MOD program service specifications.		
	External Data Sources	All Transit data by the Center for Neighborhood Technology provide an index that incorporates jobs accessible by public transportation [ ]. Furthermore, numerous transit data sets provide information on geolocation of transit accessibility [ ].		
Challenges	Privacy	None.		
	Cost	None.		
	Other	If this metric is measured through survey data, it will be important to caveat potential bias with survey method.		

			Feasibility Score	Feasibility Bucket
Metric: New access (increase in access to essential amenities, services, and opportunities by public transportation or mobility service)			**1.5**	**Low**
Current State		A few MOD projects currently track increased access to transit and local amenities through survey data (e.g., PSTA, Valley Metro) [179].		
Measurability	Internal Data Sources	This metric could be captured in the future through surveys.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in 3rd party data.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	If this metric is measured through survey data, it will be important to caveat potential bias with survey method.		
Metric: Reduction of trip times			**2.5**	**High**
Current State		This metric was stated as a goal of a handful of MOD Sandbox projects. Additionally, this metric is measured using mobile and web application-based data and survey data (e.g., BridjKC, TriMet, Valley Metro) [180, 181].		
Measurability	Internal Data Sources	Either this metric could be captured by future MOD projects through raw web or mobile application-based data, or customer surveys.		
	External Data Sources	Longitudinal travel time data and congestion reports offer a proxy measure of the overall trip time that riders experience. These metrics are available on a lagged delay and would be most helpful in post project analysis [182].		
Challenges	Privacy	None.		
	Cost	None.		
	Other	If this metric is measured through survey data, it will be important to caveat potential bias with survey method.		
Metric: Impact on accessibility			**3.0**	**High**
Current State		Accessibility is measured in current MOD Sandbox Projects (Valley Metro, PSTA, LA Metro, Tri Met). Several Independent Evaluation analyses measured this through surveys and app or TNC data.		
Measurability	Internal Data Sources	This metric could be measured in customer surveys or through ridership of transportation disadvantaged groups.		
	External Data Sources	Outside data on station accessibility exist [183].		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Budget spent on transportation			**3.0**	**High**
Current State		Budget spent on the MOD project was captured by certain MOD Sandbox projects (e.g., Altamonte Springs, FL) [184].		
Measurability	Internal Data Sources	Percentage of budget spent on transportation could be captured by future MOD projects available through a standard economic summary of a transit agency.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		

			Feasibility Score	Feasibility Bucket
Metric: Incidence of fatalities or serious injuries per capita			**3.0**	**Moderate**
Current State		A number of MOD Sandbox projects currently capture safety metrics (e.g., PSTA< Centennial, Bridj KC) [185, 186, 187].		
Measurability	Internal Data Sources	These metrics can easily be tracked by future MOD projects.		
	External Data Sources	Crash and fatality data can be collected through the U.S. Department of Transportation National Highway Traffic Safety Administration. These metrics are available on a lagged delay and would be most helpful in post project analysis [188]. These data should generally be available; however certain MOD projects had difficulties in negotiating that this be available as part of a contract with a TNC [189].		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		

Table 3-22 *Feasibility Scores and Buckets – Tier 3 (National) Performance Metrics*

			Feasibility Score	Feasibility Bucket
Metric: Increased access to jobs and other destinations			**2.5**	**Moderate**
Current State		This metric is currently captured by some MOD Sandbox projects (VTA Flex). Several independent evaluation analyses measured this metric in some way, using data sources including General Transit Feed Specification (GTFS) data, QGIS and supporting base maps, surveys, and partnerships with employers. Other BAH projects planned to measure spatial diversity of locations users travel through Origin and Destination data before and after system deployment (PSTA).		
Measurability	Internal Data Sources	This metric could be measured in customer or business surveys.		
	External Data Sources	All Transit data by the Center for Neighborhood Technology provide an index that incorporates jobs accessible by public transportation [190]. Furthermore, numerous transit data sets provide information on geolocation of transit accessibility [191].		
Challenges	Privacy	None.		
	Cost	None.		
	Other	Surveys are not a perfect proxy for true increases in access, and surveying customers who use transit may miss the customers who do not use transit because their jobs are not accessible through transit.		
Metric: Reduced transportation and living costs			**1.5**	**Moderate**
Current State		This metric is not explicitly captured in this exact form across MOD Sandbox projects researched.		
Measurability	Internal Data Sources	This metric could be measured in customer surveys and by tracking fare prices.		
	External Data Sources	There are several outside data sources about average fares and special fares (e.g., Youth fares) [192].		
Challenges	Privacy	None.		
	Cost	None.		
	Other	Surveys would not capture riders outside of the system who are not positively affected and may even be negatively affected by transit systems.		

			Feasibility Score	Feasibility Bucket
Metric: Economic development			**2.0**	**Moderate**
Current State		This metric is not explicitly captured in this exact form across MOD Sandbox projects researched.		
Measurability	Internal Data Sources	This metric could be measured through outside data sets, or potentially through survey data, but as a concept, economic development is difficult to measure broadly. MOD projects will need to be explicit in their definitions of success for Economic Development metrics to meaningfully track progress.		
	External Data Sources	Economic development can be measured through inflation, housing starts, and unemployment data available through Bureau of Labor Statistics, and US Census [193]. All Transit data by the Center for Neighborhood Technology provide an index that incorporates jobs accessible by public transportation [194]. Furthermore, numerous transit data sets provide information on geolocation of transit accessibility [195]. There is additional potential for consumer spend measures from third parties.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	There should be few data privacy or cost concerns. The most difficult part of measuring this metric will be aligning on what specifically economic development means to each MOD project.		
Metric: Alignment with National goals			**1.5**	**High**
Current State		This metric is not explicitly captured in this exact form across MOD projects researched.		
Measurability	Internal Data Sources	This metric could be measured qualitatively through agency analysis of overall alignment.		
	External Data Sources	None.		
Challenges	Privacy	None.		
	Cost	None.		
	Other	This is a qualitative measure and subject to the biases of qualitative assessment.		
Metric: Impact on accessibility			**3.0**	**High**
Current State		Accessibility is measured in current MOD Sandbox Projects (Valley Metro, PSTA, LA Metro, Tri Met). Several Independent Evaluation analyses measured this through surveys and app or TNC data.		
Measurability	Internal Data Sources	This metric could be measured in customer surveys, through walkthrough by transportation disadvantaged groups, and usability testing.		
	External Data Sources	Outside data on station accessibility exist [ ].		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Amount spent on transportation that increases access			**2.5**	**Low**
Current State		Cost measures are measured in current MOD Sandbox Projects (AC Transit, PSTA, LA Metro), and accessibility is measured in current MOD Projects (Valley Metro, PSTA, LA Metro, Tri Met). These two metrics could be combined, but it would require further information from the transit agencies.		
Measurability	Internal Data Sources	This information could be collected from MOD Projects' financial information.		
	External Data Sources	This metric focuses on a measurement that is only measurable within the specific transit system, so it is not likely to exist in third-party data.		

			Feasibility Score	Feasibility Bucket
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		
Metric: Incidence of fatalities or serious injuries			**3.0**	**Moderate**
Current State		Safety metrices are measured in current MOD Sandbox projects (Valley Metro, PSTA).		
Measurability	Internal Data Sources	These data could easily be tracked and reported by MOD projects.		
	External Data Sources	Crime data and traffic fatality data are available to the public in most states. These data should generally be available; however certain MOD projects had difficulties in negotiating that this be available as part of a contract with a TNC [,]. Crash and fatality data can be collected through the U.S. Department of Transportation National Highway Traffic Safety Administration. These metrics are available on a lagged delay and would be most helpful in post project analysis [ ].		
Challenges	Privacy	None.		
	Cost	None.		
	Other	None.		

Proposed Data Structure

The previous section discussed the current practices among MOD Sandbox projects and measurability of metrics using internal and external data sources. This section presents a proposed data structure for the organization and management and sources of the data elements. Data would be organized into four distinct raw data tables: trip, customer survey, financial, and outside (external). By aggregating the data collected in the four data tables, the transit agencies and their mobility partners would be able to derive the MPM and to evaluate their system and service performance from multiple perspectives.

The proposed data table, data source, and primary key information are summarized in Table 3-23, followed by Table 3-24, which includes a list of each data element that is required for measurement of performance metrics.

Table 3-23

Proposed Data Table Structure

Table Type	Data Source	Primary Key Information
Trip Table	For MOD projects that include a web-based or mobile-based application, the data collected from the application itself would be the source of this data table. For MOD projects that do not include a web-based or mobile-based application, the data collected from tracking trips (scheduled or un-scheduled) would be the source of this data table. In cases where a TNC is collaborating on the project, the TNC will provide the trip information for this table.	Trip # is a unique combination of Anonymized Customer ID, Anonymized Vehicle ID and Date/Time fields
Customer Survey Table	The source of this table would be a customer survey. The method of survey collection will differ by MOD project.	Survey # is a unique combination of Anonymized Customer ID, Date/Time of Survey, and Method of Survey fields
Financial Data Table	The source of this table will be the financial information, which is tracked by the transit agency itself. Or an agency partner if one exists.	Date should be a unique column in this table
Outside Data Sets Table	The source of this table will be various outside data sources, which are specified in the given evaluations of the metrics.	Date should be a unique column in this table

Table 3-24 *Required Data Elements for Performance Metrics*

Item	Trip Table	Customer Survey Table	Financial Data Table	Outside Data Sets Table
1	trip #	survey #	date	date
2	anonymized customer id	anonymized customer id	projected daily operating cost	# of crimes
3	anonymized vehicle id	date/time of survey	actual daily operating cost	# of crashes
4	date/time	method of survey	daily # of vehicles	# of injuries
5	trip deferred metric	spontaneity time	daily # of hours per vehicle	# of jobs within 15 min
6	trip surge pricing metric	trip planning and booking experience	daily # of trips	# of jobs within 30 min
7	mode 1: preferred departure time	trip value	average time per trip	# of jobs within 45 min
8	mode 1: end of trip planning time	option availability	daily # of trips with no passengers	# of amenities within 15 min
9	mode 1: predicted departure time	option reliability	daily system subsidy	# of amenities within 30 min
10	mode 1: actual departure time	travel option availability	daily transportation budget	# of amenities within 45 min
11	mode 1: predicted arrival time	connection redundancy		# of opportunities within 15 min
12	mode 1: actual arrival time	safety perception		# of opportunities within 30 min
13	mode 1: quoted price	privacy preference		# of opportunities within 45 min
14	mode 1: actual price	increase access to essential amenities		# of services within 15 min
15	mode 1: total mileage			# of services within 30 min
16	mode 2: preferred departure time			# of services within 45 min
17	mode 2: end of trip planning time			economic development metric
18	mode 2: predicted departure time			effective service area/coverage
19	mode 2: actual departure time			accessibility impact
20	mode 2: predicted arrival time			population
21	mode 2: actual arrival time			transportation and living costs
22	mode 2: quoted price			
23	mode 2: actual price			
24	mode 2: total mileage			

Summary of Feasibility Analysis

Overall, although all transit agencies will not be able to measure every metric covered under the MPM, transit agencies should be able to measure many of the metrics without additional policy, technology, regulatory, or organizational changes. At the outset of a MOD project, the proposed data tables can be used to establish which data should ideally be collected for comprehensive evaluation of a MOD or mobility integration project in the short to near term, and entire regional mobility in the long term.

With the feasibility of measuring each of the performance metrics established and the applicability of each metric, the priority of measuring each metric can now be established. In the next section, the existing gaps analysis will identify redundancies and gaps in the proposed MPM to ensure that the prioritization process accounts for these.

Gap and Redundancy Analysis

The gap and redundancy analysis identified gaps in the metrics and their data elements and also highlighted potential data redundancies within the MPM. An analysis of dependencies and interdependencies was also performed as part of the gap and redundancy analyses. For each underlying data element, the number of metrics that are dependent on the given data were tallied. Understanding the dependencies and interdependencies provided feedback to the prioritization analysis as one of the factors to be considered. Furthermore, the analysis also identified additional metrics or data sources necessary to obtain for measurement of a broad array of MOD or integrated mobility project goals. MOD Sandbox projects were selected based on their context and closeness to FTA's integrated mobility vision. These additional metrics are provided in the tables in the metric gap analyses section. Last, for newly proposed metrics and data sources, the analysis emphasizes the feasibility of obtaining each metric or data source. The gap analysis was structured into the following four sections:

- Metric Gap Analysis
- Metric Redundancy Evaluation
- Data Element Dependencies and Interdependencies Assessment
- Data Gap Analysis and Path Forward

Metric Gap Analysis

The metric gap analysis highlights the existing metric coverage gaps between MOD goals and the proposed set of MPM. The goals evaluated were the nine broad MOD goals determined as project goals during the Applicability Assessment and the four stated goals of the MOD Sandbox projects. The analysis maps the proposed MPM and the applicability and feasibility of the proposed metrics to the set of goals to highlight the applicable metric coverage across each goal, and the feasibility of measurement. The metrics are classified by their respective tiers to inform coverage across each tier. For MOD goals with low metric coverage, additional metrics are proposed to close the metric coverage gap. Table 3-25 is included as a reminder of the applicability score and feasibility bucket ranges that are used in the following tables that summarize the metric gap analyses.

Table 3-25

Refresher for Key to Applicability Scores and Feasibility Buckets

Applicability Score	Feasibility Bucket
1 (Highly Applicable)	High (Currently measurable by agency)
2 (Applicable)	Moderate (Measurable through external data sources)
3 (Somewhat Applicable)	Low (Measurable with additional investment)
4 (Not aligned with MOD goals)	Infeasible (Difficult even with additional investment)

First, the metric gap analysis findings for the nine broad MOD goals discussed in the Applicability Assessment are presented.

Customer Satisfaction

Although traveler/customer satisfaction is an important goal of MOD and transit in general, only three metrics provide insight into the achievement of this goal. Furthermore, of those three metrics, two are measured through surveys, which rely on subjective data, and all three metrics are exclusively for the traveler. Table 3-26 summarizes the metric gap analysis considerations for the Customer Satisfaction goal.

Table 3-26 *Metric Gap Analysis for Customer Satisfaction Goal*

Tier	Metrics that Measure this Goal	Applicability Score	Feasibility Bucket
Core	Trip planning and booking experience	1	High
	Trip deferments	2	High
	Met privacy preference (y/n)	3	Low
Tier 1	No coverage	N/A	N/A
Tier 2	No coverage	N/A	N/A
Tier 2	No coverage	N/A	N/A
Additional Metrics that can Measure Customer Satisfaction			
Tier	**Proposed Metric**	**Description (where applicable)**	
Core	Net promoter score	Percent of customers who rate their likelihood to recommend the service greater or equal to eight minus the percent of customers who rate their likelihood to recommend 7 or less	
Tier 1	Trips per individual passenger per year	# of trips/# of distinct passengers	
Tier 2 Tier 3	User indices and elasticities per unit of investment	E.g., percent of citizens using publicly funded transit systems per unit of investment	

Time E ectiveness

The time efficiency goal is well-covered by the MPM. There are a broad range of metrics that provide insight into the time passengers spend in their journey. In fact, one may even observe redundancies across tiers or between some of these metrics. About half of the metrics related to the time efficiency goal also fall within the high feasibility bucket, indicating that they can easily be measured or are already being measured. The traveler, system, and regional tiers are assessed through these metrics; however, the national tier is not. One other aspect to note is the distinction between time efficiency and time effectiveness. While public transit might aim to minimize commute time for every individual passenger, this is not always the optimum use of public funds. Many of these metrics consider the increase in time efficiency, whereas financial or other system-related metrics could combine with them to provide insight into time efficiency. Table 3-27 summarizes the metric gap analysis considerations for Time Effectiveness goal.

Table 3-27 *Metric Gap Analysis for Time Effectiveness Goal*

Tier	Metrics that Measure this Goal	Applicability Score	Feasibility Bucket
Core	Offset time	3	Low
	Spontaneity time	3	Infeasible
	Wait time	1	High
	Travel time	3	Low
	Connecting time	3	Low
	Total journey time	1	High
	Travel time prediction accuracy	3	Low Infeasible (if travel time not predicted)
	Travel time reliability	3	Low
Tier 1	Median wait time	1	High
	Standard deviation of wait time	1	High
Tier 2	Reduction of trip times	2	High
Tier 3	No coverage	N/A	N/A

Additional Metrics that can Measure Time Effectiveness

Tier	Proposed Metric	Description (where applicable)
Core	No additional metric identified	
Tier 1	Systemwide speed per dollar spent	Sum of all trip times (system)/sum of total distance traveled/transit budget
Tier 2	Regional speed per dollar spent	Sum of all trip times (transit + MSPs + additional systems)/sum of total distance traveled/investment
	Average daily commute time	Commute speed/commute distance
	Average daily commute speed	Commute time/commute distance
	Average trip time	Trip speed/trip distance
	Average trip speed	trip time/trip distance
	Investment-based trip time reduction	Reduction in trip times per dollar spent on transit (i.e., [Old trip times – New Trip Times]/[total annual MOD transit budget])
Tier 3	Investment-based commute time reduction	Reduction in commute times per dollar spent on transit (i.e., [Old commute times – New commute Times]/[total annual transit budget])

Cost Effectiveness

There are two aspects to the cost effectiveness: to the rider and to the system. Both these aspects are extensively covered across tiers for these metrics, and a large portion of the metrics are either currently measured or easily measurable. There are sufficient applicable and feasible metrics covering this goal, so no additional metrics were found to be necessary to supplement the Cost Effectiveness goal. Table 3-28 summarizes the metric gap analysis considerations for the Cost Effectiveness goal.

Table 3-28 *Metric Gap Analysis for Cost Effectiveness Goal*

Tier	Metrics that Measure this Goal	Applicability Score	Feasibility Bucket
Core	Trip prices (price of each trip available)	2	High
	Trip prices (price of each trip that is within traveler's travel time and mode preference)	2	High
	Trip value	3	Low
	Trip price predictability	3	Low
	Trip price consistency	3	Low
	Price accuracy	3	Low
	Travel cost prediction accuracy	3	Low
Tier 1	Number of deadheading miles per day	3	Low
	Number of deadheading hours per day	3	Low
	Annual system subsidy	3	High
	Subsidy ratio	3	High
	Median trip fare	2	High
	Median trip cost	2	High
	System cost per revenue mile	2	High
	System cost per revenue hour	2	High
Tier 2	Budget spent on transportation	1	High
Tier 3	Amount spent on transportation that increases access	1	Low

Reliability

Although several of the metrics measure a system's reliability, many of these metrics fall within the low feasibility bucket, meaning they require additional investment for systems to be able to measure them. Most are traveler or system tier metrics; however, reliability of a transit system depends on the system, so it is understandable that these metrics would not cover tiers outside of the system. There are sufficient applicable and feasible metrics covering this goal, so no additional metrics were found to be necessary to supplement Reliability goal. Table 3-29 summarizes the metric gap analysis considerations for Reliability goal.

Table 3-29

Metric Gap Analysis for Reliability Goal

Tier	Metrics that Measure this Goal	Applicability Score	Feasibility Bucket
Core	Price accuracy	3	Low
	Option reliability	2	Low
	Travel time prediction accuracy	3	Low or Infeasible
	Travel cost prediction accuracy	3	Low
	Travel time reliability	3	Low
Tier 1	Standard deviation of wait time	1	High
Tier 2	No coverage	N/A	N/A
Tier 3	No coverage	N/A	N/A

Availability

Several of the MPM measure availability of MOD transit, and many of these metrics fall within the high feasibility bucket, meaning they are already measured or can be measured easily using existing internal data sources. Most metrics measuring achievement of this goal are traveler or system tier metrics; however, reliability of a transit system depends on the system, so it is understandable that these metrics would not cover tiers outside of the system. There are sufficient applicable and feasible metrics covering this goal, so no additional metrics were found to be necessary to supplement the Availability goal. Table 3-30 summarizes the metric gap analysis considerations for the Availability goal.

Table 3-30

Metric Gap Analysis for Availability Goal

Tier	Metrics that Measure this Goal	Applicability Score	Feasibility Bucket
Core	Wait time	1	High
	Option availability	1	High
	Travel option availability	2	Low
	Connection redundancy	3	High
	Trip deferments, cluster analysis	2	High
Tier 1	Maximum number of trips per hour	3	Low
	Median Wait Time	1	High
	Passenger revenue miles per year	2	High
	Passenger revenue hours per year	2	High
Tier 2	No coverage	N/A	N/A
Tier 3	No coverage	N/A	N/A

Safety

Safety is measured at all tiers of the MPM, and most metrics measuring safety were in the high or moderate buckets for feasibility, indicating that they are easily measurable with internal or external data or are already measured. Many of these metrics would likely come from the same data source, which could be problematic if this source is inaccurate; however, several outside data sources existed for these metrics, so this scenario is unlikely. There are sufficient applicable and feasible metrics covering this goal, so no additional metrics were found to be necessary to supplement the Safety goal. Table 3-31 summarizes the metric gap analysis considerations for the Safety goal.

Table 3-31

Metric Gap Analysis for Safety Goal

Tier	Metrics that Measure this Goal	Applicability Score	Feasibility Bucket
Core	Safety perception (personal security)	1	Low
	Crime rate	1	High
	Crash rate, injury rate	1	?
Tier 1	Fatality or serious injury per 100,000 trips	1	Moderate
	Incidence of crime per 100,000 trips	1	Moderate
Tier 2	Incidence of fatalities or serious injuries per capita	1	Moderate
Tier 3	Incidence of fatalities or serious injuries	1	Moderate

Accessibility

There are two main aspects to accessibility: economic accessibility and physical accessibility. Economic accessibility is covered extensively by regional and national tier metrics; however, on the traveler and system levels, economic accessibility has much lower metric coverage. Furthermore, physical accessibility has limited coverage across all four tiers. Many of the MOD projects researched and interviewed mentioned the importance of accessibility, particularly physical accessibility, so it will be important to incorporate this goal into the measurement. Table 3-32 summarizes the metric gap analysis considerations for the Accessibility goal.

Table 3-32 *Metric Gap Analysis for Accessibility Goal*

Tier	Metrics that Measure this Goal	Applicability Score	Feasibility Bucket
Core	Met privacy preference (y/n)	3	Low
Tier 1	No coverage	N/A	N/A
Tier 2	Number of jobs and other destinations in the region that can be reached in 15, 30, and 45 minutes	3	Moderate
	Effective service area/coverage	2	Moderate
	New access – increase access to essential amenities by public transportation	2	Low
	Impact on accessibility	1	High
Tier 3	Increased access to jobs and other destinations	3	Moderate
	Impact on accessibility	1	High

Additional Metrics that can Measure Accessibility		
Tier	**Proposed Metric**	**Description (where applicable)**
Core	No additional metric was identified	N/A
Tier I	Ratio of travelers using discounted fares	# of travelers using discounted fares/# of transit travelers
	Ratio of travelers using cash or pre-paid debit cards	# of travelers paying in cash or with prepaid debit cards/# of transit travelers
	Wait times for wheelchair-accessible vehicles	How long customers wait for wheelchair accessible vehicle to arrive
	Ratio of total trips taken by transportation-disadvantaged populations	total # of trips taken by transportation disadvantaged populations/total # of trips
Tier 2	Economic equality of transit travelers index	Median income of riders/Median income of coverage area
Tier 3	No additional metric was identified	N/A

Demand for MOD

There are several metrics measuring demand for MOD at the system level, of which two thirds can currently be measured or could be measured with additional investments. However, on the traveler, regional, and national level fewer metrics exist to measure demand.

Table 3-33 summarizes the metric gap analysis considerations for the Demand for the MOD goal.

Table 3-33 *Metric Gap Analysis for Demand for MOD Goal*

Tier	Metrics that Measure this Goal	Applicability Score	Feasibility Bucket
Core	No coverage	N/A	N/A
Tier I	Number of deadheading miles per day	3	Low
	Number of deadheading hours per day	3	Low
	Number of planned trips per hour	3	High
	Number of linked trips per hour	3	Low
	Passenger revenue miles per year	2	High
	Passenger revenue hours per year	2	High
	Number of linked trips per vehicle revenue mile	3	Infeasible
	Number of linked trips per vehicle revenue hour	3	Infeasible
Tier 2	No coverage	N/A	N/A
Tier 3	No coverage	N/A	N/A

Additional Metrics that can Measure Demand for MOD		
Tier	**Proposed Metric**	**Description (where applicable)**
Core	No additional metric was identified	
Tier 1	First time MOD users	Number of first time MOD users per day
	MOD revenue	Percent of transit revenues from MOD services
	MOD usage	Number of individual MOD users/total population
Tier 2	MOD revenue	Percent of transit revenues from MOD services
	MOD usage	Number of individual MOD users/total population
Tier 3	MOD partnerships	Percent of transit agencies using MOD partnerships (with single or multiple partners)
	MOD usage	Number of individual MOD users/total population

Knowledge Transfer

Through Tier 1 metrics, there is potential to measure certain pieces of information relating to demand for MOD that could be linked to Knowledge Transfer. However, this is a relatively qualitative goal that would be challenging to measure extensively through quantitative metrics.

Table 3-34 summarizes the metric gap analysis considerations for goals associated with Advancing Learnings for Future MOD and Mobility Integration Projects.

Table 3-34 *Metric Gap Analysis for Knowledge Transfer Goal*

Tier	Metrics that Measure this Goal	Applicability Score	Feasibility Bucket
Core	No Coverage	N/A	N/A
Tier 1	Number of planned trips per hour	3	High
	Number of linked trips per hour	3	Low
	Number of linked trips per vehicle revenue mile	3	Infeasible
	Number of linked trips per vehicle revenue hour	3	Infeasible
Tier 2	No coverage	N/A	N/A
Tier 3	Alignment with national goals	3	High
Additional Metrics that can Measure Knowledge Transfer			
Tier	**Proposed Metric**	**Description (where applicable)**	
Core	No additional metric identified		
Tier 1	No additional metric identified		
Tier 2, Tier 3	Agency contributions to MOD information sharing community	Calculated or scored by USDOT based on participation in MOD-related conferences, publications, referrals to other agencies, etc.	

The metric gap analysis findings for the four stated goals of MOD Sandbox projects are discussed.

Enhancing Transit Industry Preparedness for MOD

The goal of enhancing transit industry preparedness for MOD is not covered by any of the proposed MPM. However, this is a relatively qualitative goal that would be challenging to measure extensively. Table 3-35 summarizes the metric gap analysis considerations for goals associated with Enhancing Transit Industry Preparedness for MOD.

Table 3-35 *Metric Gap Analysis for Enhancing Transit Industry Preparedness for MOD*

Tier	Metrics that Measure this Goal	Applicability Score	Feasibility Bucket
Core	No coverage	N/A	N/A
Tier 1	No coverage	N/A	N/A
Tier 2	No coverage	N/A	N/A
Tier 3	No coverage	N/A	N/A
Additional Metrics that can Measure Enhancing Transit Industry Preparedness for MOD			
Tier	**Proposed Metric**	**Description (where applicable)**	
Core	No additional metric identified		
Tier 1	Percent of agency revenue & costs from public-private partnerships		
Tier 2	Agency contributions to MOD information sharing community		
Tier 3	Percent of industry revenue & costs from public-private partnerships		
	Citizens with access to MOD services in their region		

Metric Redundancy Evaluation

The Metric Redundancy Evaluation identifies the MOD goals and data sources that are redundant across multiple metrics. The evaluation process was two-fold:

- Evaluate each proposed MPM to identify the underlying data source, MOD goal measured, and potential metric calculation.
- Cluster metrics by their underlying data source and MOD goal measured to inform the data coverage for each MOD goal.

Findings from the redundancy evaluation informed the overall prioritization of metrics in two ways:

- Metrics with unique MOD goal coverage were scored more favorably than metrics with MOD goal coverage substitutes.
- Data elements with a higher number of dependent metrics were prioritized over data elements with fewer dependent metrics.

The analysis classified metrics by the following data sources, each with distinct underlying data elements dependent on the specifics of the given MOD project:

- **Trip Table** – For MOD projects that include a web-based or mobile-based application, the data collected from the application itself would be the source of this data table. For MOD projects that do not include a web-based or mobile-based application, the data collected from tracking trips (scheduled or un-scheduled) would be the source of this data table. In cases where a TNC is collaborating on the project, the TNC will provide the trip information for this table.

- **Customer Survey Table** – The source of this table would be a customer survey. The method of survey collection will differ by MOD project.
- **Transit Agency Financial Table** – The source of this table will be the financial information, which is tracked by the transit agency itself.
- **Outside Data Sets Table** – The source of this table will be various outside data sources, which are specified in the given evaluations of the metrics.

Depending on the setup, partnerships, data sharing negotiations and availability, and objectives of a given MOD project, the underlying data sources that measure the data elements necessary to calculate the MPM may need to be aggregated across multiple data sources. Additionally, depending on these same factors, data necessary to perform measurement across all these data elements may not be available for all MOD projects.

The following series of tables show the results of the redundancy evaluations, starting with Table 3-36, which shows the Core level redundancies. Across the Core Tier, both the Trip table and the Customer Survey table provided data coverage for the majority of metrics. Whereas the Customer Survey table measured a slightly wider range of goals as compared to the Trip table, the Trip table data are more reliable given that it is sourced from raw trip (or objective) data rather than customer surveys, which could be prone to biases due to their subjective nature. Within their respective data sources, Time Effectiveness and Cost Effectiveness MOD goals are among the most widely covered goals. Going forward, these goals offer the greatest room for MOD projects to negotiate the data elements that private partners provide. On the other hand, with respective data sources, goals such as Accessibility and Safety are less well-covered by current proposed metrics providing MOD projects less room to negotiate their inclusion or exclusion when negotiating data sets. Last, there were a number of metrics that measured multiple goals such as Wait Time, Price Accuracy, Trip Deferment Analysis, among others. By capturing these metrics, agencies can measure the success across multiple goals.

Table 3-36

Redundancy Evaluation Summary for Core Metrics

Data Source	Goal Measured	Metric Coverage – Core	
		Metric	*Calculation*
Trip Table	Time Effectiveness	Offset time	Difference between: • Preferred Departure Time • Actual departure time
		Travel time	Difference between: • Actual departure time • Actual arrival time If available: • Amount of time walking to access transit
		Connecting time	For all connections within a trip, difference between: • Mode 1: Actual arrival time • Mode 2: Actual departure time
		Total journey time	Wait time plus travel time plus connecting time
	Time Effectiveness, Availability	Wait time	Difference between: • End of trip planning time • Actual departure time
	Time Effectiveness, Reliability	Travel time prediction accuracy	Metric 1 – Absolute – difference between: • Predicted travel time • Actual travel time Metric 2 – Percentage – ratio between: • Predicted travel time • Actual travel time
		Travel time reliability	Standard deviation of actual total journey time/95th percentile travel time divided by mean travel time
	Cost Effectiveness	Trip prices	Price of each trip available
		Trip Prices	Price of each trip that is within traveler's travel time and mode preference
		Trip price predictability	Ratio of: • Predicted trip price • Actual trip price • Future state measurement requires data on non-taken trips
		Trip price consistency	Variability of actual trip price across travelers and days. Requires analysis across multiple riders
	Cost Effectiveness, Reliability	Price accuracy	Difference between: • Quoted price • Actual price
		Travel cost prediction accuracy	Metric 1 – Absolute – difference between: • Quoted price • Actual price Metric 2 – Percentage – ratio between: • Quoted price • Actual Price

Data Source	Goal Measured	Metric Coverage – Core	
		Metric	*Calculation*
Customer Survey Table	Time Effectiveness	Spontaneity time	Spontaneity time response Difference in time between: • Being ready to travel • Earliest departure time
	Cost Effectiveness	Trip value	Cluster analysis across potential travel modes of ratio between: • Actual price • Predicted Travel Time
	Customer Satisfaction	Trip planning and booking experience	Trip planning and booking experience response traveler satisfaction with trip planning and booking process.
	Customer Satisfaction, Accessibility	Met Privacy Preference (y/n)	Privacy preference response – Level of privacy felt during all parts of the trip
	Customer Satisfaction, Availability	Trip deferments, cluster analysis	Trip deferments divided by 100
	Availability	Option availability	Option availability response – percent of times when planning a trip that there is at least one trip option available that fits within traveler time, cost, and mode preferences
		Travel option availability, cluster analysis	Option availability response – number of travel options available that fit traveler constraints
		Connection redundancy	Connection redundancy response – number of trip branches providing a similar travel time and cost available in real-time to travelers
	Reliability	Option reliability	Option reliability response – percent of recurring trips that offer the same menu of trip options
	Safety	Safety perception (personal security)	Safety perception response – level of safety felt during all parts of a trip
Outside Data Sets Table	Safety	Crime rate, crash rate, injury rate	Number of reported crimes, crashes, and severe injuries per 100,000 trips

Across Tier 1, the Trip table and Transit Agency Financial table provided the greatest metric coverage underscoring the importance of both tables in measuring Tier 1 metrics. Furthermore, the proposed metrics provided the greatest coverage of the Cost Effectiveness and Demand for MOD projects goals. A number of metrics offered coverage of multiple goals: Deadheading passenger, Median Wait Time, Passenger Revenue Miles per Year, among others.

Table 3-37 *Redundancy Evaluation Summary for Tier I Metrics*

Data Source	Goal Measured	Metric Coverage – Tier I	
		Metric	*Calculation*
Trip Table	Demand for MOD, Knowledge Transfer	Number of planned trips per hour	Daily trips divided by 24 hours
		Number of linked trips per hour	Distinct trips in trip table
		Number of linked trips per vehicle revenue mile	Ratio between: • Number of linked trips • Revenue miles
		Number of linked trips per vehicle revenue hour	Ratio between: • Number of linked trips • Revenue hour
	Availability, Demand for MOD	Passenger revenue miles per year	Sum total revenue mileage divided by 365 days
		Passenger revenue hours per year	Sum total revenue hours divided by 365 days
	Availability	Maximum number of trips per hour	Maximum trips taken per hour
	Time Effectiveness, Availability	Median wait time	Median total wait time
	Time Effectiveness, Reliability	Standard deviation of wait time	Standard deviation of total wait time
	Cost Effectiveness	Median trip fare	Median actual trip price
		Median hours per day with surge pricing	Hours with surge pricing divided by 24
		Standard deviation hours per day with surge pricing	Standard deviation of hours per day with surge pricing
Transit Agency Financial Table, Trip Table	Cost Effectiveness	Subsidy ratio	Ratio between: • Amount paid by rider • Total trip price
		Median trip cost	Median trip cost to the agency
		System cost per revenue mile	Ratio between: • Actual daily operation cost • Total revenue miles
		System cost per revenue hour	Ratio between: • Actual daily operation cost • Total revenue hours
Transit Agency Financial Table	Cost Effectiveness	Annual system subsidy	Average daily system subsidy multiplied by 365
	Cost Effectiveness, Demand for MOD	Number of deadheading (no passengers in the vehicle) miles per day	Number of deadheading miles divided by 24 hours
		Number of deadheading (no passengers in the vehicle) hours per day	Number of deadheading hours divided by 24 hours
Outside Data Sets Table	Safety	Fatality or serious injury per 100,000 trips	Fatality or serious injury per 100,000 trips
		Incidence of crime per 100,000 trips	Incidence of crime per 100,000 trips

Within the Tier 2 Metrics, there is a greater reliance on outside data sets to measure success. While the Transit Agency Financial Tables may indicate performance across a few metrics, ultimately the bulk of Tier 2 metrics will require a third-party data set to provide coverage. Across Tier 2, Economic Accessibility has the most redundant coverage. Given the wide range of ways accessibility is measured, it will be important for transit agencies to prioritize the measurement of accessibility along their success goals. Table 3-38 shows Tier 2 level redundancies.

Table 3-38

Redundancy Evaluation Summary for Tier 2 Metrics

Data Source	Goal Measured	Metric Coverage – Tier 2	
		Metric	*Calculation*
Transit Agency Financial Table	Time Effectiveness, Measure the impacts of MOD on travelers and transportation systems	Reduction of trip times	Median journey time
	Cost Effectiveness	Budget spent on transportation	Sum of daily transportation budget across the time period of interest
Outside Data Sets Table	Accessibility, Measure the impacts of MOD on travelers and transportation systems	Number of jobs and other destinations in the region that can be reached in 15, 30, and 45 minutes	Number of jobs and other destinations in a region that can be reached in 15, 30, and 45 minutes
		New access – increase access to essential amenities by public transportation	Effective service area/ coverage
	Measure the impacts of MOD on travelers and transportation systems	Economic development	Dependent on source (e.g., consumer spend data)
	Accessibility	Effective service area/ coverage	Effective service area/ coverage
		Impact on accessibility	Accessibility Impact Score OR difference between jobs and residences reached by those of different physical abilities
	Safety	Incidence of fatalities or serious injuries per capita	Number of injuries or fatalities divided by population in the area of interest

Within Tier 3, most coverage will need to come from outside data sets. Given the breadth of these proposed metrics, there is only minor goal measurement redundancy at the Tier 3 level. Table 3-39 shows Tier 3 level redundancies.

Table 3-39 *Redundancy Evaluation Summary for Tier 3 Metrics*

Data Source	Goal Measured	Metric Coverage – Tier 3	
		Metric	Calculation
Transit Agency Financial Table	Cost Effectiveness	Amount spent on transportation that increases access	Amount spent on transportation that increases access
Outside Data Sets Table	Accessibility	Increased access to jobs and other destinations	Median number of jobs that can be accessed in 45 minutes
		Impact on accessibility	Accessibility Impact Score OR difference between jobs and residences reached by those of different physical abilities
	Measure the impacts of MOD on travelers and transportation systems	Reduced transportation and living costs	Monthly cost of transportation as a share of local tract median monthly income
		Economic development	Dependent on source (e.g., consumer spend data)
	Safety	Incidence of fatalities or serious injuries	Incidence of fatalities or serious injuries
Agency Analysis	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	Alignment with national goals	Qualitative measures

Data Element Dependencies and Interdependencies Assessment

This section presents findings of an analysis of each distinct data element necessary to measure the MPM in which the number of metrics dependent on each element was assessed. Furthermore, the assessment investigated the interdependencies of data elements required to measure the set of metrics. By breaking down the metrics into underlying data elements and counting the number of metrics dependent on each element, the analysis informs the ultimate priority of each of the distinct pieces of data to collect. Those with higher counts of dependent metrics will be most important to collect because they inform the greatest number of metrics.

The investigation found that for a handful of MOD goals, there were several key data elements with high counts of dependent metrics. If agencies were to obtain the key elements within a goal's data element interdependency cluster, they could measure a wide set of metrics within that goal. Conversely, the investigation found that several MOD goals do not benefit from data element interdependencies, suggesting agencies would need to obtain a wider set of data elements to measure metrics for these goals. Ultimately, the analysis found that data element interdependencies were highly correlated with the count of metric dependencies and that prioritizing data elements with the highest number of dependent metrics would unlock the greatest number of metrics.

Due to the high interconnectedness of the data elements contributing to metrics in these clusters, agencies can obtain a high number of metrics with a low number of data elements. One example of a cluster measures Time Effectiveness and centers on Actual Departure Time. If an agency obtains Actual Departure Time and additional key data elements (Actual Arrival Time and End of Trip Planning Time), it could measure eight metrics: Travel Time, Connecting Time, Total Journey Time, Travel time reliability, Reduction of trip times, Wait Time, Median wait time, and Standard Deviation of Total Wait Time. Another major data element cluster measured Cost Effectiveness and centers around Trip Price. By obtaining Trip Price and Amount paid by rider, agencies could measure four metrics: Trip Price, Trip Price Consistency, Median Trip Fare, and Subsidy Ratio. Although there were additional minor interdependency clusters, the remaining MOD goals did not exhibit such centralization or clustering of interdependent metrics.

Table 3-40 lists the data element dependencies and interdependencies. Actual Departure Time and Trip Price are the two data elements with the greatest number of dependent metrics totaling nearly 20 combined metric dependencies. Ultimately, when transit agencies are negotiating data elements to obtain from private partners, the data elements with the highest number of dependent metrics will unlock pieces to the greatest total number of metrics. These two data elements, among other top data elements will inform the greatest number of metrics.

Table 3-40 *Data Element Dependencies/Interdependencies*

Data Element	Number of Dependency/ Inter-dependency	Metric Dependencies/Interdependencies
Actual departure time	11	Offset time, travel time, connecting time, total journey time, wait time, travel time prediction accuracy, travel time reliability, spontaneity time, median wait time, standard deviation of total wait time, reduction of trip times)
Trip price	8	Trip prices, trip price predictability, trip price consistency, price accuracy, travel cost prediction accuracy, trip value, median trip fare, subsidy ratio
Actual arrival time	6	Travel time, connecting time, total journey time, travel time prediction accuracy, travel time reliability, reduction of trip times
Number of reported crimes, crashes, and severe injuries per 100,000 trips	4	Crime rate, crash rate, injury rate, fatality or serious injury per 100,000 trips, incidence of fatalities or serious injuries, # injuries or fatalities
End of trip planning time	4	Total journey time, wait time, median wait time, standard deviation of total wait time
Revenue hours	3	Number of linked trips per vehicle revenue mile, passenger revenue hours per year, system cost per revenue hour
Revenue miles	3	Number of linked trips per vehicle revenue hour, passenger revenue miles per year, system cost per revenue mile

Data Element	Number of Dependency/ Inter-dependency	Metric Dependencies/Interdependencies
Quoted price	2	Price accuracy, travel cost prediction accuracy
Option availability response	2	Option availability, travel option availability, cluster analysis
Daily trips	2	Number of planned trips per hour, number of linked trips per hour
Number of linked trips	2	Number of linked trips per vehicle revenue mile, number of linked trips per vehicle revenue hour
Hours with surge pricing	2	Median hours per day with surge pricing, standard deviation hours per day with surge pricing
Amount paid by rider	2	Subsidy ratio, annual system subsidy
Actual daily operation cost	2	System cost per revenue mile, system cost per revenue hour
# of jobs and other destinations in a region that can be reached in 45 minutes	2	Number of jobs and other destinations in the region that can be reached in 15, 30, and 45 minutes, increased access to jobs and other destinations
Effective service area/coverage	2	New access – increase access to essential amenities by public transportation, effective service area/coverage
Preferred departure time	1	Offset time
Connecting time	1	Total journey time
Predicted travel time	1	Travel time prediction accuracy
Price of each trip that is within traveler's travel time and mode preference	1	Trip prices
Predicted trip price	1	Trip price predictability
Time being ready to travel	1	Spontaneity time
Predicted travel time	1	Trip value
Trip planning and booking experience response	1	Trip planning and booking experience
Privacy preference response	1	Met privacy preference (y/n)
Trip deferments	1	Trip deferments, cluster analysis
Connection redundancy response	1	Connection redundancy
Option reliability response	1	Option reliability
Safety perception response	1	Safety perception (personal security)
Maximum trips taken per hour	1	Maximum number of trips per hour
Median trip cost to the agency	1	Median trip cost
Average daily system subsidy	1	Annual system subsidy
Number of deadheading miles	1	Number of deadheading (no passengers in the vehicle) miles per day
Number of deadheading hours	1	Number of deadheading (no passengers in the vehicle) hours per day
Daily transportation budget	1	Budget spent on transportation
Economic development	1	Economic development metric Tier 2 and t Tier 3
Accessibility impact score OR	1	Impact on accessibility Tier 2 and Tier 3
Amount spent on transportation that increases access	1	Amount spent on transportation that increases access
Monthly cost of transportation as a share of local tract median monthly income	1	Reduced transportation and living costs
Qualitative measures	1	Alignment with national goals

Data Gap Analysis and Path Forward

The Data Gap Analysis highlights the MOD goals that are measured by metrics with low feasibility to inform potential gaps in underlying data. For metrics with low feasibility, the analysis proposes additional data sets to close data gaps. The Data Gap Analysis determines the feasibility of measuring metrics proposed within Metric Gap Analysis as well. Table 3-41 summarizes the applicability and feasibility of the additional metrics.

Table 3-41 *Gap Analysis Matrix Summary of Feasibility and Applicability of Proposed Metrics*

MOD Goal	Proposed Metric	Tier	Applicability Score	Feasibility Bucket
Customer Satisfaction	Net Promoter Score	Core	2	Low
	Trips per individual passenger per year	Core	2	Low
	Percent of citizens using public transit	Tier 2 or 3	2	Low
Time Effectiveness	Speed per dollar spent	Tier 1	2	Low
	Reduction in trip times per dollar spent on transit	Tier 1	1	Low
	Average daily commute time	Tier 2 and 3	2	Moderate
	Average daily commute speed	Tier 2 and 3	2	Low
Reliability	Perceived reliability	Core	2	Low
	Missed connections	Core	2	Low
	On-time performance	Tier 1	3	High
Accessibility	Percent of riders using discounted fares	Core or Tier 1	3	High
	Percent of riders paying in cash or with prepaid debit cards	Core or Tier 1	3	High
	Wait times for accessible vehicles	Core or Tier 1	3	High
	Percent of total trips taken by transportation disadvantaged populations	Core or Tier 1	2	Low
	Median income of riders/Median income of coverage area	Tier 2	1	Low
Demand for MOD	Number of first time MOD users per day	Tier 1	1	Low
	Percent of transit revenues from MOD services	Tier 1 or 2	2	High
	Percent of population using MOD transit	Tier 2 or 3	2	Low
	Percent of transit agencies using MOD services	Tier 3	2	High
Enhance Transit Preparedness for MOD	Percent of agency revenue and costs from public-private partnerships	Tier 1	2	High
	Percent of industry revenue and costs from public-private partnerships	Tier 2	2	High
	Agency contributions to MOD information sharing community	Tier 2 or 3	2	Low
	Citizens with access to MOD services in their region	Tier 3	2	Low
Measure Impacts of MOD on Travelers	Count of trips that are multimodal	Tier 1	3	High
	Percent of agency revenue and costs from public-private partnerships	Tier 1	2	High
	Percent of transit revenues from MOD services	Tier 1 or 2	2	High
	Percent of population leveraging transit system	Tier 2	2	Low

Gap and Redundancy Analysis Conclusion

Overall, the MPM align well with the broad goals of MOD projects to date and the stated goals of the MOD sandbox projects. In cases where gaps exist between the MOD project goals and the MPM, the proposed metrics and outside data sources can be used to ensure that MPM fully explain the impact to MOD project goals. The redundancy analysis was important in determining the relative prioritization of collecting data to calculate an MPM. The next section discusses combining the applicability, feasibility, and existing gap analysis to formulate a prioritization scheme for the MPM.

Prioritization Assessment

After assessing the Applicability, Feasibility, Gaps and Redundancies within the MPM, it is critical to consolidate these learnings into a prioritization to inform the order they should be collected by agencies. The prioritization analysis informs how the metrics should be prioritized within each MOD goal, the order in which the data feeds and metrics should be obtained overall, the ways to integrate various data elements, and lastly, how to use the metrics to inform decisions. By incorporating the applicability, feasibility, gaps, and redundancies across the set of metrics, the analysis accounts for a wide range of factors informing what the ultimate priority of the MPM. For entities looking to leverage MPM to help inform success of projects, the Prioritization Analysis will provide a road map to determine which metrics can and should be measured today versus which metrics should be prioritized in the future.

The prioritization assessment leverages applicability scores, feasibility buckets, and gap analysis and redundancy findings that each of the metrics received during prior analyses. A metric's applicability to MOD goals was determined by measuring how closely a metric aligned with the goals of MOD projects, as stated in interviews with MOD project leaders and MOD case studies. A metric's measurement feasibility was calculated by assessing whether or not a transit agency or outside source could provide the data necessary to compute the metric. A metric's gap and redundancies were addressed by examining its coverage of MOD goals, data element dependencies, and data element gaps.

Table 3-42 *Highest Priority Metrics*

Metrics	Applicability Bucket	Feasibility Bucket	Justification
Wait Time Standard Deviation of Wait Time Median Wait Time	1 (Highly Applicable)	1 (currently measurable by agency)	Wait time provides a sense of a system's time effectiveness and ability to cater to the demands of its riders. Furthermore, by deriving standard deviation of wait time, you can also measure a system's reliability.
Total Journey Time	1 (Highly Applicable)	1 (currently measurable by agency)	Total journey time is a strong indicator of a system's time effectiveness.

Metrics	Applicability Bucket	Feasibility Bucket	Justification
Trip Cost Median Trip Cost Budget Spent on Transportation	1 (Highly Applicable)	1 (currently measurable by agency)	Price effectiveness includes the ability of a system to support itself and utilize resources effectively. Trip cost metrics can be easily derived from an agency's annual budget and the number of trips taken by an agency.
Trip Price	2 (Applicable)	1 (currently measurable by agency)	Trip price is an essential element to provide insight into both the cost effectiveness of a system as well as the affordability of the system. Furthermore, it is a metric that should be accessible in some form for most MOD projects.
Passenger Revenue Miles Per Year or Passenger Revenue Hours Per Year	2 (Applicable)	1 (currently measurable by agency)	Ideally, transit agencies and MOD projects should be able to access passenger revenue miles per year as a measure of overall demand and coverage of the system. However, we recognize that trip distance may sometimes be too costly to collect, so if agencies believe funds can be better diverted elsewhere, revenue hours may be substituted as a proxy for revenue miles.
Option Availability	1 (Highly Applicable)	1 (currently measurable by agency)	Understanding the ability of the system to cater to the needs of its passengers is critical to understanding the success of a MOD project. Furthermore, this metric can be measured relatively easily through a survey, or more precisely through app data for trip planning platforms.
Crime Rate Crash Rate Injury Rate	1 (Highly Applicable)	1 (currently measurable by agency)	Safety is always an important concern in the transit industry, and this metric is, or should be, already measured by most transit systems, so it would require very low investment for the amount of useful information about the safety of a system that it provides.

Data Integration Strategies

The task of aggregating data even for the highest priority MPM may seem daunting; however, it is possible to create many of these metrics from the same, often easily-accessible data sources. Below is a visualization of the data sources required to build the highest priority MPM, and the additional metrics that can be created from these feeds (Figure 3-2). For example, if you have actual departure time and end of trip planning time, it is possible to create all wait time-related metrics. If you can additionally collect Actual Arrival Time, not only can you create Total Journey Time, which is a highest priority metric, but also Connecting Time, Reduction in Trip Times, Travel Time, and Travel Time Reliability. The visualization intended to demonstrate the data feeds that agencies should prioritize, given which feeds they already have available. For example, if agencies can combine existing data elements such as annual budget with new data elements such as linked trips and trip price, they could add several trip cost metrics, median trip price, and subsidy ratio. Similarly, if an agency can measure Actual Departure Time, adding End of Trip Planning Time will allow them to achieve wait time metrics, so they should focus initially on collecting this data source.

Figure 3-2 *Data Prioritization Approach*

Conclusion

By establishing systems to report and share mobility performance measures, bringing understanding of the true impact of a program on the given metric, projects will be able to make the best and most informed go-forward decisions. Investing the effort to collect the data elements necessary to calculate the mobility performance measures is only beneficial if the new metrics are leveraged to make better decisions. From interviewing agencies, it is clear there is a desire to better understand a program's true impact across the stated goals of MOD Sandbox Projects. Since the mobility performance measures are well aligned with the goals of the MOD Sandbox Projects, if leveraged correctly, the mobility performance measures can provide the necessary insight into the true impact of programs across MOD Sandbox Project goals.

Reporting and sharing metric values can take many forms and may be unique to a given project or group administering the project. For example, metric values could be shared publicly on a webpage that promotes the program or the core metric values could be tracked internally on a dashboard. Whichever method is chosen to report metrics, the method should highlight the most important metrics for the given project, be consistent throughout the course of the project, and should be in a format that is easily understandable by all key stakeholders.

Beyond reporting and sharing raw project metrics, understanding the impact of the project on those metrics necessitates an expectation for how those metrics would be trending in absence of the project. For example, to determine if the number of linked trips has truly increased, the project would have to know what the number of linked trips to be in absence of the program. While looking at the weeks prior to the program to understand what the number of linked trips were before is one way to measure performance, seasonal patterns and prior growth of a station could be the true cause of the number of linked trips increase. Creating an expectation of how mobility performance values are expected to trend during the program is an important component of understanding the true impact of a program. By comparing the actual metric performance to the expectation, the program's true impact can be understood

By recommending a prioritization of metrics, the analysis provides a framework for entities to begin to collect data sources to create the mobility performance measures. The prioritization considers the applicability of the metric, the feasibility of collecting the metric, and the gaps and redundancies that exist within the metric-set. The prioritization recognizes that it may not be feasible to collect all metrics immediately, but rather provides a recommendation for which metrics to start collecting first. While the prioritization reflects the status of metric availability, there is policy work being done to help agencies advance their data collection efforts. Ideally enacted policy changes will make it easier for entities to obtain additional MPM, which will enable collection, measurement, and analysis of a wider range of metrics than currently available today. Once the Phase 1 policy work is complete, it will be important to consider the data availability and metric priority implications of the policy changes. In particular, it will be helpful to reexamine any metrics impacted by policy changes to underlying data availability.

The goal the new mobility performance measures is to improve decision-making. Effective usage of metrics in the decision process includes procedures to ascertain true impact of an intervention on the metric and standardized ways to communicate KPI results to stakeholders. Collecting the high priority metrics outlined in this assessment is the first step.

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APPENDIX

A

Literature Review

A Review of Existing Indicators in Public and Private Transportation to Evaluate Mobility on Demand

Draft Date: December 15, 2016

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A Review of Existing Performance Indicators in Public and Private Transportation To Evaluate Mobility on Demand

LIST OF TABLES

1 INTRODUCTION

Emerging mobility services like bikeshare, carshare, e-hail, and on-demand transit are changing the way people get around cities, with important implications for public transportation. The prospect of autonomous vehicles compounds these potential implications moving into the future. As the industry changes it is important to reassess public transportation's goals, how progress towards those goals can be measured, and what the federal government's role will be in setting a national transportation agenda to incentivize progress toward the achievement of national goals.

Historically, public transportation in North America has been provided by transit agencies that operate fixed-route bus and rail lines. Agencies measure their performance using indicators that focus on services they provide directly, reflecting factors such as costs per passenger trip or mile, on-time performance, and ridership. These performance indicators inadequately capture the performance and benefits of walking and biking—transportation modes that existed long before mass transit—let alone the emerging mobility services that increasingly serve similar trips to conventional public transportation. Furthermore, existing transit performance indicators often fail to reflect important existing goals like accessibility, safety, and sustainability.

To examine what a future public transportation system would look like—one that is fully integrated with emerging mobility providers – the Federal Transit Administration (FTA) launched the Mobility on Demand (MOD) Sandbox Demonstration Program. This initiative is intended to "envision a multimodal, integrated, automated, accessible, and connected transportation system in which personalized mobility is a key feature."*(1)* Under this program, public transportation agencies will work with emerging mobility providers to pilot new partnerships and evaluate their outcomes with the FTA's support. This evaluation will require an updated set of performance indicators that reflects essential agency goals as well as today's emerging mobility landscape.

This literature review was conducted as a first step towards identifying a set of performance indicators with which to evaluate the MOD Sandbox Demonstration Program partnerships, and will inform a white paper whose mission will be to provide concrete recommendations. We begin by looking at the overarching goals commonly articulated by transportation agencies at the national, state, and regional levels. We then examine existing performance indicators used in both the public and private sectors. Because indicators to evaluate emerging mobility modes are not well established in the existing literature—and because they will be critical to the MOD Sandbox Demonstration Program—we also suggest some potential emerging mobility performance indicators at the end of this review.

2 REVIEW OF NATIONAL, REGIONAL, & AGENCY GOALS AND OBJECTIVES

Performance indicators should be selected and designed to evaluate progress toward an agency's overall goals and objectives. As a result, it is important to begin with an understanding of agency and community strategic transportation goals. This review explores goals and their associated performance indicators from 42 agencies and governing bodies around the world. This includes 13 departments of transportation, 14 local transit agencies, 8 MPOs, and two city governments from across the U.S., as well as four transit agencies and one city government from foreign countries. The USDOT's goals were also included as this project intends to inform federal goals and, where necessary, to modify these to suit MOD. Nine high level goals emerged. These are defined below in Table 1, and later (in Table 9) accompanied by sample performance indicators.

Table 1: High Level Agency Goals

Goals Area	Definition
1. Connectivity	The usefulness, quality, and accessibility of the service
2. Financial Management	The financial sustainability of the agency and the effective allocation of resources
3. Planning	Community engagement, economic development, land use decisions, and system planning
4. Environmental Sustainability	The environmental footprint of the agency
5. Equity	The availability and usefulness of the system for all people
6. Safety & Security	The ability to protect the system, riders, and employees from harm
7. Customer Satisfaction	Rider happiness with the system
8. Organizational Excellence	The capacity of an agency to deliver transportation services
9. State of Good Repair	The maintenance of the transportation system to protect long term investment of infrastructure

These goals provide a framework in which to consider performance metrics for transportation agencies in general, and MOD partnerships' value can be evaluated to the degree that those partnerships support these goals.

2.1 National Goals

The US Department of Transportation (USDOT) sets a national policy agenda, provides funding, and creates incentives for agencies operating at the local, regional, and state levels. The relevant performance indicators to the MOD project are not those USDOT uses to evaluate its own performance, but rather those for which it requires reporting at the local and regional levels. This section discusses Federal Transit Administration and Federal Highway Administration reporting requirements for transit agencies and metropolitan planning organizations, respectively.

2.1.1 Federal Transit Administration

The FTA's mission is to "[i]mprove public transportation for America's communities."*(2)* The agency's efforts are guided by the goals stated in USDOT's most recent strategic plan, *Transportation for a New Generation*, shown in Table 2.*(3)*

Table 2: USDOT Goals

Goal Area	**Goals**
Safety	Improve public health and safety by reducing transportation-related fatalities, injuries, and crashes
State of Good Repair	Ensure the U.S. proactively maintains critical transportation infrastructure in a state of good repair
Economic Competitiveness	Promote transportation policies and investments that bring lasting and equitable economic benefits to the Nation and its citizens
Quality of Life in Communities	Foster quality of life in communities by integrating transportation policies, plans, and investments with coordinated housing and economic development policies to increase transportation choices and access to transportation services for all
Environmental Sustainability	Advance environmentally sustainable policies and investments that reduce carbon and other harmful emissions from transportation sources

Source: USDOT, Transportation for a New Generation, Strategic Plan | Fiscal Years 2014-28

The FTA's role is to "provide financial and technical assistance to local public transit systems, including buses, subways, light rail, commuter rail, trolleys and ferries. FTA also oversees safety measures and helps develop next-generation technology research."*(4)* Funding, in particular, has a significant impact on transit agency decisions regarding service and operations. The FTA directs a significant amount of its funding to agencies via formula grants and capital investment programs. Agencies receiving formula grants are required to report on a specified set of performance indicators for the FTA's National Transit Database (NTD).*(5)* For urbanized areas with 50,000 to 199,999 residents, the FTA bases its formula grants on population and population density, whereas for areas with 200,000 and more residents, the FTA bases its formula on "a combination of bus revenue vehicle miles, bus passenger miles, bus operating costs, fixed guideway vehicle revenue miles, and fixed guideway route miles, as well as population and population density."*(6)(7)* Thus, in these larger urban areas, transit subsidies are largely dependent on the amount of service provided and consumed.

The FTA also makes formula grants for rural areas. This program "provides formula funding to States and Indian tribes for the purpose of supporting public transportation in areas with a population of less than 50,000."*(7)* This funding is "based on a formula that includes land area, population, revenue vehicle miles, and low-income individuals."*(7)(8)*

Additional discussion regarding specific agency indicators required by the FTA can be found in a later section of this review and summarized in Table 6. It is noteworthy, however, that the FTA does not articulate goals that are specific to its role. Additionally, there is a disconnect between the indicators required for formula funding and the USDOT's high level goals, discussed above. In previous years, the FTA developed agency-specific strategic plans which contained detailed goals and vision strategies that were tailored to the agency's mission. A detailed table of the goals and objectives from the FTA's 1995 strategic plan can be found in Appendix A. While out of date, these goals are included in this literature review because they continue to resonate in the contemporary transportation environment.

2.1.2 Federal Highway Administration

In 2012, Congress enacted the Moving Ahead for Progress in the 21st Century Act (MAP-21). One important feature of MAP-21 is the requirement that metropolitan planning organizations (MPOs) use a standard set of performance indicators in their transportation plans in order to qualify for federal funding.*(9)* MAP-21 requires "statewide and metropolitan long-range plans [to] describe the performance measures and targets that States and MPOs use in assessing system performance and progress in achieving the performance targets."*(10)* These performance requirements were preserved in the Fixing America's Surface Transportation Act (FAST) Act, passed in 2015, which provides "long-term funding certainty for surface transportation" programs through 2020.*(11)* The national performance goals for the federal-aid highway program set out by MAP-21 are shown in Table 3 below.*(12)*

Table 3: Federal Highway Administration Goals

Goal Area	National Goal
Safety	To achieve a significant reduction in traffic fatalities and serious injuries on all public roads
Infrastructure condition	To maintain the highway infrastructure asset system in a state of good repair
Congestion reduction	To achieve a significant reduction in congestion on the National Highway System
System reliability	To improve the efficiency of the surface transportation system
Freight movement and economic vitality	To improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development
Environmental sustainability	To enhance the performance of the transportation system while protecting and enhancing the natural environment
Reduced project delivery delays	To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices

Source: FHWA MAP-21 Performance Management

To achieve these national goals, MAP-21 requires MPOs to establish performance indicators in the following seven areas listed below into their long-range transportation plans *(12)*:

- *Pavement condition on the Interstate System and on remainder of the National Highway System (NHS)*
- *Performance of the Interstate System and the remainder of the NHS*
- *Bridge condition on the NHS*
- *Fatalities and serious injuries—both number and rate per vehicle mile traveled--on all public roads*
- *Traffic congestion*
- *On-road mobile source emissions*
- *Freight movement on the Interstate System*

On the website discussing performance management under MAP-21, the FHWA states that, "to ensure consistency, each MPO must, to the maximum extent practicable, coordinate with the relevant State and public transportation providers when setting performance targets."*(12)* There are no performance indicators required from public transportation agencies under MAP-21. Private providers are also omitted.

2.1.3 International Cases

On the international stage, Singapore provides a model of effective use of performance indicators that point to achievement of national goals. There are three stated "desired outcomes" presented in Singapore's Revenue and Expenditure Estimates for the Ministry of Transport, each of which is linked to a brief set of performance indicators. These goals center around aviation, maritime travel and freight, and land transport. For the purposes of this literature review, we will only focus on the latter. This desired outcome and its related indicators are as follows:*(13)*

- Desired Outcome: Develop an Efficient, Sustainable and People-centric Land Transport System
    - Key Performance Indicators
        - Customer satisfaction with Public Transport (%)
            - This is the percentage of public transport commuters who express satisfaction with public transport (bus and rail) services in an annual survey.
        - Peak-hours Public Transport Journeys <= 20km Completed within 60 minutes (%)
        - Peak-hour Mode Share of Public Transport (%)
        - Public Transport Affordability (%)
            - This is the percentage of household income spent on public transport by those in the second quintile of the household income distribution. It is used by the Public Transport Council to assess public transport affordability for the average commuter.
        - No. of Delays > 5 Minutes Per 100,000 Km on MRT/LRT Network
        - Customer Satisfaction with Taxi Services (%)
            - This is the percentage of taxi commuters who express satisfaction with taxi services in an annual survey.

Singapore notably sets clear goals and indicators for housing and land use through its Ministry of National Development. This is important for MOD in the capacity that density and housing relates to travelers' ability to move around a region. Some of the goals and indicators of note include:*(14)*

- Desired Outcome: Singapore as a distinctive, attractive and vibrant city
    - Key Performance Indicators
        - Number of people living and working in the Central Area
        - Percent of public satisfied with Singapore's living, working and leisure environment
            - Surveys have been conducted once every three years since 2003.
        - Percent of public who agreed that our city centre is distinctive and vibrant
            - Surveys have been conducted once every three years since 2003.

- Desired Outcome: Promoting design and construction practices that will create an attractive and environmentally friendly city for our people
  - Key Performance Indicators
    - Number of projects that meet Green Mark standards (cumulative)

Seoul, Korea, provides another international example of a reliable and integrated transportation system. In 2004, the Seoul Metropolitan Government (SMG) reformed the city's transportation system. This reorganization included "completely reorganizing bus operations, introducing the first Bus Rapid Transit (BRT) corridors, better coordination of bus and metro services, improving the quality of the bus fleet, introducing natural gas buses to improve air quality and implementing a fully integrated fare structure and ticketing system between routes as well as across modes."*(15)*

The SMG's "Seoul Traffic Vision 2030" aims to make Seoul into "a city whose advanced transportation network makes private car ownership unnecessary." The vision organizes goals into three and centers goals around three core values, seen in Table 4.*(16)* More detailed goals from the Seoul Traffic Vision 2030 can be found in Appendix F.

Table 4: Seoul's Core Transportation Values & Goals

People-Oriented Traffic	All Sharing Traffic	Environmentally-Friendly Traffic
Promotion of walking and cycling	Construction of a train-centered public transport system	Creation of a low mobility society
Reduction of fatal accidents	Realization of faster public transportation	Construction of an efficient and Environment-Friendly Traffic network
Protection of general rights of the 'people with mobility handicaps'	Creation of a joint-ownership traffic environment	Advancing the traffic culture together with the citizens

2.2 Metropolitan Planning Organization (MPO) Goals

Metropolitan planning organizations (MPOs) are federally-mandated, regional bodies formed to coordinate transportation policy across jurisdictional boundaries. MPOs are a primary conduit for federal transportation funding, and are charged with coordinating among local governments and transit agencies within metropolitan regions. MPOs commonly set goals around the economic vitality, environment sustainability, safety, and quality of life of a metropolitan area.

MPOs' regional vantage point is unique in its regional consideration of transportation, but MPOs vary in their influence across the country. In many regions MPOs simply act as a reporting entity, and do not meaningfully coordinate goals across local stakeholder agencies.

Five common regional transportation goal areas emerged from the eight MPOs reviewed (see Appendix B for a list of MPOs). These are shown in the following table, along with sample indicators and data sources. It is common for MPOs to coordinate their goals with the various jurisdictions with whom they work at the local, state, and federal levels. This is reflected in the diversity of data sources listed below.

Table 5: A Summary of MPO Goals, Indicators, and Data Sources

Goal Area	Sample Indicators	Sample Data Sources
Environmental Sustainability	• GHG emissions • Noise pollution	• US Energy Information Administration • State energy commission
Economic vitality	• Jobs accessibility • State domestic & foreign shipments	• Bureau of Labor Statistics • State department of labor/employment
Safety	• Collision rates by severity by mode • Fatalities per 100 million Vehicle Miles Traveled (VMT) • Annual bicycle & pedestrian fatalities and serious injuries	• State highway patrol • State DOT • US Census • National Highway Traffic Safety Administration
Transportation System Utilization & Effectiveness	• Congestion reduction • Commute time • Person delay per capita	• State DOT • INRIX • Federal Highway Administration • US Census • National Transit Database
Location/Land Use Efficiency	• Number of homes within a 1/4 mile walking distance to regional attractors and generators • Share of growth in High Quality Transit Areas (HQTAs)	• State Department of Finance • US Census (Building Permit Survey) • Construction Industry Research Board • State conservation department

Though it is not always stated as a direct goal, reducing congestion is a key issue for MPOs—in part due to the FHWA's reporting requirements. More commonly, MPOs will consider congestion reduction as an objective under one or more of the above-stated goals, alongside a variety of related objectives such as travel delay reduction. Similarly, several MPOs have established goals around mobility and accessibility, which are grouped under the umbrella of Transportation System Utilization & Effectiveness in the table above.

Some MPOs add an explicit focus on "livable communities," in addition to the five core goal categories identified above, to promote the use of walking, biking, and public transportation. For example, the Metropolitan Transportation Commission in the San Francisco Bay Area (MTC) allocates significant funding toward its Transportation for Livable Communities program, which finances "pedestrian, bicycle and streetscape improvements near public transit in cities around the Bay Area."*(17)* The Delaware Valley Regional Planning Commission (DVRPC) focuses on zoning and "center-based" development recommendations to promote more compact, dense places.*(18)* The New York Metropolitan Transportation Council (NYMTC) emphasizes intra-regional mobility, mitigating the "negative impacts" design and construction of transportation projects have on communities, and promoting cycling and walking.*(19)*

The Southern California Association of Governments (SCAG) is one MPO that places great emphasis on equity and environmental justice. SCAG is clear about equity as a priority, stating that it is important that "the benefits of [its] Plan are realized by all populations in [the]

Southern California region while its burdens are not carried disproportionately by one group over another."*(20)* To this end, SCAG's regional transportation plan includes a set of 18 indicators dedicated solely to understanding environmental justice in the region. Some examples of these indicators include jobs-housing imbalance, accessibility to employment and services, roadway noise impacts, public health impacts, distribution of travel time savings and travel distance reductions, and comparison of transportation system usage by mode for different income groups.*(20)*

MTC is also focused on environmental justice and social equity. MTC's *Transportation 2035* plan is organized within a sustainability triple bottom line framework—environment, the economy, and equity—a useful structure but possibly a political non-starter at the federal level.*(21)*

MTC and Philadelphia's DVRPC present their regions' progress toward their goals, with websites that report publicly on current performance indicators. Both MPOs organize their indicators within four categories: Transportation, Economic, Community, and Environmental. These are key organizing principles that reflect their regional goals. DVRPC intends its online *Tracking Progress* report to "be used as a tool to align DVRPC's planning and implementation activities and to serve as a guide for the region's investment strategies."*(22)* MTC intends for its *Vital Signs* website to be used by the public, agency staff, and policymakers.*(23)* In addition to providing information about local and regional performance, *Vital Signs* compares the region's performance with national trends.

2.3 State Departments of Transportation

The majority of state department of transportation performance indicators focus on automobile travel performance, such as average traffic speed, traffic congestion delay, vehicle operating costs, and per-mile traffic crash rates. Many DOTs also recognize other modes in their strategic plans. According to the National Cooperative Highway Research (NCHRP) study, *State DOT Public Transportation Performance Measures: State of the Practice and Future Needs*, two-thirds of DOTs surveyed "indicated they have some public transit performance measures."*(24)*

Among the 13 state DOTs reviewed (see Appendix B for complete list), most had weak to moderate links between goals and performance indicators. Tennessee and New York State's DOTs provide clear examples of the general state of practice. Tennessee DOT's (TDOT) strategic and operational goals, for example, do not align with the seven categories the agency uses to measure performance, which the agency refers to as "guiding principles."*(25)* TDOT uses these guiding principles to track its performance measurement to national goals. However, while there is indeed some overlap, there is no clear relationship between the agency's strategic and operational goals and these guiding principles.*(26)*

The New York State DOT's (NYSDOT) goals have little connection to publicly reported performance indicators. NYSDOT's 2030 transportation plan defines its goals in terms of five "Priority Result Areas" which include: Mobility and Reliability, Safety, Security, Environmental Sustainability, and Economic Competitiveness.*(27)* NYSDOT's transportation plan, however, does not describe any performance indicators that might be associated with these priority result areas. The performance indicators NYSDOT does make publicly available are related to the American Recovery and Reinvestment Act (ARRA).*(28)* These indicators are not connected to the abovementioned priority result areas from NYSDOT's strategic plan. Without a clear connection between goals and performance indicators, it is difficult for a member of the public to determine whether an agency is meeting its strategic and operational goals.

There are some DOTs that are effective in connecting their goals to performance indicators. MassDOT provides clear breakdowns of its primary goals within each of its divisions, and associates each goal with specific performance indicators. These remain consistent across the agency's strategic plan and annual performance reports.*(29)(30)* Similarly, Caltrans' strategic plan clearly provides objectives, performance indicators, and targets for each of its goals.*(31)* Virginia's DOT (VDOT) also links specific indicators to goals in its strategic plan.*(32)*

Washington State's DOT (WSDOT) not only connects performance indicators to goals, but also coordinates these goals with other state agencies. WSDOT's strategic plan, *Results WSDOT,* is guided by the state's strategic plan, *Results Washington*. WSDOT publishes the *Gray Notebook*, a quarterly report that includes updates on the agency's performance toward its six high level goals.*(33)* WSDOT also contributes to the Washington Office of Financial Management's (OFM) biennial attainment reports, which details the performance of the entire state transportation system and is not limited to any one agency.*(34)* The high level transportation goals stated in WSDOT's strategic plan and the *Gray Notebook* are the same goals stated in OFM's biennial reports, and performance is measured directly under each one. A sample of WSDOT's and the OFM's transportation performance goals and indicators is shown in Table 6. *(35)*

Table 6: WSDOT and Washington OFM's Transportation Goals and Sample Indicators

Goal Area	Sample Indicators
Safety	• Number and rate of traffic fatalities per 100 million VMT • Number of pedestrian and bicyclist fatalities • Number of passenger injuries per 1 million passenger miles
Preservation	• % of state highway pavement in fair or better condition • % of state bridges rates structurally deficient • % of state ferry terminal systems in fair or better condition
Mobility (Addressing congestion)	• Annual hours of delay per traveler on major corridors in greater Seattle and Spokane areas • Annual hours of delay avoided through operational or public transportation enhancements • % of commute trips taken while driving alone • Transit ridership inside and outside of the Puget Sound area • Walking or biking mode share
Environment	• Number of culverts fixed and miles of stream habitat opened up • % of storm water quality measurements requiring Ecology notification • Tons of greenhouse gases produced statewide
Stewardship	• % of 2003 (Nickel) and 2005 (TPA) revenue packages' capital projects completed on time and on budget

Goal Area	Sample Indicators
	• Time that ferry vessels are out of service • Survey local, regional and statewide customers (public perception ratings)
Economic Vitality	• Number of jobs created or sustained by transportation projects • Amount of freight cargo moving in, out and within Washington through the air, by water or by rail

Washington State's multi-agency alignment of transportation goals is a novel phenomenon, but it is a good example of how transportation performance can be incorporated into an overarching statewide agenda.

2.4 Transit Agencies

There is significant variation amongst the transit agencies reviewed, but many do draw clear connections between strategic goals and performance indicators. For example, Valley Metro, serving the Phoenix metropolitan area, provides goals, tactics, and "measurable outcomes" associated with each tactic in its five-year strategic plan. The agency also indicates whether these tactics are achievable in the short-, mid-, or long-term. Many of the agency's measurements, however, are vague and in many ways look more like tactics themselves than performance indicators.*(36)* Alameda-Contra Costa Transit District (AC Transit), in Oakland, CA, ties specific objectives to its overarching goals. These objectives contain performance indicators, such as on-time performance and accident rates.*(37)*

Dallas Area Rapid Transit (DART) also ties its goals tightly to performance indicators. Additionally, DART differentiates between leading and lagging indicators under each goal area.*(38)* Memphis Area Transit Authority (MATA) likewise connects its indicators directly to its four high level goals.*(39)* MATA began reporting on these indicators to its Board of Commissioners in monthly reports in 2013, as well as making the data available to the public through its website.*(39)* This data, however, is only available through October 2014. It is unclear whether the data is still being collected and reported.

The San Francisco Metropolitan Transportation Agency (SFMTA) provides very clear links between its goals and their associated performance indicators. SFMTA draws these links by using an intermediate "objectives" tier in the hierarchy: at the highest level, goals (e.g. "Create a safer transportation experience for everyone") are subdivided into objectives ("Improve the safety of the transportation system"), and objectives tied to specific performance indicators ("Muni collisions per 100,000 miles").*(40)* This statement of objectives makes the SFMTA's planning and operational priorities transparent and explicit, supporting public and internal accountability.

The SFMTA is unique in the US in that it is a truly multi-modal agency, responsible for transit, walking, bicycling, and driving infrastructure in the San Francisco region. Hence, the agency's goals necessarily have multimodal implications.*(40)* The agency's indicators are not only tightly tied to its goals and objectives, but are also each accompanied by a specific target.*(41)* This approach provides a good example of multimodal goal-setting and performance indicators, but it is the exception to the rule. The New York Metropolitan Transportation Authority (MTA) similarly ties its performance indicators to its goals, and organizes those goals within four categories: customers; business, residents, and taxpayers; employees and unions; and government partners.*(42)*

Some transit agencies lack a clear link between goals and performance indicators. Rhode Island Public Transit Authority (RIPTA) provides qualitative “action steps” associated with each goal, rather than listing specific quantitative indicators,*(43)* while the Central Ohio Transit Authority (COTA) sets standards for route and schedule design, which includes minimum standards for frequency, on-time performance, loads, and others.*(44)* COTA also has standards for route performance which primarily use ridership measurements.

Transit agencies are largely operational entities, generally tasked with providing fixed-route public transportation service within a politically-defined jurisdiction. As such, their goals and performance indicators tend to be more narrowly defined—with a special focus on operational issues—than MPO or state DOT goals.

3 PERFORMANCE INDICATORS IN THE PUBLIC SECTOR

This review now moves from goals to specific performance indicators. In this section indicators used by public agencies are discussed. A more detailed list of public sector metrics identified through this review is included in Appendix C.

3.1 Metropolitan Planning Organizations (MPOs)

Because MPOs are charged by the USDOT with tackling congestion in their regions, they often emphasize travel time reliability indicators. These are defined by the FHWA as:

- *Congested hours: the average number of hours during specified time periods in which road sections are congested*
- *Travel time index (TTI): the ratio of the peak-period travel time as compared to the free-flow travel time*
- *Planning time index: the ratio of the 95th percentile travel time as compared to the free-flow travel time (45)*

These indicators prioritize the free-flow of traffic rather than, for example, minimizing travel time in general. This congestion-oriented approach may make sense for a highway agency but is too narrow for a multimodal undertaking like MOD.

The indicators MPOs use to evaluate the economic vitality, environmental sustainability, mobility, and quality of life are commonly informed directly by goals set by other agencies in the region, and often give consideration to multiple modes. For example, SCAG presents performance indicators for multiple modes under eight goal areas: Location Efficiency, Mobility & Accessibility, Safety & Health, Environmental Quality, Economic Opportunity, Investment

Effectiveness, Transportation System Sustainability, and Environmental Justice.*(20)* These goals bear similarities to the nine common high level agency goals identified earlier in this report. There are, however, a few interesting distinctions that have a broad regional focus, including economic opportunity and environmental justice. A breakdown of how SCAG's goals relate to specific performance indicators can be found in Appendix D.

As discussed in a previous section, MTC's *Vital Signs* website organizes indicators into four categories – Transportation, Land and People, Economy, and Environment – and displays indicators from several local and regional agencies. For example, the transit ridership indicator shown on *Vital Signs* includes ridership from AC Transit, CalTrain, BART, SFMTA, VTA, Muni, Golden Gate Transit, and SamTrans.*(46)* The website looks at data from CalTrans and FHWA for its Daily Miles Traveled indicator, and uses data from the US Census Bureau to inform its Commute Patterns indicator.*(47)(48)* The latter is an example of a distinctly regional indicator, where commute flows are measured between the counties in the Bay Area.

3.2 Transit Agencies

At a bare minimum, transit agencies use the performance indicators that are required for national transit database (NTD) reporting in order to qualify for FTA grant funding. Some key service measurements required by the FTA include ridership counts (unlinked trips), passenger miles, vehicle revenue miles, vehicle revenue hours, and vehicles available for maximum service, among others.*(49)* Agencies also report their operating expenses by mode per vehicle mile, per vehicle hour, per passenger mile, and per unlinked passenger trip.*(5)(49)*

Table 7: Summary of NTD-Required Indicators for Urbanized Areas

Annual Reporting Indicators	Monthly Reporting Indicators	Safety and Security Reporting Indicators
• Demographic data • Service area • Types of service (directly operated or purchased transportation) • Modes • Financial data (operating expenses, capital expenses, full cost of operations) • Funding sources	• Unlinked passenger trips • Passenger miles traveled (PMT) • Vehicle revenue miles • Vehicle revenue hours • Vehicles operated in maximum service • Regular service days for each month	• Fatalities • Injuries • Collisions • Derailments • Fires • Hazardous material spills • Evacuations • Arrests • Significant security events

For large urbanized areas with populations over 200,000, FTA funding is apportioned based on population, population density, operating costs, revenue miles, and passenger miles.*(49)* For "Small Transit Intensive Cities" – where the population is smaller than 200,000 but that have transit service levels that are comparable with larger cities – funding is based on indicators such as passenger miles traveled per vehicle revenue mile, passenger miles traveled per vehicle revenue hour, vehicle revenue miles per capita, vehicle revenue hours per capita, passenger miles traveled per capita, and passengers per capita.*(49)*

As discussed earlier in this review, there is a lack of congruity between the USDOT's strategic goals (Table 2) and the performance indicators the FTA requires from grantee agencies. For example, ridership indicators can disincentivize agencies from partnering with private providers because trips made with private services are not counted in current FTA funding formulas. A stronger connection between FTA goals and the indicators it requires for funding can effectively influence how agencies approach service provision and delivery.

In addition to basic NTD reporting data, transit agencies "collect other measures to help identify how well service is being provided to their customers, the areas where improvement may be needed, and the effects of actions previously taken to improve performance."*(50)* To this end, agencies frequently measure key operational data focused on understanding system reliability and schedule adherence (e.g. on-time performance), cleanliness, and customer satisfaction.*(51)(52)(53)* In its report, *A Guidebook for Developing a Transit Performance-Measurement System*, the Transit Cooperative Research Program (TCRP) points out the four key perspectives that come into play when considering performance. These are summarized in Table 8 below, along with their corresponding performance indicators of concern.*(50)*

Table 8: Performance Points of View

Perspective	Areas of Focus	
Customer	• Spatial availability • Temporal availability • Information availability • Capacity availability • Comfort	• Service delivery • Travel time • Safety and security • Maintenance • Customer satisfaction
Community	• Provision of transportation to persons without ready access to a private automobile • Reduction of air pollution • Travel when an automobile is not available • Parking congestion mitigation • Reduction of traffic congestion	• Job accessibility • Taxes directly or indirectly paid for transit service • Visual attractiveness of public facilities • Loud noise or diesel fumes from buses • Perception of waste or inefficiency of bus service • Empty buses
Agency	• Operating efficiency • Operating effectiveness • Organizational performance	• How well the service is working • Customer and community concerns
Vehicle/Driver (vehicle-oriented)	• Vehicle capacity • Roadway capacity • Presence of transit signal priority	• Traffic congestion • System speed • Delay

There is an industry trend toward customer-oriented indicators like those touched on in Table 8. In his book, *Perspectives on Intelligent Transportation Systems (ITS),* Joseph S. Sussman noted this trend, saying “performance metrics should matter to the customer of the system, and further, should be something the manager is convinced matters to the customer.”*(54)* MBTA demonstrates this approach, with an accessible and understandable website that reports on performance on reliability, ridership, financial, and customer satisfaction.*(51)* SFMTA also provides customers with an online performance dashboard that organizes its indicators by the agency’s strategic goals.*(41)*

Some integrated agencies, like SFMTA and London’s Transport for London (TfL) use more comprehensive, multimodal performance indicators, in part because both agencies govern their local streets, transit, taxis, bicycles, and the pedestrian environment.*(40)(55)* This multimodal approach presents a good starting point from which to measure performance from a MOD perspective. While these agencies collect traditional data, such as bunching and gaps in bus service, they are also well situated to consider all measurements together in order to provide a more comprehensive evaluation of overall transportation system performance. This would ideally include an understanding of complete, door-to-door trips, and customer perceptions across multiple modes.

TfL is particularly noteworthy because its goal/metric framework can be adapted to include other modes as the agency tailors its indicators for each mode it governs. This flexibility is valuable in light of the changing mobility landscape, and increasing recognition of the longstanding reality that customers’ transit trips begin and end before they ever set foot on a transit vehicle. While the governance structures of TfL and SFMTA incentivize those agencies to think multimodally, such governance structures are not a prerequisite to doing so.

3.3 Departments of Transportation

In a study of performance measures across 30 state DOTs, a 2011 NCHRP report found that:

> “Among the best practices and lessons learned, several state DOTs emphasized the importance of picking measures that could be consistently used over many years. Others emphasized the importance of selecting measures that are meaningful to the storyline surrounding public transportation performance in the state. It was found that the type of service being measured affects what is considered meaningful. For example, rural public transportation systems must often look beyond traditional cost-efficiency measures to those that gauge social value and quality of life.”*(24)*

A consistent theme is the importance of context-sensitivity in indicator development, but while state DOTs often operate rural public transportation systems, the report recognizes the limited role state DOTs have over investment decisions for urban public transportation.*(24)* This limits state DOTs’ ability to use indicators as incentives to improve service delivery, public transparency, accountability, and operational efficiency in urban areas.

State DOTs face other significant challenges in measuring public transportation performance. As the NCHRP report discusses, “Collecting data and connecting performance to funding decisions are two key challenges. Many state DOTs pointed to a need to find ways to compare disparate public transportation systems and to collect accurate and relevant data from their public transportation providers."*(24)* Data standardization may be facilitated in the longer-term as real-time data becomes more consistent, perhaps following the example of schedule data reported using the General Transit Feed Specification (GTFS). The FTA, with its NTD reporting requirements, also provides an example of data standardization practice that could to some degree be replicated or augmented at the state level.

Caltrans, California's transportation department, makes some effort to address non-automobile modes in its goals and performance indicators, which are heavily grounded in the state's sustainability-oriented policy goals. Caltrans groups its indicators using a sustainability triple bottom line framework of "people, planet, prosperity" (comparable to the Bay Area's "equity, environment, economy" framework discussed in Section 2.2).*(31)* The agency's *Strategic Plan 2015-2020* lists performance indicators such as: percentage increase of non-auto modes for: bicycle, pedestrian, transit; accessibility score; and livability Score (e.g. quality of life, noise, safety, localized emissions, environmental justice concerns, etc.) Caltrans has targets to develop the Accessibility Score and Livability Score by December 2016, and to complete corridor system plans by 2017.*(31)*

California is also one of few states that requires data reporting from transportation network companies (TNCs) like Uber and Lyft, not through its Department of Transportation but rather through the California Public Utilities Commission (CPUC).*(56)* The diversity of regulatory structures that govern TNCs and the taxi industry more broadly creates varied pathways for tracking performance in the for-hire vehicle sector.

The Minnesota DOT (MDOT) conducted a commuter study in 2012 that suggested the implementation of a regional rideshare program. The report states that "creation of a more formalized, long-term regional rideshare program will enable the Central Minnesota region to achieve a number of its goals for improving commuter transportation."*(57)* MDOT also lists out specific performance indicators for traditional ridesharing services, including indicators such as percent employees using a non-SOV mode, and number of ride matches available, and number of new carpools or vanpools formed.*(57)* While these indicators apply to a more traditional definition of ridesharing as administered by public agencies, these, too, could be broadened and expanded upon to apply to newer modes in order to serve a larger MOD context. It does not appear that MDOT followed through with a regional rideshare program to date.

The Virginia Department of Transportation (VDOT) has also developed a unique approach to funding transportation projects with its SMART SCALE scoring system, which was developed in partnership with the Virginia Department of Rail and Public Transportation (DRPT) and the Office of Intermodal Planning and Investment. Such coordination itself is unique and is worth exploring under an MOD scenario. Using the SMART SCALE system, "[t]ransportation projects are scored based on an objective, outcome-based process that is transparent to the public and allows decision-makers to be held accountable to taxpayers."*(58)* The system uses six factor areas that are closely aligned with agency goals. Notably, one of the key measures is *Person Throughput*, which is discussed in more depth later in this review.*(58)* This measure is listed under the Congestion Mitigation factor area, but the concept could easily be applied to transit and other emerging modes to replace or augment simple ridership counts. SMART SCALE also differentiates between rural and denser urban communities by using slightly different project evaluation criteria for each.

WSDOT, as discussed earlier in this review, employs a comprehensive approach to performance measurement, working in coordination with the state's strategic plan and the Office of Financial Management (Table 6). WSDOT's *Gray Notebook* provides quarterly performance updates, and includes "key performance indicators for five of the six policy goals. It shows the current and previous performance mark for each measure, and indicates which way the program is trending."*(33)* While the majority of these indicators are highway-oriented, WSDOT also issues an annual *Corridor Capacity Report* (CCR) that is "designed to help transportation policy makers, planners and engineers implement multimodal capacity opportunities for state highways" in order to reduce congestion.*(59)* The 2015 CCR included "multimodal capacity…along with travel time analyses for all major urban areas statewide where data is available."*(59)* These multimodal indicators include annual passenger miles traveled on transit, capacity savings due to transit, percent transit seats occupied, percent park and ride spaces occupied, commute travel times by mode (SOV, HOV, transit), and transit system use by time of day.

3.4 Existing Indicators in the Public Sector

In a review of more than 900 indicators used across the country by public agencies—either transit agencies or state DOTs—the following is a summary of indicators that could contribute to an MOD framework. These are organized by the set of goals listed in Table 10, which also includes sample metrics for each goal. Several of these goals are not commonly associated with specific indicators. Others—such as Organizational Excellence and State of Good Repair—are not included below because they are not immediately relevant to mobility on demand.[1]

3.4.1 Connectivity Indicators

Travel Time
Measured both by transit agencies and state DOTs, but for different modes. Whereas DOTs typically look at delay per traveler as it relates to vehicle congestion and level of service,*(60)* transit agencies look at delay in terms of service quality and accessibility *(61)(62)*. The University of California Transportation Center's (UCTC) report, *Measuring Multimodal Transport Level of Service,* discusses key travel time indicators such as in-vehicle travel time, transfer time, access/egress time, and waiting time.*(62)* Transport for London (TfL) measures excess wait time, excess journey time, and lost customer hours.*(55)* Fehr & Peers' *Multi-Modal Level of Service Toolkit* includes extensive discussion around person delay, with suggestions for evaluating person delay per mode to allow "for an 'apples to apples' comparison amongst the various modes."*(63)* Travel time indicators could be combined with passenger miles travelled (discussed later) to be more a more effective measure of connectivity.

[1] This is not to say, however, that Organizational Excellence and State of Good Repair are not impacted by MOD—but MOD's impacts on those goals are, in general, secondary.

Availability
Availability is a broad measurement category that includes several indicators used by transit agencies to gauge the availability of service. TCRP's Report 88 discusses service denials (or pass-ups),*(50)* while the Environmental Protection Agency (EPA) includes discussion of distance to transit stops*(64)* as important availability indicators. The University of Florida's Transportation Research Center (TRC), in an extensive review of existing performance measures for the Florida DOT, details several other indicators of interest, including hours of service, off-peak transit availability, missed trips, and percent person-minutes served (i.e., "percentage of time an average person has transit service available"*(60)*). This category of metrics could also be valuable if applied to emerging mobility providers like Uber and Lyft, for whom service availability is not typically guaranteed but rather incentivized through dynamic pricing.

Walk- and bike-ability
Walkability indicators are widely discussed in the literature but not commonly used in practice, and can measure key enabling conditions for MOD. The EPA recommends overall pedestrian mode share, pedestrian level of service (LOS), and pedestrian trip counts.*(64)* Litman describes several walkability indicators used by the City of Ottawa, including walking mode share and sidewalk coverage.*(65)* TRC describes many indicators in this category, including sidewalk quality, sidewalk width, and sidewalk shade,*(60)* while Roughton discusses indicators such as percent of roadways with sidewalks and percent of new developments meeting pedestrian standards.*(66)*

Similarly, a number of bikeability indicators have emerged, but are not commonly used. These are in many ways similar to the indicators suggested for walkability, including bicycle counts, bicycle LOS, and length and quality of bike lanes,*(64)* as well as other indicators like bike parking requirements,*(60)* existence of a bike plan,*(61)* number of bicycle parking spaces, and percent of transit stops with bicycle parking or secure bicycle parking.*(66)*

3.4.2 Financial Management Indicators

Farebox recovery
Farebox recovery is one of the measurements required by the NTD, and is therefore reported by every FTA grantee. Because farebox revenues do not cover an agency's operating expenses, they directly impact the level of subsidies needed from local, state, and Federal sources.*(50)* Farebox recovery is often lower in low density places with low ridership, requiring higher the government subsidies to operate service. This indicator will be of particular interest if applied to for-profit private services whose fares may be subsidized by private investment capital*(67)* or, in the case of agency partnerships, by local governments.*(68)*

Cost per revenue hour / Cost per revenue mile
As above, FTA grantee agencies are required to report operating costs per vehicle revenue hour for each mode in the system. These indicators, along with farebox recovery (above) and cost

per passenger trip (below), enable agencies to evaluate the efficiency and effectiveness of service.*(50)*

Cost per passenger trip

Agencies must report the average cost per trip and average fares per trip, thus indicating the costs per passenger or per trip. This is an important metric in determining the size of subsidies for each mode. Cost per passenger trip is a cost effectiveness indicator, and will generally decrease as ridership increases in a fixed-route system, but is dependent on other factors (scheduling, travel times, routing) in demand-response systems.*(50)* Additionally, “cost per passenger is traditionally much higher for demand-responsive service than it is for fixed-route service” because of the high level of maintenance and overhead required to serve a relatively low number of passengers.*(50)* This is an important consideration for paratransit as well as for emerging demand-response modes.

3.4.3 Planning Indicators

Ridership

This metric is one of the most commonly used in transit agencies across the US and elsewhere, and therefore merits discussion. Ridership can be measured in a variety of ways, depending on the goal of the agency, but for NTD purposes it is generally considered to be the sum of unlinked trips (or boardings) on a system, route, or in a region. Some specific indicators used by agencies to measure the effectiveness of its system include average vehicle ridership*(65)*, ridership by mode*(57)*,and percent change in ridership from prior year. Of these, average vehicle ridership, as defined by Litman in *Measuring Transport*, is of particular interest. Litman defines this metric as “All person trips divided by the number of private vehicle trips.”*(69)*

Ridership is an operationally useful indicator for transit agencies but problematic when it is considered in a modal vacuum. A decrease in transit ridership is not a bad thing, per se, since those ‘lost’ riders may instead be walking or biking, for example—a desirable outcome by many measures. The FTA’s ridership reporting requirement may as a result cause an agency to appear to underperform, even in cases where people in that agency’s jurisdiction have improved access to transportation options.

One approach to ridership that takes into account multiple modes is the Virginia DOT’s concept of *Person Throughput,* which looks at “change in corridor total (multimodal) person throughput attributed” to a proposed project.*(70)* Though VDOT uses this measure primarily in relation to congestion mitigation, it is defined broadly enough to recognize the multimodal, multi-provider nature of today’s transportation system.*(58)* As MOD continues to evolve, *Person Throughput* is an indicator that can be reoriented to report usage of all modes in a system or corridor – including bicycling, walking, and emerging mobility options. *Person Throughput* can thus supplement simple unlinked trip counts, which measures volume of use on a single mode, to better evaluate overall mobility.

Passenger (or Person) Miles Traveled (PMT)

Passenger miles traveled (PMT) is used to measure transit productivity and is also required for NTD reporting. According to TCRP's *A Guidebook for Developing a Transit Performance-Measurement System*, PMT "allows comparisons between different modes by describing the number of persons moved."*(50)* This metric has some drawbacks, namely in that it places a premium on distance, which is not necessarily an indicator of success.

Vehicle Miles Traveled (VMT)

It should be noted that many DOTs measure Vehicle Miles Traveled (VMT) to determine road and highway productivity, while transit agencies use it to determine transit productivity, as required for NTD reporting. This measure is also frequently used to determine environmental impacts. DOTs in Massachusetts, Oregon, and California, among others, are experimenting with using VMT to implement user fees – known in some states as Road Charges – which can have equity impacts as well.*(71)(72)(73)* This metric can have interesting implications for emerging mobility modes such as bikeshare, TNCs, and demand-responsive options.

Mode share

Mode share is ubiquitous, as mode share data is collected by the US Census' American Community Survey—though only for work commute travel behavior. Common categories include bicycle, pedestrian, transit, carpool, and drive alone. This indicator supports measurement of long term progress but can be somewhat insensitive to short-term transportation system changes.

Mode shift

Litman defines mode shift as the "number of portion of automobile trips shifted to other modes."*(69)* In its *Central Minnesota Area Commuter Study,* the Minnesota DOT proposes such indicators as SOV trips reduced and vehicle miles of travel (VMT) reduced in its evaluation of rideshare programs.*(57)* This metric can be also be applied in relation to other modes, for instance shifting trips from paratransit to wheelchair accessible taxis or TNCs.

Average Vehicle Occupancy (AVO)

Also referred to as average vehicle ridership or vehicle occupancy rate, this metric encompasses average auto occupancy, as well as transit vehicle occupancy, and is connected to seat capacity. The EPA defines this as "the number of passengers traveling on a roadway segment or network divided by the number of vehicles traveling on the segment or network."*(64)* The EPA offers a sample formula, "AVO = (% carpool trips * avg. carpool occupancy) + (% SOV trips *1) + (% vanpool trips * avg. vanpool occupancy) + (% bus trips * avg. bus occupancy)."*(64)* This indicator has multimodal applications, and provides a foundational insight into mode share. It also has land use and environmental implications, all making it a natural candidate for inclusion in MOD indicators.

3.4.4 Environmental Sustainability Indicators

Greenhouse gas (GHG) emissions from passenger travel

When there's a stated sustainability goal, transit agencies and state DOTs look at GHG generated/passenger,*(55)* system wide daily VMT/CO_2 emissions,*(64)* passenger transportation CO_2 emissions per capita,*(64)* index of emissions intensity of the road-vehicle fleet,*(61)* among many others. Energy and emission reductions are targets that are based on these indicators. There appears to be no standard metric used by the various agencies, which would make it more useful in both local as well as regional and national contexts. However, measuring emissions has a valid use in MOD as it can influence prioritization of modes and may itself reduce emissions. According to a TCRP study, *Ridesharing as a Complement to Transit: A Synthesis of Transit Practice*, a reduction in Carbon emissions via ridesharing is currently measured by some transit agencies.*(74)* This metric has the potential to be employed on a broader scale by and through other emerging mobility providers for the greater public benefit.

3.4.5 Equity

While some agencies indeed look specifically at equity indicators, these were not commonly found across the transit agencies and state DOTs we looked at. USDOT and FTA require fixed-route transit providers that receive federal funding to report on certain indicators every three years as part of satisfying Title VI of the Civil Rights Act of 1964.*(75)* Title VI "prohibits recipients of Federal financial assistance (e.g., states, local governments, transit providers) from discriminating on the basis of race, color, or national origin in their programs or activities, and it obligates Federal funding agencies to enforce compliance."*(75)*

The indicators required by Title VI are both qualitative and quantitative, addressing service standards and service policies. For fixed-route transit providers with more than 50 vehicles at peak service and in Urbanized Areas (UZA) with a population of 200,000 or more, the quantitative indicators required under Title VI reporting include: vehicle load for each mode, vehicle headways for each mode, on-time performance for each mode, and service availability for each mode.*(75)* The qualitative indicators are: vehicle assignment for each mode, and distribution of transit amenities (such as benches, bus shelters, or information provision).*(75)* Additionally, providers are required to collect and report on demographic data to show "the extent to which members of minority groups are beneficiaries of programs receiving Federal financial assistance."*(75)* This data includes "demographic and service profile maps and charts as well as customer demographics and travel patterns."*(75)* In order to determine whether a service change would have a "disparate impact" on Title VI protected populations, the FTA states "[t]he typical measure…involves a comparison between the proportion of persons in the protected class who are adversely affected by the service or fare change and the proportion of persons not in the protected class who are adversely affected."*(75)*

Beyond the scope of Title VI, TCRP recommends the following indicators, for agencies to identify "transit disadvantaged populations," with a focus on mobility and availability: households with no automobiles, population with physical disabilities, low-income single parents, people too young or old to drive, unemployed adults, and recent immigrants.*(50)* Other potential indicators include fares relative to incomes and portion of vehicles and stations that accommodate travelers with disabilities. These indicators are not commonly used today.

3.4.6 Safety & Security

Crash counts and rates
Crashes are measured in a variety of ways for each mode. Along with more traditional crash counts involving transit vehicles, some agencies have begun to measure bicycle crashes and pedestrian crashes.

Crash fatalities and disabling injuries
As with crash counts, data regarding fatalities and injuries are required for NTD reporting. Similarly, we found several ways agencies measured these, including rate and number of fatal and severe injury crashes,*(58)* and annual crash fatalities and disabling injuries.*(64)* Many agencies also collect data on personal security and crime, such as transit related crime rate and number of transit vandalism incidents. *(60)(61)* Also as above, some agencies are beginning to record bike or pedestrian injuries/fatalities,*(61)* and taxi passenger casualty rates.*(76)* These approaches hint at possible applications of both of these safety indicators within MOD.

Few transit agencies currently collect data that reflect the safety advantages transit-oriented communities have over automobile-dependent areas, especially in terms of reducing per capita traffic crash casualty and injury rates.*(77)* Such data would require a comparison of per capita crash injuries and fatality rates in transit-oriented and automobile-dependent areas.

3.4.7 Customer Satisfaction

Public satisfaction with transportation system by mode
Customer satisfaction is yet another commonly-found metric across agencies. TCRP defines customer satisfaction ratings as “a measure of the gap between expectations of a service and perception of service performance.”*(50)* Transit agencies often perform rider surveys annually, or every few years, depending on resources. Most often these indicators emphasize the public’s satisfaction with transit system, but state DOTs will also measure satisfaction with the auto traffic system. More recently, a minority of agencies have also measured satisfaction with the bike system and walking system,*(65)* and with the ridesharing system.*(74)*

4 GOALS IN THE PRIVATE SECTOR

We conducted interviews with private emerging mobility providers and transportation companies, ranging from bikeshare to on-demand transit to trip-planning apps to understand their definitions of success. As for-profit enterprises, the goal of making money is the most fundamental distinction between their operations and public agencies’. There is nuance in companies’ other goals, however, which can complement those of the public sector.

Some goals expressed in interviews conducted for this literature review include:
- Reduce friction to help users shift commute choices
- Introduce customers to new mobility products to create new revenue streams
- Collect and leverage data on diverse trip behaviors
- Maintain fixed fares for on-demand mobility

- Help agencies institutionalize learning from private providers in order to inform future investments

Most of these goals are also supported by monopolizing a transportation market segment—consistent user experience, comprehensive data collection, and a captive audience to whom to market new mobility products. As Uber has already demonstrated in many markets, this drive toward monopoly will inevitably create friction and risk between the private and public sectors, with the latter needing to make value judgments about transportation provision according to local and regional context. For example, public agencies may need to make trade-offs between maintaining market competition in the long term (which could add costs in the short term) and providing the most robust service possible in the short term (which could increase monopoly-driven cost risks in the long term).

Because companies' strategic plans (and many performance indicators) are not public, it is not possible to systematically evaluate the alignment between their goals and performance indicators—but many are tied to profit, whether directly or indirectly, which allows for some clarity. For example, the firms interviewed for this review focus heavily on customer experience and satisfaction, which ultimately attract more customers and thus more revenue.

5 PERFORMANCE INDICATORS IN THE PRIVATE SECTOR

Private sector firms tend to be reluctant to share financial and performance data, which limits the potential to explore existing performance indicators. Even when emerging mobility providers have partnered with transportation agencies, data remains sparse. Pilot projects like those between Florida's Pinellas Suncoast Transportation Authority and Uber, and between the Kansas City Area Transportation Authority and Bridj *(68)* remain opaque to the public because data is not made available.

Furthermore, multiple private providers noted that in negotiating partnerships, public agencies generally ask companies to determine which indicators should be used to evaluate those companies' success. This apparent lack of vision on the part of public sector partners could reflect a lack of understanding of new services, which will hopefully be addressed with time and exposure. Wherever it comes from, it is problematic to have companies writing their own evaluation criteria.

One notable exception to the above-mentioned dynamic concerning both goal-setting and data-sharing is found in Go Centennial, a pilot partnership between the City of Centennial, Colorado, and several private providers, including Lyft and Xerox (which operates the Go Denver trip planning and fare payment app). The program was developed as a first-last mile solution, providing free on-demand rides to and from Centennial's Regional Transportation District (RTD) Dry Creek light rail station. The application for funding specifies six focus areas*(78)*:

1. Influencing Commuter Behavior
2. Benefiting Drivers and Transit Users

3. Cost Effectiveness
4. Technology/User Experience
5. Transferability and Sustainability
6. Long-Term Change for Centennial

Each of these focus areas has several goals, performance indicators, and targets associated with it. For example, under the first focus area, Influencing Commuter Behavior, one goal is to "Increase light rail ridership; make more efficient use of seating space."*(78)* The specific target associated with this goal is to increase RTD light rail ridership from Dry Creek Station from an average of 1,904 trips per day to 2,100 trips per day.*(78)* (A summary table of goals and indicators from this partnership can be found in Appendix E.) Go Centennial is fairly new and thus its success cannot yet be evaluated, but the program provides a model upon which future MOD partnerships can be developed, where the goals are clearly articulated and specific indicators and targets are linked to them.

Bikeshare systems have a stronger track record of data transparency, in part due to the quasi-public nature of bikeshare systems, and in part due to users' need for real-time availability information. It should then come as no surprise that some of the most developed private sector indicators come from this industry.

Capital Bikeshare, in the Washington, DC region, publishes performance data online, grouping indicators into four categories: Ridership, Fleet Performance & Safety, Customer Service, and Membership. Some indicators of note include trips per time interval, percentage of trips per time interval, miles traveled per month, stations full or empty (number of instances), stations full or empty (percentage of instances per time interval), rebalancing (number of times bicycles picked up and dropped off at stations by the system operator), total number of users, and new members.*(79)* Citibike, in New York City, reports on ridership (in terms of membership numbers and trip numbers), trip distance, environmental impact (in terms of calories burned and pounds of carbon saved), as well as station maintenance operations and customer service indicators similar to those of Capital Bikeshare.*(80)*

The Institute for Transportation and Development Policy (ITDP) created a *Bike-share Planning Guide* which makes an interesting distinction between casual users (defined as those with subscriptions of 7 days or less) and long-term users (month+ subscriptions).*(81)* The guide also promotes the use of two critical performance indicators -- average number of daily uses per bike and average daily trips per resident, because they represent system efficiency and market penetration, respectively.*(81)* ITDP's guide also includes information about London's Barclays Cycle Hire (now Santander Cycles), which used four categories of service indicators: customer service, IT system, maintenance, and redistribution.

Some taxi indicators, too, are available, as taxis are also sometimes considered a public/private mode. Transport for New South Wales, in Australia, provides public data on taxi availability and customer service measures,*(82)* while the New York City's Taxi & Limousine Commission (TLC) publishes a "Factbook" that includes data for each TLC-governed mode (yellow/medallion taxi, green taxi, for-hire vehicles, and commuter vans), summarized in Table 9 below.*(83)* It should be noted that New York City is unique in that TNCs like Uber and Lyft, and microtransit services like VIA, are considered for-hire vehicles and fall under the regulatory authority of the TLC. They are thus subject to TLC rules and requirements, and must comply with the agency's data-sharing requirements. While the TLC has long collected data from yellow/medallion taxis and green taxis, the agency only began collecting data from for-hire vehicles – including traditional radio-dispatched vehicles as well as from TNCs– in 2015.*(83)* It is highly unusual to find such a high level of publicly-available data within the traditional taxi industry and the emerging mobility industry. That the TLC is able to collect and share such data proves not only that it is possible to do so, but that the data is useful to policymakers, planners, and the public alike.

Table 9: Summary of NYC TLC Service Data

Service Provided	Service Consumed	Demographic Information	Safety
• Number of active drivers • Average vehicle age • Number of hybrid medallion taxis • Number of wheelchair accessible taxis • Average number of cars active by time of day • Total e-hail requests fulfilled	• Number of trips • Number of trips in a wheelchair accessible vehicle (WAV) • Total e-hail requests • Average percentage occupancy by time of day • Percent of trips paid by credit card • Average gross driver fare revenue per hour	• Average driver age • Driver population gender • Birthplace of drivers • Current place of residence	• Crashes involving TLC-licensed vehicles • TLC Vision Zero outreach events conducted • TLC Safety Honor Roll drivers

The Ridesharing Institute's *Transportation Performance Measures and Ridesharing* puts forth a set of recommendations for ridesharing performance indicators, with an emphasis on peak period travel. The short memo strongly advocates for the use of PMT over VMT, stating that "PMT are fundamentally better measures of performance than vehicle miles traveled."*(84)* While this may be so, PMT itself has its weaknesses, as discussed above. PMT should not necessarily be used alone but, rather, in combination with other indicators, such as Number of Trips or Travel Time. The memo also emphasizes "tiered" indicators based on scale: national, state, metropolitan region, local, individual corridors, and individual pilot projects.*(84)* Such an approach could be helpful in an MOD deployment.

The following list is a selection of existing – and publicly available – indicators that are used to measure operational health within the private transportation industry.[2] These are organized by the seven relevant existing goals as the public indicators were, though only a few of the categories apply here.

[2] Note that when an indicator does not have a citation, it emerged from our interviews with private mobility providers who wished not to have their company specifically cited.

5.1 Connectivity

Availability

Some existing indicators in the on-demand transit/microtransit sector include headways, access to identified points of interest, missed trips, and no-shows. Bikeshare indicators include station density ratio, bicycles-to-population ratio, and time required to check out a bike.*(79)(80)* Transport for New South Wales' availability indicators for taxi service include percentage of abandoned phone calls , average answering time, average pick up, percentage of no car available (NCA).*(82)* NYC TLC's taxi and for-hire vehicle indicators include number of cars available by taxi mode, number of active drivers, number of wheelchair vehicles available, and number of e-hail requests fulfilled.*(83)* Anecdotally, TNCs have stated that estimated time of arrival (ETA) is a key indicator of availability.*(85)* For carshare, fleet size and percentage of an area in walking distance from a carshare vehicle may be used. *(86)*

Travel Time

Similar to that used by agencies, some private providers, especially on-demand transit providers, look at delays and early arrivals, often comparing these to conventional transit to measure performance. Travel time is not reported by traditional taxi services but, in New York City, travel times can be calculated using publicly available data provided by the TLC.*(87)*

The above-mentioned indicators all have usefulness in MOD deployments, as they are specific gauges of the services available to riders, measured by mode.

5.2 Financial Management

Ridership

Ridership can refer to the total number of users, such as is measured by Capital Bikeshare and Citibike, or actual trips for a given privately operated service or taxi service, such as trips and passenger counts as measured by NYC TLC.*(87)* In this context, ridership serves as a financial indicator, however if private ridership information is shared with public agencies, it can better inform mode shift and mode share, and can aid in local and regional mobility planning efforts.

Trips Per Hour

This indicator gauges the use of the vehicle or bike, and feeds into other indicators, such as revenue per hour, discussed below.

Cost per passenger

In his article, "New Approaches to Strategic Urban Transport Assessment," researcher Chris Hale describes this indicator as cost per passenger served. Alternatively, the Ridesharing Institute suggests consideration of cost per passenger mile for different modes (including carpooling and vanpooling as separate modes, as well as SOV highway travel and transit modes), and cost per passenger trip for different modes (including carpooling and vanpooling as separate modes, as well as SOV highway travel and transit modes).*(84)* Cost per trip also informs farebox recovery data.

Average Vehicle Occupancy (AVO)
While this is similar to that of transit, for private providers this is both planning indicator (as it is with transit), and a financial indicator. TNCs and on-demand transit providers use this to determine utilization and cost. AVO is often combined with other indicators, such as price per trip and trips per hour.

Cost/Revenue per vehicle hour
This is a key metric for private providers who need to determine whether the business is profitable. It is derived from a combination of the above-mentioned indicators, such as AVO, price per trip, and trips per hour. This metric may be useful to agencies partnering with private providers to determine if the partnership is feasible, affordable, and successful.

VMT
In this context, typically VMT is used to measure bikeshare miles traveled per month,*(79)* though it can have applications in other modes.

5.3 Planning

Instances of full/empty bikeshare stations
When stations are full, Capital Bikeshare measures the instances of additional time granted and the total number of extra miles granted.*(79)* This indicator also falls under the Customer Satisfaction category. While this approach to service is primarily seen in the private sector, it can have interesting implications if adopted by the public sector when, for instance, customers miss transit trips because of overcrowding.

Adherence to regulations
Primarily measured for bicycling and bikeshare at the moment. This can be calculated as the percent of new developments that include secure bicycle parking or other end-of-trip facilities.*(66)* This indicator can also be applied to siting of docks and other contractual requirements for private providers.

Number of successfully matched rides
This is a supply/demand metric that can measure the usefulness, utilization, and ease of use of emerging mobility services, including TNCs, carpools/vanpools, and traditional ridesharing. Currently, there are few publicly-available data sources reflecting this indicator, with the exception of NYC TLC's measure of e-hail requests fulfilled.*(83)*

5.4 Environmental Sustainability

As noted above, Citibike in NYC estimates its reductions in greenhouse gas emissions, but other sustainability indicators were not commonly found among the private providers reviewed. In partnership with the Bay Area's Metropolitan Transportation Commission, UC Berkeley, and the National Resources Defense Council, Lyft and Uber have shared data to understand their impact on greenhouse gas emissions in the region,*(88)* which could yield a methodology that can be applied to those and other providers moving forward.

5.5 Equity

Some private providers have taken steps to ensure wheelchair accessibility across their services as a matter of policy, though none interviewed for this research identified specific performance indicators with which they track progress. If a TNC offers some form of wheelchair accessible service, for example, the company may measure the difference in wait time for such vehicle requests compared to a 'standard' request. The NYC TLC counts the number of wheelchair accessible vehicles (WAV) and total trips in WAVs, as well as tracking the method by which WAV requests were made (phone call, text, app, online).*(83)*

Coverage of service area is a straightforward indicator of geographic equity, but was not mentioned as a concern. Some providers have worked with municipalities or transit agencies—as in the case of car2go and Seattle *(68)*—to ensure some degree of equitable coverage, though these cases reflect goals set by the public sector.

Racial and income equity are challenging for the private sector, as few companies collect or maintain such demographic data on their users, and as profit-driven enterprises there is little incentive to provide cost-equitable service absent public subsidy.

5.6 Safety & Security

Specific performance indicators were not apparent, but at a minimum TNCs commonly perform a background check on their drivers. Traditional taxi services—and TNCs in some jurisdictions, notably New York City, Houston, and Austin—are also commonly required to fingerprint their drivers as a part of such background checks.*(89)(90)(91)* Similarly, drivers for traditional taxi services are also required by many cities to submit to regular drug screening, often yearly.*(92)* Relevant metrics could include a binary "yes/no" regarding whether these various requirements are in place, or a percentage of drivers who have submitted to such requirements, for example in jurisdictions where compliance is optional.

5.7 Customer Satisfaction

Wait time
The uncertainty of waiting for a bus, especially late at night when transit service runs infrequently, is a pain point that private companies are happy to capitalize on. Short wait times mean happy customers.

Public satisfaction with transportation system by mode
Capital Bikeshare measures public satisfaction with its system.*(79)* This is measured widely in the public sector, but can be used in other modes, and for an overall system in MOD deployments.

Driver/passenger 'courtesy'
This is commonly measured through star-rating systems. In the case of TNCs, drivers can also rate customers. Operationally, these ratings are used by TNCs to minimize bad behavior on the part of drivers—drivers who fall below a certain star-rating threshold may be stripped of their driving privileges,*(93)* creating a positive incentive for customer service.

6 OVERLAPS AND GAPS

Exploring the overlaps between and gaps in knowledge across the public and private sectors may prove instructive for MOD. This section first identifies common ground between the public and private sectors, and then identifies remaining performance indicator needs that do not appear to be well understood.

6.1 Overlaps

Ridership indicators were one of few consistent threads between private and public sector transit providers. Ridership is applicable for any mode individually, though data collection becomes complicated when inter-modal trips are considered that include bikeshare, TNCs, microtransit, and other emerging modes. Similarly, average vehicle occupancy (AVO) is in use by both private and public providers, though TNCs and microtransit providers give it more priority, since it is directly tied to such companies' profits.

Service availability, customer satisfaction, VMT, and [provider] cost per passenger or trip are all important to both public and private transportation providers. Cost per trip and customer satisfaction may be of particular interest, considering that part of MOD's speculated promise is in reducing public subsidies while maintaining or improving service quality for certain modes, such as paratransit.*(94)(95)*

6.2 Gaps

The novelty of MOD ensures that there is much left to learn. Several gaps remain to be filled with a better understanding of multimodal performance indicators. In some cases, existing indicators are still relevant and may even be ideal—in others, a more radical change may be required to understand performance in a meaningful way.

Equity is one of the areas where performance indicators are inconsistent and a critical gap remains. Litman suggests indicators that consider different types of demand by age, income, gender, circumstance, and ability, and the consequences of not meeting these demands. Groups include: youths (10-22 years old), seniors (over 65), lower-income households, non-driving tourists, urban peak commuters, neighborhood trips, and post-drinking or drug use.*(76)* Breaking down users by type is echoed by the EPA, which suggests measuring the distribution of benefits by income group.*(64)* Roughton, et al., of Alta Planning + Design, touch on this briefly, categorizing bike infrastructure by the extent to which it caters to bicyclists of varying comfort levels (*Miles of bikeways catering to each type of bicyclist i.e. Strong and Fearless, Enthusiastic and Confident, and Interested but Concerned).(66)* User types can be applied in the context of any mode provided that relevant demographic data is available.

Litman also describes a brief list of equity criteria & indicators, which include: egalitarianism, users bear the costs they impose, progressive with respect to income, benefits transportation disadvantaged, and improves basic mobility.*(76)* TCRP's *Guidebook for Developing a Transit Performance-Measurement System* also recommends looking at "service equity,"*(50)* while the University of California Transportation Center (UCTC) states that equity "involves factors such as travel cost, accessibility, and emissions, under a specific sociodemographic distribution."*(62)*

The few existing indicators used by agencies to measure accessibility in compliance with the Americans with Disabilities Act (ADA) have to do primarily with paratransit availability, usage, and ADA complaints.*(65)(52)* With respect to wheelchair accessibility, New York's MTA measures bus passenger wheelchair lift usage and provides real-time information on elevator availability in subway stations.*(42)* As discussed above, Transport for New South Wales and the NYC Taxi & Limousine Commission report on wheelchair accessible taxi availability.*(75)(76)(77)* Specific federal reporting requirements for wheelchair accessibility in transit merits more detailed exploration, given that the ADA requires equal access.*(96)*

Land use provides a significant challenge to measuring performance, but researchers and agencies have recommended some paths forward, especially within the context of developing sustainable and smart cities. Litman, the EPA, the Transportation Research Center (TRC), CalTrans, and others all suggest a variety of approaches to measuring land use and its impact on transportation accessibility. Litman suggests the use of land use density and mix as an indicator, which is the "number of job opportunities and commercial services within 30-minute travel distance of residents."*(65)* The TRC discusses vehicle occupancy by land use (average number of people per vehicle by land use type through counts of inbound/outbound vehicle occupancy to/from specific land types).*(60)* Though this is an automobile-oriented measure, it may be useful in MOD deployments if broadened to include all modes. The EPA suggests several land use indicators, such as ratio of jobs to housing, employment to dwelling unit ratio, amount of square footage of buildings, and acres of land consumed per residential unit.*(64)* Hale also suggests policy-driven (though hard to explicitly define) land use indicators such as housing stress, suburbanization (proportion of households in urban/suburban/rural locations), and transit–real estate strategy.*(97)*

Related to land use, the UCTC's *Measuring Multimodal Transport Level of Service* discusses transfer and first-last mile issues in the context of scheduling coordination and physical integration toward improving first-last mile connections.*(62)* Though the study's emphasis is on rail-to-airport connections specifically, first-last mile connections are a highly relevant topic not touched upon or accounted for in most existing agency indicators. Some private providers are forming partnerships that attempt to provide these connections, but it is unclear on what basis these partnerships are being evaluated.*(68)*

In *Creating Walkable and Bikeable Communities: A User Guide to Developing Pedestrian and Bicycle Master Plans*, Roughton identifies other novel indicators for non-motorized transport performance. These include percent of buses equipped with bicycle racks, percent of roadways with sidewalks, percent of intersections up to ADA standards, number of transit stops with pedestrian amenities, number of walking and bicycling trips per day along key corridors, average trip distance across all modes, and mode shift resulting from individualized marketing programs, among others.*(66)* Hale also identifies some less commonly-used indicators such as mode share splits by journey types, fuel taxes, station access mode splits (relative usage of various modes to access local mass transit station).*(97)* Some of these indicators have been challenging to measure, but are becoming increasingly feasible with the support of new data (e.g. cell phone and GPS tracking data).

7 DISCUSSION

A few broad and open questions remain to be rigorously addressed. How can public agencies access the data necessary to calculate multimodal performance indicators comprehensively? How can transportation accessibility be measured when affordability, coverage, technological barriers to entry, and ADA accessibility vary so greatly across modes and for different demographics? What does it mean, quantitatively, for one transportation mode to ‘complement’ another, and from whose perspective should we view such complementariness? These questions are the tip of the iceberg, and any agency seeking a MOD partnership will need to grapple with them.

It’s important to start with a clear articulation of goals, and connect those directly to objectives and performance indicators, as demonstrated by SFMTA. The limitations of some indicators may necessitate a portfolio of indicators rather than reliance on one indicator for any given purpose—this could become increasingly true as the mobility system continues to diversify. Different indicators will also apply regionally rather than at the city level, within a transit agency rather than an MPO, or perhaps at a state DOT that also operates transit. Not to mention that one MPO may play a dramatically different role in its region relative to a neighboring MPO.

Of course, goal-setting is not itself an objective process. Different agencies will have different priorities, and these are not always explicit. KCATA effectively set an objective to maintain a basic pay floor for its drivers when it decided to use its own in-house unionized employees in its partnership with Bridj, for example.

Many MOD partnerships to date have been undertaken to some degree for the sake of experimenting, without clear goals and objectives set out in advance—or at least not by the public sector agencies involved. There is a need for more up-front clarity on the types of goals that MOD partnerships can help achieve, and how progress toward those goals can be measured. This alone will greatly strengthen the foundations of many MOD partnerships to come.

Some of the most valuable performance indicators may in fact not be quantitative in the first place. At this early stage, agencies also benefit merely from the learning process and through exposure to emerging mobility services. Staff or public surveys may serve as valuable tools in this respect. Some evaluation criteria may also be sensitive to governance, for example, suggesting a more general agency survey may be of value: who has jurisdiction over streets? Is there an integrated fare payment system? If so, does it support unbanked populations? Which modes are accessible via this fare payment system? There is also potential value in meta-evaluations, for example exploring whether the stated and achieved goals of a specific MOD partnership mirror an agency's articulation of its goals more generally.

The federal role in all of this inevitably must allow for contextual variation across transit agencies, governance structures, and land use contexts. For this reason, the FTA must consider not only what performance indicators are important but rather to what degree the FTA can and should be prescriptive about those indicators. The FTA could, for example, require a baseline of standardized data submission while allowing individual transit agency MOD participants to choose indicators that reflect their own values, ensuring that indicators are tied to both federal and local program goals.

The importance of federal flexibility is to some degree in tension with the value of federal standardization, especially where data is concerned. The federal government could also use this opportunity to set out clearer expectations for private providers with regard to what data they will need to share in order to receive and/or maintain federal subsidies. Where many cities and states have failed to negotiate for more robust data, the weight of the FTA could succeed.

Transit agencies, DOTs, and MPOs are responding to incentives that the federal government creates. What is clear from this review of performance indicators is that these incentives are not working. The federal government can amend the reporting requirements it gives to MPOs, DOTs, and transit agencies to yield more cooperation across public agencies as well as between the public and private sectors. As we move toward expanding MOD deployment, goals should be aligned between USDOT, MPOs, transit agencies, and state DOTs. If that is possible, private providers will respond productively to those goals. If clear incentives and regulations are set forth by the public sector, private providers should be able to help achieve regional goals at least as cost-effectively and equitably as public agencies currently do, if not more so.

Table 10 below proposes a basic approach to identifying performance indicators within a framework of today's common transportation agency goals. The specific indicators that make sense may vary by project or region or by governance level, and this table is provided as a tentative first step toward an MOD evaluation framework.

The indicators presented in this literature review can help public transportation move toward MOD, though the indicators will require refinement and expansion. Tension will likely remain between public agency and private provider goals, making it important to protect the public interest while exploring areas of potential, constructive overlap. Public agencies must set clear goals; articulate specific performance objectives in line with those goals; and select measurable performance indicators when partnering with private mobility providers.

Table 10: Potential MOD Evaluation Framework

Goals Areas	Preliminary Definition	Sample Objectives	Sample Performance Indicators
1. Connectivity	The usefulness, quality, and accessibility of the service, providing basic mobility for travelers	• Improve walking and cycling conditions • Improve public transportation and MOD services • Create more accessible neighborhoods	• route-level headways • access to points of interest • delays • missed trips • no-shows • bikeshare station density • carshare fleet size • number/variety of non-fixed route services in area • number of options (e.g. Uber, Lyft) per service
2. Financial Management	The financial sustainability of the provider and the effective allocation of resources	• Improve utilization by mode • Promote cost-efficient service • Increase utilization • Reduce deadhead time and mileage	• ridership • passengers per vehicle mile • average vehicle occupancy • cost per passenger trip • cost/revenue per vehicle hour • cost per passenger trip by mode • number of people subscribed to/signed up for ridesharing program
3. Planning	Community engagement, economic development, land use decisions, and system planning	• Engage local communities • Provide transportation options to low-income neighborhoods • Create more compact, mixed, multi-modal neighborhoods with complete streets and efficient parking management	• bikeshare stations full or empty • number of successfully matched rides • bicycles-to-population ratio • mode shift • peak/off-peak ratio • community impacts • adherence to regulations • transportation-efficient land use • Development density and mix • per capita vehicle ownership and use • use of non-automobile modes
4. Environmental Sustainability	The environmental footprint of the company	• Reduce automobile travel • Shift travel to resource efficient modes using cost-effective incentives, including improvements to efficient modes and more efficient pricing • Reduce air and noise pollution	• per capita motor vehicle travel • mode share • GHG generated/passenger • noise pollution • percent of alternative fuel vehicles in the fleet • energy used/passenger trip • impact to natural and cultural resources • regulation-compliant vehicles

Goals Areas	Preliminary Definition	Sample Objectives	Sample Performance Indicators
		• Reduce impacts on communities and natural resources	
5. Equity	The availability and usefulness of the system for all people	• Improve affordable modes (walking, cycling, public transportation and MOD services • Provide equal transportation options and availability for people with disabilities • Ensure that affordable housing is located in accessible neighborhoods	• access to wheelchair accessible vehicles (WAVs) • fare affordability • elevator availability • bus passenger wheelchair lift usage • paratransit response time • geographic coverage • percentage of residents with access to service
6. Safety & Security	The ability to protect the system, riders, and employees from harm	• Ensure customer and worker safety in all modes • Ensure customer and worker security in all modes • Protect customers and workers from harm	• illnesses and deaths • crimes by mode • accident/crash rates • existence of drug & alcohol testing • existence of fingerprinting and background checks • number of preventable collisions
7. Customer Satisfaction	Rider happiness with the system	• Ensure the comfort and convenience of travelers, regardless of mode	• wait time • satisfaction with entire system • satisfaction with driver • satisfaction ratings by mode • complaint rate by mode • customer loyalty by mode • customer service response time
8. Organizational Excellence	The capacity to deliver transportation services	• Create an inclusive, innovative, and productive work environment to facilitate the seamless and efficient delivery of transportation services	• employee rating • percent of employees with performance plans prepared by the start of fiscal year • female representatives in workforce • minority representatives in workforce
9. State of Good Repair	The maintenance of the transportation system to protect long term investment of infrastructure	• Maintain all transportation facilities and vehicles (including shared bikes and cars) to the highest standards of safety and quality	• average miles between breakdowns • average age of vehicles/bikes • average daily % of fleet unavailable for service • number of vehicles/bikes inspected/repaired per month

8 APPENDIX

Appendix A: FTA 1995 Strategic Plan Goals and Objectives

Goals	Objectives
Maximize security and safety of transit systems for service users	• Improve personal security • Improve operational safety • Develop and demonstrate new and innovative technologies • Improve emergency management planning
Foster customer-oriented public transportation	• Emphasize improved transit services for minorities and transit-dependent persons living in economically distressed communities • Make transit systems easier to use and more reliable to the customer • Support the development of full service transit systems that have the ability to meet a variety of customer needs
Foster industry adaptability to enable the industry to respond to changes in transportation patterns, technologies, and needs	• Increase and improve public transportation effectiveness through research and adoption of new technology, management practices and service innovation • Foster production of "better" transit vehicles and components • Promote the collection, dissemination, and exchange of information on research, technology, management practices, and innovation • Provide assistance to domestic transit manufacturers and technical service industries to enhance the US competitive position in global markets
Maximize a multimodal approach to transportation	• Lead the development of seamless transportation systems that provide options and ensure convenient linkages between modes for all persons in all communities combines with a public awareness of those transportation choices through easily accessible integrated information • Promote a collaborative process among Federal, State, Local, and other organizations (public and private) which provides a greater variety of choices in the transportation of people and goods • Identify and address community and individual transportation needs through intermodalism
Ensure a quality organization that emphasizes mutual respect	• Foster an environment which supports mutual respect and courtesy, ensures that all employees are treated fairly, and strives to maintain and upgrade the professional/technical knowledge and competence of employees • Foster an environment which actively promotes the employment and retention of a diverse workforce within FTA • Promote career development and the establishment of a fair and equitable reward system to include awards other than monetary. These initiatives will maximize individual contributions to the agency while improving employee quality of life • Encourage mutual understanding of the program challenges of headquarters and regional offices • Operate under the principle that employees are valued, empowered to make decisions and take risks while functioning as a team to accomplish the agency's mission
Ensure the highest level of transit service assistance Delivery	• Provide improved technical assistance to FTA grantees • Provide stable and reliable sources of funds for improved service • Improve ongoing program evaluation to increase effectiveness of the FTA program in supporting and improving public transportation and mobility • Streamline the grant delivery process and provide improved program management to FTA grantees

Goals	Objectives
Promote linkages between transit needs and community needs	• Promote the development of transit facilities and services that meet the needs of communities, which are linked to land use planning and design that encourages pedestrian/bicycle access • Link transit and environmental planning to enhance environmental preservation • Promote a participatory planning and design process that stresses community involvement
Foster a positive image for public transportation and FTA	• Promote public transportation in America with FTA as an active partner

Source: FTA Strategic Plan (in Transit Planning & Research Reports 1995) *(98)*

Appendix B: List of Agencies Reviewed

State DOTs	Transit Agencies	MPOs, Cities, Other
1. USDOT *(3)*	1. FTA *(98)*	1. Central Lane MPO *(64)*
2. MassDOT *(29)*	2. Valley Metro (Phoenix metro area) *(36)*	2. Mid-America Regional Council -- Kansas City Region *(64)*
3. MinnDOT *(57)*	3. SFMTA *(40)*	3. Bay Area Metropolitan Transportation Commission (MTC) *(109)*
4. CalTrans *(31)*	4. COTA (Central Ohio Transit Authority) *(44)*	4. Broward Metropolitan Planning Organization *(110)*
5. Virginia DOT *(32)*	5. MBTA *(29)*	5. Memphis Metropolitan Planning Organization *(111)*
6. Arizona DOT *(99)*	6. CTA *(52)*	6. New York Metropolitan Transportation Council (NYMTC) *(19)*
7. Tennessee DOT *(100)*	7. KCATA *(53)*	7. Delaware Valley Regional Planning Commission (DVRPC) *(112)*
8. Mississippi DOT *(101)*	8. DART (Dallas Area Rapid Transit) *(38)*	8. Southern California Association of Governments (SCAG)*(20)*
9. Ohio DOT *(102)*	9. TfL (London) *(55)*	9. Centennial, Colorado *(78)*
10. NYS DOT *(27)*	10. MTA / NYCT *(42)*	10. City of Ottawa *(65)*
11. ConnDOT *(103)*	11. King County Metro (Seattle) *(106)*	11. Seoul Metropolitan Government *(16)*
12. TxDOT *(104)*	12. LA Metro *(107)*	
13. WSDOT *(105)*	13. RIPTA (Rhode Island Public Transit Authority) *(43)*	
	14. AC Transit (Oakland) *(37)*	
	15. Memphis Area Transit Authority (MATA) *(39)*	
	16. Transport for New South Wales (Australia) *(82)*	
	17. Ministry of Transport & Communications (Finland) *(108)*	
	18. Singapore Ministry of Transport *(13)*	

Appendix C: Sample Indicators by Goal Area

Connectivity Indicators

Connectivity	Performance Indicator	Mode
Availability	Transit service hours per capita	Transit
	Number of service denials/pass-ups	Transit
	Hours of service (total cumulative hours of service provided by a transit system each day)	Transit
	Frequency of canceled trips (percent of scheduled trips that are canceled	Transit
	Stations full or empty (number of instances)	Bikeshare
	Stations full or empty (time interval)	Bikeshare
	Stations full or empty (percentage of instances per time interval)	Bikeshare
	Time required to check out a bike (minutes)	Bikeshare
	Percentage of abandoned phone calls	Taxi
	Average answering time (minutes)	Taxi
	Average pick up (minutes)	Taxi
	Percentage of no car available (NCA)	Taxi
	On-vehicle bicycle carrying facilities (# of vehicles available for bike carry on vehicle/total # of vehicles)	Transit/Bike
	Percent person-minutes served (percentage of time an average person has transit service available)	Transit
	Distance to transit stops (miles)	Transit
	Transit convenience/ stop accessibility (availability of transit within 1/2-mile (or 1/4-mile) air distance at an origin and destination)	Transit
	Bicycle network density (miles of bike network accessible w/in 1/4-mile or # of diverse uses accessible w/in 3 miles)	Bike
	Accessibility (percentage of an area in walking distance from a carsharing vehicle percentage of an area in walking distance from a carsharing vehicle)	Carshare
Travel Time	Delay per traveler ((actual travel time-FFS or PSL travel time)*(250 weekdays/year)*(hr/60min); annual hours))	Transit
	In-vehicle travel time (minutes)	Transit
	Transfer time (minutes)	Transit
	Access time/accessibility (minutes)	Transit
	Waiting time (minutes)	Transit
	Average door-to-door commute times for residents (minutes)	Transit
	Average commute time (minutes)	Transit
	Total travel time (minutes)	Transit
	Transit priority delay reductions (minutes)	Transit
Reliability	On-time performance (percent of trips no more than 1 min early or 5 mins late)	Transit
	Transit reliability (percent of on time arrival -- on-time is a 0-5 minute late from a scheduled time for fixed schedule transit, and 30 minute time window from the requested pick-up time for demand responsive transit)	Transit

Connectivity	Performance Indicator	Mode
Frequency	Average Frequency (number of buses per hour)	Transit
Headway	Average Headway (time between buses, or the inverse of average frequency)	Transit
Serious and severe disruptions	Annual count	Transit
Number of transfers	Between origin and destination	Transit
Activity connectedness	CBD Access (proportion regional households within 30 minute transit journey to CBD; can be considered proxy for employment accessibility)	Transit
	Higher education access (proportion regional households within 30 minute transit journey to major university)	Transit
	Public health access (proportion regional households within 30 minute transit journey to major hospital)	Transit
	Jobs accessible via frequent transit (percent jobs within 400m of transit with 10-min or less headways during morning peak)	Transit
	Destinations accessible by transit (number)	Transit
Geographic service coverage	(∑1/4-mile buffer areas of bus stops+ ∑1/2-mile buffer areas of busways or rail stations)/area	Transit
Population service coverage	(∑population in 1/4-mile buffer areas of bus stops+ ∑population in 1/2-mile buffer areas of busways or rail stations)/population	Transit
Multiple route choices	Number of possible routes between origin and destination	Multi
Intermodal Connectivity	Bicycle/pedestrian connectivity (number of dead ends or offset interactions; ratio of the straight line distance to the path distance)	Multi
	Bicycle parking at stops and stations (number of stops with bike parking / total number of stops)	Multi
	Percent of new developments that include secure bicycle parking or other end-of-trip facilities	Multi
	Intermodal connections (number and location of connections between modes w/in a specific area -- mapped, quantity identified)	Multi
	Number of transit stops with pedestrian amenities	Multi
	Connectivity to intermodal facilities (percent of a geographic area that is within 5 miles of an intermodal facility -- 1 mile for a metropolitan area)	Multi
Walkability	Walkability Index A (walkway quantity relative to roadway length)	Walk
	Walkability Index B (walkway quality relative to roadway length)	Walk
	Percent of roadways with sidewalks	Walk
	Sidewalk coverage (percent of arterial & collector roads w/ sidewalks or pathways on both sides)	Walk
	Crosswalk spacing (average crosswalk spacing at signal supported)	Walk
	Number of safe crossings per mile (number of crosswalks or mid-block crossings per mile)	Walk
Bikeability	Length dedicated to protected bike paths (per capita)	Bike
	Bicycle parking spaces at schools (bicycle parking spaces / 1000 students)	Bike
Para-Transit Supply Index	Para-transit vehicle supply per capita	Paratransit
Bus accessibility	City Bus Transport Supply Index (bus service supply per capita)	Transit
Trip Length	Average trip distance across all modes	Multi

Connectivity	Performance Indicator	Mode
	Average trip length per traveler (miles from a specific TAZ or land use type)	Multi
	Average trip length (miles)	Multi
Transit signal priority	Number of intersections with TSP (also reported as percent completion of planned TSP network)	Transit
Miles of express fixed-transit route/dedicated bus lanes	Miles	Transit
Parking spaces designated for carpools or vanpools	Parking spaces for carpools or vanpools/total parking space	Rideshare
Taxi supply and conditions	Number of taxis	Taxi
Per capita taxi travel	Trips per capita	Taxi
Number of fare media outlets	Number	Transit

Financial Sustainability Indicators

Financial Sustainability	Performance Indicator	Mode
Costs	Average transit fare (dollars/ride)	Transit
	Cost per passenger (cost per passenger served)	Transit
	Average annual cost per revenue hour (average)	Transit
	Cost per passenger mile (cost/passenger mile for different modes, including carpooling and vanpooling as separate modes, as well as SOV highway travel and transit modes)	Multi
	Cost per passenger trip (cost/passenger trip for different modes, including carpooling and vanpooling as separate modes, as well as SOV highway travel and transit modes)	Multi
	Cost savings from rideshare (estimated fuel savings; gallons of gasoline saved)	Rideshare, Transit
	Cost savings from rideshare (estimated savings on auto operation and maintenance)	Rideshare, Transit
	Cost per unit of reduction (measures of cost-effectiveness are calculated by dividing program costs by a unit of change)	Rideshare, Transit
	person trips per dollar of public and private expenditure	All
Utilization	Number or portion of trips that use a travel service or alternative mode	All
Load factor	Percent of seats occupied each day	Transit
Percent of network that is "effective"	Percent of a community or area's roadway network that provides an effective through path for travel	Auto
Number of successfully matched rides	Count	Rideshare
Number of carpools/vanpools measured against a goal	Count	Rideshare
Number of ride matches available	Count	Rideshare
Number of new carpools formed	Count	Rideshare
Number of new vanpools formed	Count	Rideshare
Number of service gaps closed (via ridesharing, other modes)	Count	Transit
Service volume	Maximum service volume (passenger car/hr/lane)	Auto
Bicycles in service	Count	Bikeshare
Vehicle growth rate	Percent change in fleet size	Carshare
Member-vehicle ratio	Members / vehicles	Carshare
Market share	Company portion of the market / total industry	Carshare
Reduced vehicle ownership	Percent change in VMT/VKT	Carshare
	Percent average monthly cost savings	Carshare

Planning Indicators

Planning	Performance Indicator	Mode
Mode Share	Bicycle mode share (bicycle trips/total trips)	Bike
	Pedestrian mode share (pedestrian trips/total trips)	Walk
	Transit mode share (percent of total trips)	Transit
	Shared ride (2 or more) mode share (percent of total trips)	Rideshare
	Drive alone mode share (percent of total trips)	Auto
	Percent non-auto trips (of total trips)	Multi
	SOV mode split (percent of travel in SOVs; percent in other modes)	Auto
	Mode split (portion of travelers who use each transportation mode)	All
	Proportion of total PMT for non-SOVs (ratio of PMT by non-SOVs to total PMT: (PMThov+PMTbus+PMTrail)/PMTtot ; PMTtot is total PMT by all modes)	Multi
	Person trips per auto trip (person trips/auto trips)	Auto
	Percent of peak period passenger miles that is non-SOV	Multi
	Percent employees using a non-SOV mode	Multi
Mode shift	Vehicle trip reduction (number or percentage of automobiles removed from traffic)	Auto, Multi
	SOV trips reduced (number or percentage of SOV trips)	Auto, Multi
	Vehicle miles of travel (VMT) reduced (number or percentage of VMT)	Auto, Multi
	Reduced vehicle ownership (number of vehicles removed from transportation network per carsharing vehicle)	Carshare
	Reduced vehicle ownership (percent participants selling personal vehicle)	Carshare
	Reduced vehicle ownership (percent participants walking more)	Carshare
	Reduced vehicle ownership (percent participants taking transit more)	Carshare
	Reduced vehicle ownership (percent participants avoiding vehicle purchase)	Carshare
Trip origin/destination	Trip origin/destination by municipality	Transit, Bikeshare
	Trip origin/destination by station	Transit, Bikeshare
Fare payment	Fare integration / regional smartcard (yes/no)	Multi
Peak/off-peak ratio	Transit peak hour occupancy (average number of occupants in a vehicle during the peak hour)	Transit
	Peak period factor -- roads (percent daily person-trips taking place during peak travel periods	Transit
	Peak period factor -- transit (percent daily person-trips taking place during peak travel periods)	Transit
Average Vehicle Occupancy (aka average vehicle ridership or vehicle occupancy rate)	Average vehicle occupancy (AVO) (the number of passengers traveling on a roadway segment or network divided by the number of vehicles traveling on the segment or network; can be derived from mode share figures; sample formula: AVO = (percent carpool trips * avg. carpool occupancy) + (percent SOV trips *1) + (percent vanpool trips * avg. vanpool occupancy) + (percent bus trips * avg. bus occupancy); or regional travel demand model)	Auto, Rideshare, Transit
	Average auto occupancy (persons/vehicle -- during evening peak)	Auto
	Seat capacity/person capacity	Auto, Transit
Bunching	Percent of bunched intervals	Transit

Planning	Performance Indicator	Mode
Gaps	Percent of big gap intervals	Transit
	Number of walking and bicycling trips per day along key corridors	
Throughput	Person throughput (people/hr)	Multi
	Vehicle throughput (vehicles/hr)	Auto, Transit
Travel Time Index	Peak period travel time/free-flow travel time	
On-street Parking Interference Index	1/(percent major road length used for on-street parking + on-street parking demand)	Auto
Land Use	Transportation-efficient land use (areas are rated High, Latent, and Low on a TE scale)	All
	Vehicle occupancy by land use (person/vehicle; average number of people per vehicle by land use type -- count inbound/outbound vehicle occupancy to/from specific land type)	Auto, Transit
	Housing stress (proportion of regional households where averaged housing costs exceed 30 percent of household budgets; good indicator of housing cost/supply/demand outcomes)	All
	Land use within transit supportive area (various ratio of land use within transit supporting area: retail/residential; office/retail; office/residential; recreation/residential)	Transit
	Land Use Mix (ratio of jobs to housing)	All
	Land Use Mix (employment to dwelling unit ratio)	All
	Land Use Mix: index of population and employment mix (1-ABS = {[(reg. pop/reg.empl)*study area pop] - study area empl}/{[(reg.pop/reg.empl)*study area pop.] + study area empl})	All
Auto/demand response transit (DRT) travel time ratio	Auto trip time/DRT travel time; ratio 0-1	Auto, demand-response
Auto/transit travel time ratio	Ratio of travel time (door to door) for auto vs. transit	Auto, transit
Trips per time interval	Number of trips per time interval	Bikeshare
	Percentage of trips per time interval	Bikeshare
Station density ratio	Average number of stations within a given area	Bikeshare
Bicycles-to-population ratio	Average number of bikes per person in the coverage area	Bikeshare
Docks-per-bike ratio	Average number of docking spaces per bike	Bikeshare
	Percent person trips under 1 mile	All
Traffic volume growth	Percent change in volume / Percent change in population (during evening peak)	Auto
Fare integration	Yes/No	Multi
Rebalancing	Number of times bicycles picked up and dropped off at stations	Bikeshare
Bicycle parking requirements	Existence of bicycle parking reqs	Bike
Number of walking and bicycling trips per day along key corridors	Count	Walk, Bike
Ridership	Ridership (total passenger trips or journeys)	Transit
	Ridership (number of trips per month)	Transit
	Ridership (average number of daily uses per public bike)	Bikeshare

Planning	Performance Indicator	Mode
	Average daily trips per resident (ideally, 1 daily trip per 20 to 40 residents; a metric of market penetration; high quantity of uses among the population of coverage area is key to achieving the primary objectives of a bikesharing system, including increased bicycle mode share, decreased congestion of vehicle and transit networks, and promotion of safe, clean, healthy modes)	Bikeshare
	Number of trips made by bike share	Bikeshare
	Average vehicle ridership (all person trips divided by number of private vehicle trips; includes transit vehicle users and walkers)	Multi
	Transit ridership (rides/capita/yr)	Transit
	Total number of users	Bikeshare, Rideshare, Carshare
	Number of new members	Bikeshare, Rideshare, Carshare
	Number of GRH participants	GRH
	Percent change in ridership from prior year	Transit
	Average weekday transit boardings per vehicle revenue hour	Transit
	Average transit boardings per vehicle revenue mile	Transit
	Average annual transit boardings per route mile	Transit
	Member/vehicle ratio (customers served per vehicle)	Carshare
	Member/vehicle ratio (relative usage of carshare members)	Carshare
Passenger miles traveled (PMT)	Passenger miles traveled (PMT) per vehicle revenue mile	Transit
Vehicle miles traveled (VMT)	VMT per capita	Transit, Auto
	Light duty VMT per capita (excluding heavy duty vehicles)	Auto
	VMT per employee (work trips)	Transit, Auto
	Peak-period vehicle-mile (number)	Transit, Auto
	Miles traveled per month (miles/month)	Bikeshare

Environmental Sustainability Indicators

Environmental Sustainability	Performance Indicator	Mode
Financial	Additional fuel tax (cents/gallon)	Auto
Pollution Emissions	GHG generated/passenger	Auto, Transit
	GHG/passenger mile (based on life-cycle GHG, CO2 per passenger-kilometer or mile, among others)	Auto, Transit
	Systemwide daily VMT/CO2 emissions	Auto, Transit
	NOx emissions from passenger travel (kg NOx per capita-yr)	Auto, Transit
	Daily NOx, CO, and VOC emissions (grams per mile per day, quantifies mobile source emissions)	Auto, Transit
	Total PM10 emissions	Auto, Transit
	Passenger transportation CO2 emissions per capita (CO2 = VMT / average fuel economy (miles per gallon) x carbon content of fuel (grams per gallon) \\ OR emissions models such as EPA's MOVES model \\ OR VMT per capita)	Auto
	Heavy duty vehicle CO2 emissions per capita (CO2 = VMT / average fuel economy (miles per gallon) x carbon content of fuel (grams per gallon) \\ OR emissions models such as EPA's MOVES model \\ OR VMT per capita)	Transit
	Daily CO2 emissions (grams per mile per day)	Auto, Transit
	Decreased Carbon emissions (grams)	Rideshare, Carshare
	Pollution rate (air pollution/veh-km)	Auto, Transit
Energy and emission reductions	Calculated by multiplying VMT reductions times average vehicle energy consumption and emission rates	All
Noise pollution	Degree of loudness; db	All
Impact on wildlife habitat	Degree of impact	All
Alternative resources	Percent of alternative fuel vehicles in the fleet	Transit
	Number of compliant vehicles	Transit
	Percent of passenger-kms and tonne-kms fueled by renewable energy	Auto, Transit
	Transport facility resource efficiency (use of renewable materials and energy efficient lighting)	Transit
	Percent of labor force regularly telecommuting	All

Equity Indicators

Equity	Performance Indicator	Mode
Affordability	Transportation Affordability (ratio of transportation cost to total annual income)	All
	Taxi fare affordability	Taxi
	Cost of vehicle ownership (Dollars/year)	Auto
	Combined transportation and housing costs as a percentage of median income	All
Access by income and/or sociodemographic group	Access to employment by income group (number of jobs accessible w/in a given travel time from each TAZ)	All
	Access to other destinations by income group (includes health care, education & rec. facilities accessible w/in a given travel time from each TAZ)	All
	Average distance to nearest transit stop by income group	Transit
	Equitable distribution of accessibility (spatial distribution of transportation accessibility by different socio-demographic group)	All
Travel Time by Income Group	Work trip travel time by income group (time by mode & income group)	All
	Non work trip travel time by income group (time by mode & income group)	All
	Travel time to key destinations by income group (time by mode & income group)	All
	Travel time for some specific trip types (shopping , recreation) by income group (time by mode & income group)	All
	Travel to specific major activity centers by income group (time by mode & income group)	All
Availability by income group	Availability of nighttime service by income group	Transit
	Availability of low-cost transit options by income group	All
	Frequency of service by income group	Transit
	Degree of crowding by income group	Transit
	Number and quality of bus shelters by income group	Transit
Paratransit supply & usage	Paratransit Supply Index (paratransit vehicle supply per capita)	Paratransit
	Paratransit usage (eligible passenger trips/capita-yr)	Paratransit
	Demand-responsive transit trips not served (number, percent)	Paratransit
	Response time for Demand-responsive transit (minutes)	Paratransit
Spending	Average annual transportation expenditures per capita (dollars)	All
ADA Standards for Intersections	Pedestrian crossing accessibility (percent crossings with depressed curbs)	Walk
	Traffic signal accessibility (percent signals with 'accessibility features')	Walk
	Percent of intersections up to current ADA standards	Walk
Environmental justice	Percent of transportation investments in environmental justice tracts	All
Wheelchair accessible taxi service availability	Number of wheelchair accessible taxis operating on network	Taxi
	Percentage of abandoned phone calls (wheelchair accessible taxi)	Taxi
	Average answering time (wheelchair accessible taxi)	Taxi
	Average pick up time (wheelchair accessible taxi)	Taxi
	Percentage of no car available (NCA) (wheelchair accessible taxi)	Taxi
	Percentage of calls answered within 1 min (wheelchair accessible taxi)	Taxi
	Percentage of calls answered within 2 mins (wheelchair accessible taxi)	Taxi

Safety & Security Indicators

Safety & Security	Performance Indicator	Mode
Transit vandalism incidents	Number/year	Transit
Transit related crime	Transit related crime rate (crime rate per year a location or along a corridor or within a geographic area; crimes per 100 riders)	Transit
	Number of crimes by mode	Transit
	Traveler crime and assault rates	Transit
Crash statistics	Number of crashes by location	All
	Crash rate (crashes/capita)	All
	Road injury frequency (road injury frequency)	Auto
	Transit accident rate (number/year)	Transit
	Vehicle accident rate (accidents per mile per year, or accidents per 100,000 vehicle service miles)	Auto
	Bicycle and pedestrian crash rates	Bike, Walk
	Crashes and casualties by type	All
	Crashes and crash fatalities per capita (per capita crash and fatality rates)	All
	Crash frequency (crashes/veh-km)	Auto
	Crash costs (per capita)	All
	Bicycle crashes per 1000 cyclists	Bike
	Cyclist crash frequency (reported bike collisions/yr)	Bike
	Pedestrian crashes per 1000 pedestrians	Walk
	Pedestrian crash frequency (reported pedestrian collisions/yr)	Walk
	Annual severe crashes (roadway segments: 0.000365*BaseCrashRate*ADT*Length; Intersection (only for rural hwy or urban st): 0.000365*BaseCrashRate*(ADT on major+ADT on minor); severe crashes per miles per year)	Auto
	Number of preventable collisions	Transit, Auto
Training	Number of safety trainings offered per year	Transit
Enforcement	Number of enforcement efforts per year	Transit, Auto
Data	Number of data protection breaches	Bikeshare
Perception of transit safety	Rating	Transit
Workplace injuries	Count	Transit
Operator behavior	Percent of positive drug/alcohol tests	Transit
	Percent of buses exceeding the speed limit	Transit
	Number of traffic tickets issued to operators	Transit
Crossings	Crosswalk spacing (average crosswalk spacing at signal supported)	Walk
	Number of safe crossings per mile (number of crosswalks or mid-block crossings per mile)	Walk
Crash fatalities and disabling injuries	Rate of fatal and severe injury crashes (percentage)	Transit, Auto
	Annual crash fatalities and disabling injuries (number)	Transit, Auto

Safety & Security	Performance Indicator	Mode
	Number of fatal and severe injury crashes (number)	Transit, Auto
	Traffic fatalities (per 100 million VMT)	Auto
	Safety Index (1/(traffic fatalities per 100k residents))	Auto
	Bike/pedestrian injuries/fatalities (on a specific segment or area; accidents; accidents/mile; accidents per VMT)	Bike, Walk
	Taxi passenger casualty rates	Taxi
	Active transport safety (portion of crash casualties that are pedestrians and cyclists)	Bike, Walk
	Crashes and casualties by type	All
	Crashes and crash fatalities per capita (per capita crash and fatality rates)	All
	Pedestrian casualty (crash and assault) rates	Walk

Customer Satisfaction Indicators

Customer Satisfaction	Performance Indicator	Mode
Public satisfaction with transportation system by mode	Public satisfaction with overall transportation system (percent people rating quality as [good/excellent])	All
	Public satisfaction with transit system (percent people rating quality as [good/excellent])	Transit
	Public satisfaction with auto traffic system (percent people rating quality as [good/excellent])	Auto
	Public satisfaction with bike system (percent people rating quality as [good/excellent])	Bike
	Public satisfaction with walking system (percent people rating quality as [good/excellent])	Walk
	Taxi user satisfaction ratings	Taxi
	Satisfaction with services received (ridesharing)	Rideshare
Transit comfort	user perception	Transit
Transit ease of using the system	user perception of the ease of using transit, availability of info about the transit system	Transit
	Wayfinding information (presence of signs)	Transit
Transit reliability/performance (perceived)	Travel time reliability	Transit
Complaints	Complaint (compliment) rate	Transit
	Transit complaint rate	Transit
	Number of transit complaints	Transit
	Number of complaints received and resolved	Rideshare
Transit customer loyalty	Combined index of overall satisfactions, likelihood of continued riding, and likelihood of recommending to others	Transit
Awareness	Awareness (the portion of potential users who are aware of a program or service)	All
	Awareness of commute programs amongst employees of participating employers	Rideshare
	Percent of commuters and/or employers who are familiar with or who have used the program	Rideshare
Participation	Number of people who use a service or alternative mode	All
Information Accessibility	Transit info accessibility (percent of transit schedule info accessible on web)	Transit
	Number of sustainable transport indicators regularly updated and widely reported	All
	Universal provision of real time info (yes/no; an indicator of customer ease-of-use)	Transit
	Information integration (yes/no)	All
Customer service response	Percent of missed phone calls	Transit
	Percent of calls held excessively long	Transit
	Customer service calls - number of incoming calls and lost calls	Bikeshare
	Customer service hotline average wait time	Transit
	Customer service hotline average wait time	Transit
	Number of phone inquiries received	Rideshare
Courtesy	Driver courtesy	Transit
Community satisfaction	Employee satisfaction	Transit

Customer Satisfaction	Performance Indicator	Mode
	Stakeholder satisfaction	Transit
	Business community satisfaction	Transit
Web activity	Number of web site hits	Rideshare
Cleanliness	Average interior rail clean inspection score	Transit
	Average interior bus clean inspection score	Transit

Appendix D: SCAG Goals & Performance Indicators

Goal Area	Indicators	Units	Mode
Location Efficiency	Share of growth in High Quality Transit Areas (HQTAs)	Percent of households in HQTAs	Transit
		Percent of jobs in HQTAs	Transit
	Land Consumption	Greenfield land consumed and refill land consumed	All
	VMT	Automobiles and light-duty trucks	Auto, Freight
	Transit mode share	The share of total trips that use transit for work and non-work trips	Transit
	Average distance traveled for work and non-work trips	Work, and non-work trips	All
	Percent of trips less than 3 miles	Work, and non-work trips	All
	Work trip length distribution	The statistical distribution of work trip length in the region -- trip length: 10 miles or less; 25 miles or less	All
Mobility & Accessibility	Person delay per capita	Daily minutes of delay per capita	Auto
	Person delay by facility type	Delay: Excess travel time resulting from the difference between a reference speed and actual speed; Highway, HOV, Arterial	Auto
	Truck delay by facility type	Delay: Excess travel time resulting from the difference between a reference speed and actual speed; Highway, Arterial	Auto, Freight
	Travel time distribution for transit, SOV and HOV modes for work and non-work trips	% of PM peak transit trips <45 minutes	Transit, Auto
		% of PM peak HOV trips <45 minutes	Auto
		% of PM peak SOV trips <45 minutes	Auto
Safety & Health	Collision rates by severity by mode (per 100 million vehicle miles)	Serious injuries, fatalities	Auto
	Criteria pollutants emissions (tons per day)	ROG, CO, NOx, PM 2.5, PM 10 and VOC	All
	Air pollution-related health measures	Pollution-related health incidences (annual)	All
		Pollution-related health costs (annual)	All
	Physical activity-related health measures	Daily per capita walking	Walk
		Daily per capita biking	Bike
		Daily per capita driving	Auto
		Obese population (%)	N/A
		High blood pressure (%)	N/A
		Heart disease (%)	N/A
		Diabetes Type 2 (%)	N/A
	Mode share of walking and bicycling	Walk share (Work)	Walk
		Bike share (Work)	Bike
		Walk share (Non-Work)	Walk
		Bike share (Non-Work)	Bike
		Walk share (All Trips)	Walk
		Bike share (All Trips)	Bike

Goal Area	Indicators	Units	Mode
Environmental Quality	Greenhouse gas emissions	CO, NOx, PM 2.5, PM 10 and VOC emissions; and per capita greenhouse gas emissions (CO2)	All
Economic Opportunity	Additional jobs supported by improving competitiveness (Number of jobs added to the economy as a result of improved transportation conditions which make the region more economically competitive)	Annual number of new jobs generated	All
	Additional jobs supported by transportation investments (Total number of jobs supported in the economy as a result of transportation expenditures)	Annual number of new jobs generated	All
Investment Effectiveness	Benefit/Cost Ratio (Ratio of monetized user and societal benefits to the agency transportation costs)	Benefit ratio per $1 investment	All
Transportation System Sustainability	Cost to preserve multimodal system to current and state of good repair	Annual cost per capita required to preserve the regional multimodal transportation system to current conditions/ cost per capita (per year)	All
Environmental Justice	Separate Table of 18 metrics		All

Source: SCAG 2016-2040 Regional Transportation Plan, 2016 *(20)*

Appendix E: Go Centennial Program Goals and Indicators

Focus Area	Goal	Performance Target/Measure	Data Source
1. Influencing Commuter Behavior	1-1. Increase light rail ridership; make more efficient use of seating space	Increase RTD Light Rail ridership from Dry Creek Station • Aug 2015 – Jan 2016 1,904 trips per day • Goal: 2,100 per day	RTD Light Rail ridership
	1-2. Reduce SOV trips to the Park-n-Ride; reduce congestion due to fewer SOVs on the roadway	10% decrease in the monthly total of cars parked at the Dry Creek Park-n-Ride station (from approximately 112)	Monthly RTD Park-n-Ride data at Dry Creek Station
	1-3. Reduce regional VMT	VMT reduced by 250,000 miles by February 2017	Go Denver registration data; number of trips per user
	1-4. Increase first and last mile trips to the Dry Creek Station	Increase trips to the light rail station (Call-n-Ride + Lyft Line trips) by 50%	RTD Dry Creek Call-n-Ride ridership, Lyft data reporting
2. Benefiting Drivers and Transit Users	2-1. Provide a safe travel option for users	No collisions or personal security incidents related to the program	Police reports from the Arapahoe County Sheriff's Office
	2-2. Improve service levels for first and last mile service riders	25% reduction in average wait time to station or destination relative to existing Call-n-Ride service	Wait time data from Lyft and RTD Call-n-Ride (baseline)
	2-3. Create an equitable system that is accessible to all types of users	No users who would like to use service but are unable to	Survey data
	2-4. Reduce commuter stress levels and enhance wellbeing by providing comfortable service	95% of survey respondents report being 'satisfied' or 'highly satisfied' with level of comfort during FLMP service	Survey data
	2-5. Ensure customer satisfaction	95% of survey respondents report being 'satisfied' or 'highly satisfied' with overall satisfaction during Go Centennial service; Average rating of driver from program trips is 4.8 out of 5 stars	Survey data; Lyft rating data
3. Cost Effectiveness	3-1. Reduce costs for first and final mile services	Decrease in average per trip cost for first and last mile service from $21 (for Call-n-Ride service) to $8 (for Lyft service)	Lyft invoicing; RTD subsidy for Call-n-Ride (baseline)
	3-2. Provide a high return on investment for the City of Centennial	Benefit/cost ratio of greater than 1.0 for City of Centennial investment of $200,000	Cost reduction relative to existing RTD Call-n-Ride subsidy
4. Technology/ User Experience	4-1. Provide a responsive, on-demand service	Average wait time for Lyft Line ride under 10 minutes	Wait time (between request and pick-up) from Lyft
	4-2. Develop reliable and integrated trip planning and payment systems	Less than 15 calls monthly to concierge service regarding payment troubleshooting	Centennial Citizen Response Center (CRC) concierge service data
	4-3. Increase ease of booking a first	90% of survey respondents	Survey data

Focus Area	Goal	Performance Target/Measure	Data Source
	or last mile trip	report the Go Denver App being 'easy' or 'very easy' to use	
5. Transferability and Sustainability	5-1. Retain new users	50% of users return to FLMP service within two weeks of initial trip	Lyft ride information by user ID
	5-2. Produce a pilot evaluation that assesses transferability and sustainability	Centennial i-team produces final evaluation report by end of March 2017	i-team
6. Long-Term Change for Centennial	6-1. Contribute to Centennial-based employers' recruiting efforts	Survey of Centennial employers	Survey data
	6-2. Create overlay parking requirements for developers and employers in the program service area	Reduced number of single occupancy vehicle trips	Survey data
	6-3. Normalize new commute behaviors and patterns	Continuation of FLMP program beyond February 2017	Program status

Source: City of Centennial, Staff Report, City Council Meeting, 2016 *(78)*

Appendix F: Seoul Traffic Vision 2030 Goals & Objectives

GOALS	OBJECTIVES
People-Oriented Traffic: In order to embody the 「People-Oriented Traffic」 policy, our government plans to promote a pedestrian-first and bicycle-friendly lifestyle, which it is hoped will result in a dramatic reduction in the number of traffic-related accidents.	
Creating a pedestrian-oriented traffic environment	• Doubling of the surface area of sidewalks in downtown areas (2013, 10,130,000㎡). • Remodeling of Sejong-rointo a pedestrian area and implying this road remodeling project to the other side of town. • Expansion of the trial run of the 'exclusive public transportation area' in Yeonsei-ro. • Development of a promenade that combines city tours, culture and shopping into one integrated experience.
Creating a bicycle-centered environment	• Expansion of the public bicycle rental service in Seoul, similar to the VELIB (public bicycle sharing system) in Paris, which will enable people to ride by bicycle everywhere in town. • Reinforcement of the connection with public transportation by extending bicycle paths to public residential areas. • Extension of the public bicycle service to the main parts of the city. • Connection of the public bicycle service with existing rental services operating under each district office and along the Han River.
Realizing a 'Road Safety Conscious Metropolitan City'	• Improvement of traffic conditions in residential areas. • Preventing road deaths by setting the speed limit at 30km/h within residential zones in the entire city by 2030. • Implementation of the 'car park lot proving system', a mandatory system which obliges car owners to own a parking lot at the time of car purchase, will reduce the number of pedestrian accidents caused by illegal parking in the narrow streets of residential areas. • Construction of a dynamic management system using public transportation, including buses and taxis, to collect and manage information on road traffic conditions.
Creating obstacle-free traffic conditions and providing services that everyone can use	• Conversion of all city buses into low floor buses (2013. 27% or 2,022 buses). • Expansion of the 'obstacle-free streets' construction,which is going on in between Ttukseom Station and Seoul Forest, to the other side of the town. • Promotion of the use of normal taxis in call-taxi services for the disabled. *50 such taxis will be in service by July.
All Sharing Traffic: Seoul Metropolitan Government plans to reorganize the public transport systems and establish a road space/car sharing culture throughout the entire city in a bid to realize 「All Sharing Traffic」.	
Constructing an efficient railway-centered public transportation system	• Operation of more express trips on metro lines where demand is high. • Construction of railway lines in between downtown areas. • Creation of an environment in which subway stations are accessible within ten minutes from anywhere in town. • Reconfiguration of the three downtown areas, i.e. Hanyang-Doseong (the old central city), Gangnam, and Yeouido, connecting trunk lines with KTX and Great Train Express(GTX), the new railways promoted by the central government. • Extension of railway lines to all transport-underprivileged regions. • Continuous expansion of Great Train Express(GTX) lines that connect Metropolitan areas.
Providing fast and convenient public transport services	• while completing the connections between the bus lanes, operating them in various form during the high demanding hours and areas • Redevelopment of the current bus lines into railway supportive lines. • Provision of a better service during peak hours: enlarging and regulating 'night bus' lines in consideration of floating population, providing a 'safe taxi on demand' service.

<table>
<tr><th>GOALS</th><th>OBJECTIVES</th></tr>
<tr><td>Promoting the Common Sharing Traffic culture, a culture of sharing road space and transportation</td><td>• Introduction of the ‘Complete Street’ concept, whereby pedestrians, cyclists, car drivers and other users of various means of transportation all share one road.
• Extra road space will be needed for all users (pedestrians, cyclists, car drivers, public transport users), while establishing new roadsand repairing old ones.
• Generalization of the car-sharing service to foster a sharing culture aimed at the convenient utilization of cars, even for persons who do not own a car. * Expansion of the 292 car-sharing service center (2013) → 1,200 centers (by 2030), so that people can access the service center within 5 minutes from anywhere in town. * Planning of a long-term project for personal car sharing (P2P).</td></tr>
<tr><td colspan="2">Environment-Friendly Transportation: To establish an 「Environment-Friendly Traffic Culture」, the rate of car distribution will need to be reduced from 18.4% → 10%, existing public cars will need to be transformed into/replaced by environment-friendly cars (0.2% → 100%), and traffic congestion on highways will need to be reduced from 19%→10%.</td></tr>
<tr><td>Lowering the unnecessary movement, ‘low mobility society’</td><td>• Application of a mileage-based payment plan whereby driver are charged according to the distance traveled.
• Construction of large buildings with zero parking lots.
• Implementation of telecommunication and smart work to ensure flexibility in work shifts : reducing traffic congestion during peak times and unnecessary commuter journeys.</td></tr>
<tr><td>Transforming the transportations and facilities into environment-friendly transports</td><td>• Conversion of energy consuming roads into the self-energy producing and self-pollutant purifying roads. * Realization of the energy-producing ‘Solar Way’ by utilizing public transport facilities such as bus stop shelters, streetlamps, soundproofed walls and road surfaces. * Application of rain and pollutant absorbent road pavements together with renewable pavements.
• Generalized adoption of eco-friendly cars with no emission of pollutants in the entire car industry including buses, taxis and private cars.</td></tr>
<tr><td>Creating a clear congestion-free traffic environment with no severance of roads (UNCLEAR!)</td><td>• Conversion of highways, (mainly Jemulpo-gil, Sebuganseon-doro and Dongbuganseon-doro) into underground tunnels and development of the upper ground into public parks or bicycle roads as public life and recreation spaces.
• Provision of a ‘traffic forecast alarm system’, a service that notifies users of current or imminent traffic conditions and allows them to identify the best route, most effective mode of transport, and quickest travel time.</td></tr>
<tr><td>Communicating and reaching a consensus with the public throughout the whole process of the government’s promotion and establishment of its traffic policies will result in the creation of an advanced, citizen-oriented, ‘traffic-culture city.’</td><td>• Adoption of a monitoring system and policy-governance led by the public (members of the generalpublic, professionals, and the ‘people with mobility handicaps’)inthe planning phase of any traffic projects* Minimization of problems in the early stage and rapid complementation of policies through an organic monitoring and feedback system.</td></tr>
<tr><td colspan="2">Goal of achieving “Triple 30%”: volume of car traffic ↓ by 30%, commuting time by public transportation ↓ by 30%, and size of green transportation area ↑ by 30%: Seoul city will keep its eleven promises based on its “Seoul Traffic Vision 2030 (proposal)” in order to achieve the ‘Triple 30’, namely, a 30% reduction in car travel, a 30% reduction in commuting times by public transport, and a 30% rise in the use of green transport. Therefore, an increase in the rate of green transport (walking, cycling, public transport) distribution, from 70% to 80%, and a decrease in greenhouse gas emissions from 1.2 tons per year to 0.8 tons per year are anticipated by 2030 as a result of the implementation of this vision.</td></tr>
</table>

Source: Seoul Metropolitan Government, Seoul Traffic Vision 2030 *(16)*

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