Regional Mobility Policy Background Report

Policy Analysis and Best Practices

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1 Overview

The 2018 Regional Transportation Plan (RTP) adopted by JPACT and Metro in December 2018 failed to meet state requirements for demonstrating consistency with the Highway Mobility Policy (Policy 1F) contained in the Oregon Highway Plan (OHP) originally adopted in 1999. That policy establishes mobility targets aimed at maintaining "acceptable and reliable levels of mobility on the state highway system, consistent with the expectations for each facility type, location and functional objectives."[47] As defined in the OHP, the mobility policy is applied as a target to regional and local transportation system plans, and as a standard to plan amendments subject to section -0060 of the Transportation Planning Rule (TPR). If a local government cannot demonstrate that its transportation system plan (TSP) meets the targets for state-owned facilities, then the jurisdiction must adopt alternative targets through a prescribed process[46] and seek approval by the Oregon Transportation Commission. If a proposed plan amendment would not meet the applicable mobility standard for state-owned facilities, the local jurisdiction or applicant have several options for mitigating the impact.

The 2018 RTP failed to meet the current policy, particularly for the region's throughway system, triggering the need to consider alternative approaches for measuring mobility and success under state law. As a result, the Oregon Department of Transportation (ODOT) agreed to work with Metro to update the mobility policy for the Portland metropolitan area in both the next RTP and OHP. Built around key priorities of advancing equity, mitigating climate change, improving safety, and managing congestion, the 2018 RTP recognizes that a growing and changing region needs an updated mobility policy for measuring performance of the transportation system and identifying the transportation needs of people and goods.

This report is one of the first steps in the Regional Mobility Policy (RMP) Update project to be conducted by Metro and ODOT in 2020 and 2021. This report provides a foundation of knowledge, with an overall goal of developing a shared understanding of the current status of RTP and OHP mobility measures for the Portland area, their history and uses in the region, and potential options for new mobility measures, targets and standards for application during regional and local transportation system planning and evaluation of local plan amendments. This research also informs complementary research being conducted by ODOT as part of planned updates to the Oregon Transportation Plan (OTP) and OHP.

The purpose of this research is to review and summarize information about:

- the policy framework, measures, thresholds, methods and practices currently used to guide local and regional transportation system planning and to evaluate traffic impacts of plan amendments in the Portland metropolitan region
- best practices in measuring multimodal mobility at the state, regional and local levels and system-level, corridor-level and comprehensive plan amendment scales.

The overall timeline for the RMP Update project is shown in Figure 1. This background report is part of the first phase of the project, which started in 2019. The report will be one input into the second phase, beginning in summer 2020. Throughout the process, Metro and ODOT are using a stakeholder and public engagement plan to guide efforts. During the first phase, JLA Public Involvement interviewed 64 stakeholders to understand how they defined mobility, collect their insights regarding the outcomes for this policy update, and provide an opportunity to share views and experiences related to the region's mobility policy. Those findings were summarized in an October 2019 report and also serve as a key input into phase two. The phase two effort will include developing criteria for evaluating and selecting measures for testing through case studies. A consultant team has been selected for this work. The findings from that effort will be used in the third phase, which will take place in 2021. During that phase, Metro, ODOT, and regional partners will work together to develop and recommend to JPACT and the Metro Council a new mobility policy and action plan for implementation. Parallel to this Portland Metro-focused effort, ODOT will begin updating OTP and OHP in 2020, thus providing an opportunity for the region to help inform and coordinate with those efforts.

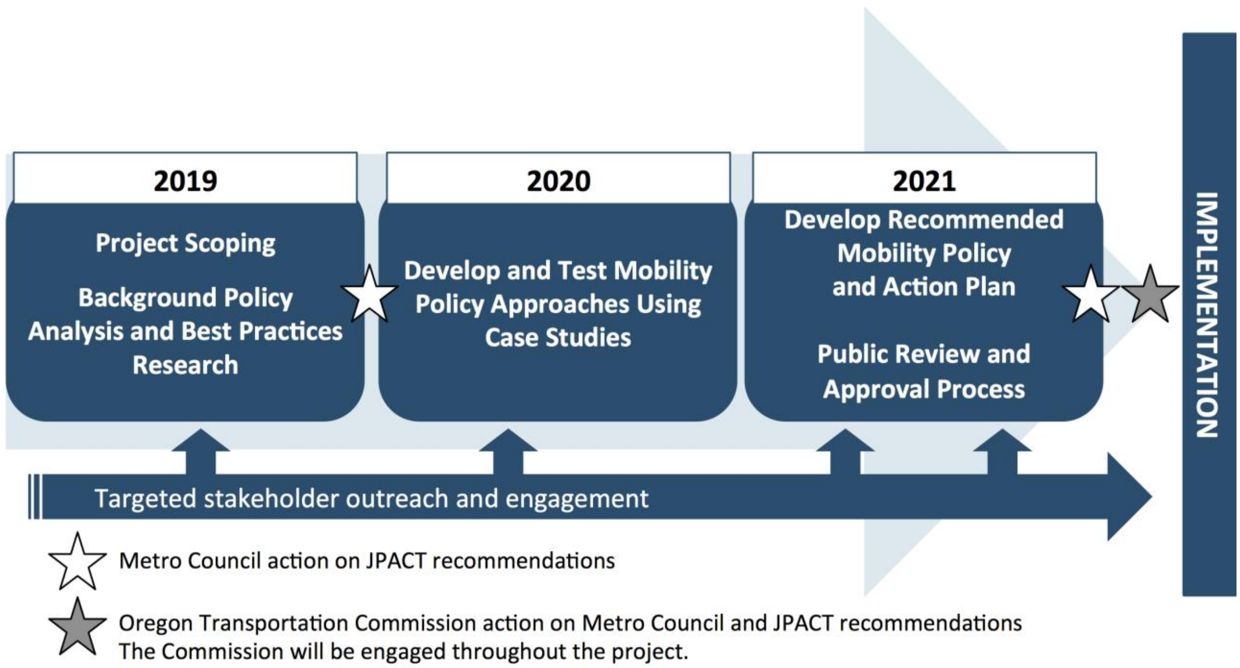

Figure 1 Project timeline

For this background report, we reviewed over 70 documents to identify and document examples of mobility measures. The objective was to develop a broad list of measures which would feed into the phase two analysis and case studies. We included measures that have been used for a variety of planning purposes both in Oregon and other states, as well as measures that have not been used extensively. The report first presents some background about the current mobility measures. The third section presents information about 27 measures identified in the documents reviewed.

2 Background

The current OHP mobility targets use volume-to-capacity (v/c) ratio for measuring performance and identifying current and future system deficiencies. V/c ratio is commonly defined as the number (volume) of motor vehicles traveling on a roadway divided by the maximum flow rate of vehicles a roadway can accommodate (capacity). For most of the state, the OHP v/c targets range from 0.70 to 1.0 depending upon the type of facility and location (Figure 2).

VOLUME TO CAPACITY RATIO TARGETS OUTSIDE METRO[17A, B, C, D]							
Highway Category	**Inside Urban Growth Boundary**					**Outside Urban Growth Boundary**	
	STA[E]	**MPO**	**Non-MPO Outside of STAs where non-freeway posted speed <= 35 mph, or a Designated UBA**	**Non-MPO outside of STAs where non-freeway speed > 35 mph but < 45 mph**	**Non-MPO where non-freeway speed limit >= 45 mph**	**Unincorporated Communities[F]**	**Rural Lands**
Interstate Highways	N/A	0.85	N/A	N/A	0.80	0.70	0.70
Statewide Expressways	N/A	0.85	0.85	0.80	0.80	0.70	0.70
Freight Route on a Statewide Highway	0.90	0.85	0.85	0.80	0.80	0.70	0.70
Statewide (not a Freight Route)	0.95	0.90	0.90	0.85	0.80	0.75	0.70
Freight Route on a regional or District Highway	0.95	0.90	0.90	0.85	0.85	0.75	0.70
Expressway on a Regional or District Highway	N/A	0.90	N/A	0.85	0.85	0.75	0.70
Regional Highways	1.0	0.95	0.90	0.85	0.85	0.75	0.70
District/Local Interest Roads	1.0	0.95	0.95	0.90	0.90	0.80	0.75

Table 6: Volume to Capacity Ratio Targets for Peak Hour Operating Conditions

Figure 2: Table 6 from the Oregon Highway Plan, with V/C targets for areas outside Portland Metro

There is a separate set of v/c targets for inside the Portland metropolitan region urban growth boundary (aka "Metro") of either 0.99 or 1.1 (depending on location) that apply to the first or second hour of the two-hour weekday peak periods (Figure 3). These targets were an outcome of the 2000 Regional Transportation Plan and approved as an "interim" mobility policy through an amendment to the OHP approved in 2002. The targets represented a new approach to managing mobility and at the time were considered "an incremental step toward a more comprehensive set of measures that consider system performance for all modes, as well as financial, social equity, environmental and community impacts."[39] Among other things, the policy recognized that the practice of "building our way out" of peak-hour congestion was not feasible.

VOLUME TO CAPACITY RATIO TARGETS INSIDE METRO[A, B]		
Locations	**Target**	
	1st hour	**2nd hour**
Central City Regional Centers Town Centers Main Streets Station Communities	1.1	.99
Corridors Industrial Areas Intermodal Facilities Employment Areas Inner Neighborhoods Outer Neighborhoods	.99	.99
I-84 *(from I-5 to I-205)*	1.1	.99
I-5 North *(from Marquam Bridge to Interstate Bridge)*	1.1	.99
OR 99E *(from Lincoln Street to OR 224 Interchange)*	1.1	.99
US 26 *(from I-405 to Sylvan Interchange)*	1.1	.99
I-405[C] *(from I-5 South to I-5 North)*	1.1	.99
Other Principal Arterial Routes I-205 [C] I-84 *(east of I-205)* I-5 *(Marquam Bridge to Wilsonville)*[C] OR 217 US 26 *(west of Sylvan)* US 30 OR 8 *(Murray Blvd to Brookwood Avenue)* [C] OR 224 OR 47 OR 213 242nd/US 26 in Gresham OR 99W	.99	.99

Table 7: Volume to Capacity Ratio Targets within Portland Metropolitan Region

Figure 3: Table 7 from the Oregon Highway Plan, with V/C targets for the Portland Metro region

Separate design mobility standards for state highways are contained in Table 10-2 in Chapter 10 of ODOT's Highway Design Manual (HDM). The v/c standards in Table 10-2 of the ODHM (Figure 4) are different from the OHP v/c values to provide a "20-year design life solution."[49] The peak hour is the 30th highest annual hour. This approximates weekday peak hour traffic in larger urban areas.

Issues may arise when a large difference occurs between the planning and design v/c ratios. This is the case in the Portland metropolitan region for which alternative mobility targets (Figure 3) have been adopted by the OTC.

Table 10-2: 20 Year Design-Mobility Standards (Volume/Capacity [V/C]) Ratio

Highway Category	Land Use Type/Speed Limits					
	Inside Urban Growth Boundary				Outside Urban Growth Boundary	
	STAs	MPO	Non-MPO outside of STAs where non-freeway speed limit <45 mph	Non-MPO where non-freeway speed limit >= 45 mph	Unincorporated Communities	Rural Lands
Interstate Highways and Statewide (NHS) Expressways	N/A	0.75	0.70	0.65	0.60	0.60
Statewide (NHS) Freight Routes	0.85	0.75	0.70	0.70	0.60	0.60
Statewide (NHS) Non-Freight Routes and Regional or District Expressways	0.90	0.80	0.75	0.70	0.60	0.60
Regional Highways	0.95	0.85	0.75	0.75	0.70	0.65
District/Local Interest Roads	0.95	0.85	0.80	0.75	0.75	0.70

Figure 4: Table 10-2 from the Oregon Highway Design Manual, with V/C ratios for project development/design in Oregon

In transportation planning in the U.S., v/c ratio has often been used interchangeably with the term "level of service" (LOS) and equated with an A-F rating scale, with each letter assigned to a range of v/c ratios. Nationally, the use of v/c as a performance measure has faced increasing criticism for a number of reasons. [34, 10, 9] By definition, v/c-based measures focus on motor vehicle traffic and do not account for mobility by transit, bicycle, or foot. A v/c ratio also does not capture some aspects of congestion, such as reliability, that may be of greater importance to some system users (e.g. freight). A v/c measure also focuses solely on mobility and time delay, largely ignoring the fundamental reason for most travel – accessibility, i.e. access to destinations. Critics also assert that the reliance on v/c-based LOS standards leads to increasing roadway capacity, which can induce more demand for travel, thus producing more congestion and pollutant emissions in the long-term.

These national critiques are consistent with the reasons Metro and ODOT identified for updating the mobility policy and measures, including the following:[36]

- The current policy focuses solely on vehicles and does not adequately measure mobility for people riding a bus or train, biking, walking or moving goods, nor does it address important concepts such as reliability, system completeness or access to destinations.
- The current policy has led to transportation projects that are increasingly expensive and that may have undesirable land use, housing, air quality public health and environmental impacts, conflicting with local, regional and state goals.
- Cities and counties are increasingly unable to meet the current policy or pay for needed transportation investments. This is especially true in planned growth areas including urban growth boundary expansion areas.
- The 2018 RTP failed to meet the current policy, particularly for the region's throughway system, triggering the need to consider alternative approaches for measuring mobility and transportation system adequacy under state law.
- ODOT will be updating the Oregon Transportation Plan and Oregon Highway Plan next year – this project provides an opportunity for the region to help coordinate with and help inform those statewide efforts.

3 Mobility Measures

This section describes 27 measures of mobility found in our review of the literature. These measures focus on the *movement* or *access* of people and/or goods or the provision of transportation facilities that facilitate mobility, rather than other aspects of the performance of transportation systems, such as safety. In some cases, a measure may include some definition variants that all measure the same concept.

The following sections define each of the selected measures, assess the measures' applicability for different transportation modes, planning processes, and spatial scales, and describes the data needs for calculating each measure. Four planning processes are included: TSP/Corridor planning, plan amendments, development (land use) review, and performance monitoring. To assess performance monitoring, we considered the availability and quality of data on a regular basis. In addition, five of the eleven goals of the 2018 Regional Transportation Plan (RTP) were selected to assess how well each potential measure supports the RTP policy priorities – equity, safety, climate, and congestion – and the RTP goal for shared economic prosperity:

- **Shared Prosperity** – Goal 2 considers access to jobs, goods, and services in order to ensure equitable access to a strong and diverse economy in the Portland region. Our interpretation of shared prosperity was to examine how measures can be used to enhance our understanding of job access and goods movement.
- **Transportation Choices** – Goal 3 looks to provide safe, convenient, and affordable transportation options that connect to essential destinations. Our assessment examines the applicability of the measure for different modes of transportation.
- **Reliability and Efficiency** – Goal 4 aims to ensure congestion mitigation, safety, reliability, and efficiency when traveling to a destination. To assess of reliability and efficiency, we examined how each measure can portray the degree of variability in travel time and congestion.
- **Climate Leadership –** Goal 8 intends to improve the health and prosperity of the greater Portland region through minimizing the impacts of climate change and transportation-related greenhouse gas emissions. Our use of climate leadership in the report was assessing the environmental impacts of collective transportation choices in accordance with Climate Smart Strategy implementation.
- **Equitable Transportation** – Goal 9 aims to eliminate transportation-related disparities and barriers for marginalized communities in the greater Portland region, especially for people of color. For this report, equitable transportation was applied to identify measures that can inform whether disparities exist in access to transportation systems and resources, and how user experience differs between groups of people, all with the goal of reducing disparities, particularly in RTP Equity Focus Areas.

For consistency across these categories, applicability is symbolized as follows:

● [FULL CIRCLE] – Highly applicable

◖ [HALF CIRCLE] – Somewhat applicable

○ [EMPTY CIRCLE] – Low applicability

3.1 Travel Time

Definition: Time spent traveling between key origin-destination pairs. Travel time can be examined during mid-day and/or peak hours.[50] Travel time is influenced by design speed, free flow speed, traffic control delay, traffic volume, and travel distance[54] and variance can be attributed to driver behavior, system delays during peak hours, or non-recurring delays such as crashes or closures.[44] Uses for travel time include facility operations and sizing and land use impact assessment.[24]

While primarily a measure for private motor vehicles, models can estimate travel times for other modes such as for designated freight corridors, bicycle routes, or through considering transit schedules and stop location for calculating transit travel time.[54] Actual transit travel times can also be measured using GPS on transit vehicles. Travel time can be applied to different trip types as well to further match the measurement with its intended purpose such as work-based trips.[54]

By using GPS devices, smart phones, and bluetooth monitoring, travel time between exact origins and destinations has become easier to measure for private motor vehicles, trucks, as well as transit vehicles.[50] While decreasing travel time is a benchmark of efficiency, tactics to reduce travel time can result in increased VMT, such as capacity expansions that lead to induced investment and induced demand.[41]

Spatial Scale: This measure works best for a single segment or facility. To apply this on a regional scale, an agency would need to choose several segments or facilities to represent the region.

Current Examples of Usage:

Oregon Department of Transportation (ODOT): Travel time is used as a System Performance Measure for Region 1's top corridors in the ODOT Traffic Performance Report.[55] Travel time is also included in ODOT's Analysis Procedures Manual (APM) as a Facility Plan and Project Development measure as well as a supplemental measure for Regional Transportation and Transportation System plans.[52]

Metro: Travel time is used as a System Performance Measure in the RTP for motor vehicles, transit, freight trucks, and bicycle travel, It is also used as a RTP Monitoring Performance measure.[50]

Oregon: West Eugene bus rapid transit (BRT) project used transit travel time to compare project conditions with no-build conditions.[8] Use of travel time was also suggested as an alternate mobility measure in a 2014 consultant report for Washington County.[30]

Nationally: Reducing peak period travel time is a strategy used by Caltrans (CA) to reduce vehicle miles traveled (VMT) and transportation-related greenhouse gas emissions (GHG).[76]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	●	
Transportation Choice	◖	
Reliability and Efficiency	●	
Climate Leadership	◖	
Equitable Transportation	○	Would need to measure or predict travel times for different users to address this goal, which would be challenging.
Mode		
Private motor vehicles	●	
Freight	●	
Transit	●	
Bicycles	◖	Corridor travel times dependent primarily on distance. Origin-to-destination travel times are more relevant to these modes.
Pedestrians	◖	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	◖	
Development Review	○	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Travel time data for private motor vehicles, including large freight trucks, and transit are available through • pavement detectors[24] • vehicle onboard devices (GPS/Smart Phones)[50] • license plate matching[50] • roadside/electronic monitoring[50] using Bluetooth Data on actual bicycle and pedestrian travel times is not as readily available, but can be estimated using speed assumptions.
Forecasts	Travel times for all modes can be forecasted using travel demand models.[8]

3.2 Travel Time Reliability (Planning and Buffer Travel Time Indexes)

Definition: These measures are used to assess how a traveler plans for on-time arrival and speak to reliability[30] and variability in travel times[50] and can act as an indicator of congestion severity.[54] As an indicator of the impact of congestion, considering the reliability of travel time rather than total travel time may be more useful for freight and for commuters, both by private motor vehicle and bus transit.[7] For bicyclists, pedestrians, and rail transit, where infrastructure is separated from traffic congestion, planning travel time may be less relevant. For freight, reliability of travel time is an important metric for the movement of goods and on-time manufacturing process and arrival.[50] In addition, the value of reliability (VOR) for freight considers how the cost of shipping increases as the unreliability on the road increases.[44]

There are several different measures that aim to measure travel time reliability based on the concept that people plan on extra travel time so that they have a greater chance of arriving on time, expecting that they will encounter some congestion. For example, during free-flow conditions, a trip might only take 20 minutes. But because of congestion, the traveler needs to plan on 30 minutes to feel comfortable that they will arrive on time. Most of the measures that use this concept compare two numbers: a baseline travel time and a very congested time. The very congested travel time is usually represented by a high percentile, e.g. 95th percentile. That means that 95% of the time, the travel time is less than that, so if you plan your travel using such as measure, you will only be late 5% of the time. The are many different ways to express this concept as a performance measure.

The **Planning Time Index** typically uses free-flow travel time as the baseline. Examples include:

- (95th percentile travel time – free-flow travel time) / free-flow travel time. [24]
- 95th percentile travel time / free-flow travel time. For example, 2.25 means the 95th percentile travel time is 2.25 times as long as when conditions are free-flowing.[30]

A **Buffer Travel Time Index** is similar but uses the average travel time as the baseline. For example, (95th percentile travel time – mean travel time) / mean travel time.[24] This form results in a percentage measure, e.g. a buffer travel time of 50% means a traveler would need to add an additional 10-minute buffer to a trip with a 20-minute travel time on average to guarantee on-time arrival most of the time.[50] These two indexes are illustrated in Figure 5.

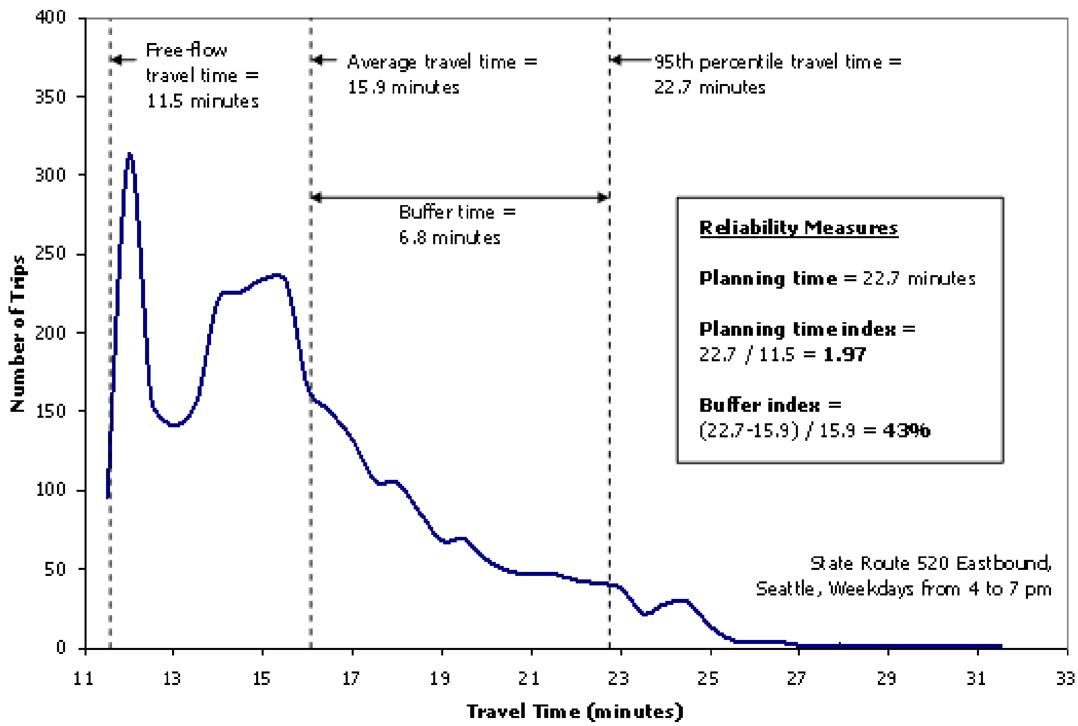

Figure 5 Example of Planning Time Index and Buffer Index
Source: ***https://ops.fhwa.dot.gov/publications/tt_reliability/long_descriptions/Figure5.htm***

Planning travel time can also be understood as the ratio of travel time on the worst day of the month over the time required to make the same trip at free-flow speeds[50] or as the variability in travel times and the number of times/trips a system succeeds or fails in relation to a standard.[4]

As part of the federal performance measures required under MAP-21 and the FAST Act, the Federal Highway Administration (FHWA) uses the **Level of Travel Time Reliability Metric** (LOTTR) that is calculated as 80th percentile travel time / 50th percentile travel time.[75] (Note that the 50th percentile equates to the median.) The measure is calculated for four different time periods (6 to 10 am, 10 am to 4 pm, and 4 to 8 pm on weekdays and 6 am to 8 pm weekends) using 15-minute data from FHWA's National Performance Management Research Data Set (NPMRDS). Segment-level LOTTRs are then used in an overall reliability metric representing the share of travel that occurs on segments meeting a certain LOTTR target deemed to be reliable. For freight reliability, FHWA uses a **Truck Travel Time Reliability** (TTTR) measure: 95th percentile travel time / 50th percentile travel time for five time periods – the same as for the LOTTR, plus overnight. The maximum TTTR for each segment is then used for an overall freight reliability measure representing the share of the system that is reliable for truck traffic.

Another travel time reliability measure is **On-Time Arrival**. Florida DOT uses this measure, defined as the percentage of trips (autos and trucks) occurring at a certain speed.[15] That chosen speed (45 mph for urbanized areas for Florida) is assumed to be "on-time."

All of these measures involve decisions that can have significant impacts on the outcomes and interpretation of the measures – the selection of the baseline (e.g. free-flow, mean, or median), the very congested times (e.g. 95th or 80th percentile), the on-time speed, and the time periods measured. Conceptually, using mean or median travel time as the baseline (vs. free-flow) acknowledges that travelers do or should not expect to travel at free-flow speeds during peak times. Choosing a higher very congested time for comparison (e.g. 95th percentile vs. the 80th percentile) indicates a higher standard for reliability, e.g. being late only 5% of the time vs. 20% of the time. A higher standard might be used for freight because of the direct financial impacts of late deliveries. Florida's choice of 45 mph for being on-time for trips on freeways is another example of a choice that represents what the expectation is for the system.

These same types of indexes could be applied to transit, but the more common and simpler approach is to measure of **transit on time performance**. This measure is used by most transit agencies in the U.S. and is typically expressed as a percent of transit trips that are on time compared to the schedule. As with the other vehicle-based measures discussed above, there are key decisions embedded in this measure, most importantly what buffer is allowed for defining "on time." These often range from being 0 to 2 minutes early to being 3 to 7 minutes late.[73]

Spatial Scale: Facility, District to area-wide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): Both buffer travel time and planning travel time are used to assess the reliability of top corridors of Region 1 in the ODOT Traffic Performance Report.[55]

Metro: Metro calculates and reports the FHWA reliability measures based on LOTTR (percent of reliable person miles) and TTTR (percent of miles with reliable truck travel times) described above.[40] Transit on-time performance used by Metro to support the Congestion Management Process monitoring and reporting.[40]

Oregon: Use of buffer travel time was also suggested as an alternate mobility measure in a 2014 consultant report for Washington County.[30]

Nationally: Florida Department of Transportation (FDOT) reports on truck travel time reliability to the Federal Highway Administration as a performance measure and planning travel time. On-time performance and travel time reliability are used by FDOT as current mobility measures.[15, 14]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	●	
Transportation Choice	◖	
Reliability and Efficiency	●	
Climate Leadership	○	
Equitable Transportation	○	Reliability measures could be examined separately for road segments or transit routes in corridors located in RTP equity focus areas.
Mode		
Private motor vehicles	●	
Freight	●	
Transit	●	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	◖	
Development Review	○	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Planning travel time data for private motor vehicles, including large freight trucks, and transit are available through • Travel times by time segment[24] • X percentile travel time[50] • Transit schedules[24] • Modeled free-flow travel time skims[24] • National Performance Management Research Data Set (NMPRDS)[40] • TriMet, SMART, and C-TRANS Performance Reports[40]
Forecasts	Planning travel times can be forecasted using Intelligent Transportation Systmes[24] and Dynamic Traffic Assignment[50,24]

3.3 Waiting Time

Definition: Waiting time is defined as the time spent waiting outside of the vehicle by transit riders, including the time spent waiting during a transfer. Largely a measure of frequency and reliability, waiting time strongly affects user experience and satisfaction with transit systems. As wait time decreases and frequency and reliability increase, transit demand increases, along with transit ridership.[24] Waiting time has potential to be used to identify inequitable access to destinations indicated by longer wait time due to more transfers on average.

Spatial Scale: Segment and facility[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: None identified.

Oregon: None identified.

Nationally: None identified.

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	○	
Transportation Choice	◖	
Reliability and Efficiency	○	
Climate Leadership	○	
Equitable Transportation	◖	Could be measured separately for routes in RTP equity focus areas
Mode		
Private motor vehicles	○	
Freight	○	
Transit	●	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	◖	
Plan Amendment	○	
Development Review	○	
Performance Monitoring	◖	

Data Analysis & Availability	
Existing conditions	Waiting time data for and transit is available through • On-board surveys[24] • Transit agency on-time performance data[24]
Forecasts	Waiting time can also be forecasted through use of modeled transit networks[24]

3.4 Vehicle Hours Traveled (VHT)

Definition: VHT refers to the hours traveled by vehicles in a specific area during a specified period of time. VHT can be weighted by volume for motor vehicles or by commodity weight or value for freight.[24] VHT can be a good indicator of transportation-related emissions of greenhouse gases and VHT standards can be set for climate action planning. VHT can also be interpreted as the time that transit riders spend in transit vehicles as a measure of congestion-induced delay.[24] Despite only measuring motor vehicle trips, reductions in VHT can be an indicator of increases in transit and active transportation trips.[69] VHT can experience short-term improvements through increasing travel speeds and capacity but the long-term implications include addition motor vehicle travel, congestion, and negative impacts on active transportation modes.[69]

Spatial Scale: System and district to area-wide[5]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: Reduction of VHT is a goal of the Metro Regional Transportation Plan.[29]

Oregon: None identified.

Nationally – Used: Reduction of VHT is a desirable outcome of the Los Angeles Mobility Plan 2035 (CA)42[11].

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	●	
Transportation Choice	◖	
Reliability and Efficiency	●	
Climate Leadership	◖	
Equitable Transportation	○	
Mode		
Private motor vehicles	●	
Freight	●	
Transit	●	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	◖	
Development Review	○	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	VHT data for and private motor vehicles, large freight trucks, and transit are available through[24] • Measured travel times • Shipment data for freight • Pavement detectors • On-board vehicle devices
Forecasts	• VHT can also be forecasted through use of modeled networks[24]

3.5 Vehicle Miles Traveled (VMT)

Definition: VMT is a measure of the number of vehicle mils traveled within a certain area and time period.[50] VMT is a good indicator of reliance and dependence on private motor vehicles[29] and the implied relationship of this dependence on existing land use patterns that support alternate modes of transportation.[50] Typically, VMT tends to decrease when density and land use mix increase as a result of people living closer to destinations and places of employment and increased walkability.[7,54] VMT has also been shown to decrease every mile closer to a transit stop[7] again reflecting transportation demand and supply in urban settings[54] and, despite measuring only motor vehicle trips, reductions in VMT can be a measure of increases in transit and active transportation trips.[69] VMT has been shown to increase directly with the growth of personal income[50,66], signifying that private vehicle ownership and the coinciding motor vehicle infrastructure benefits high-income populations most. Reducing VMT by supporting other modes of transportation is a more equitable approach to mobility. VMT can also be used as an indicator of the environmental implications of automotive transportation through fuel consumption, greenhouse gas emissions, trip lengths, and automobile share[7] and VMT is measured as part of the energy analysis for Environmental Impact Statements in Oregon.[54] VMT is easy to calculate, needing estimates of trip generation rates and trip lengths, and can easily be modeled using tools like the Environmental Protection Agency's (EPA) Mixed-Use Development (MXD) Model.[69]

Spatial Scale: Facility, district to area-wide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): VMT is used as a Corridor Performance Indicator for the top corridors in Region 1 in the ODOT Traffic Performance Report.[55] VMT is also included in the ODOT Analysis Procedures Manual (APM) as a RTP measure and a supplemental measure for TSP and Project Development.[52]

Metro: VMT is a current Metro RTP Monitoring Performance Measure.[29] Daily VMT is used by Metro to support Congestion Management Process (CMP) and Climate Smart Strategy implementation monitoring and reporting.[40] VMT is also used in the 2018 RTP as a key performance measure for addressing Goal 8 (Climate Leadership).[39]

Oregon: Use of VMT was also suggested as an alternate mobility measure in a 2014 consultant report for Washington County.[30]

Nationally: VMT is now being used throughout California as an alternative to v/c-based LOS measures. It is included as a performance measure by San Francisco County Transportation Authority and in the Los Angeles Mobility Plan 2035 (CA).[42] The City of Los Angeles has developed a VMT calculator to estimate VMT per capita and per employee for new land development projects.[31, 32] The calculator first uses information about the land uses included in the project and its location. The location is linked to information from the city's travel demand model, which provides information about surrounding land use and travel patterns. The tool then calculates a base VMT using the Institute of Transportation Engineer's (ITE) *Trip Generation Manual* and additional adjustments for projects located in places where the ITE rates may be too high, e.g. in more walkable, transit-rich, mixed-use neighborhoods. In the next step, the user can apply different transportation demand management (TDM) strategies, such as parking pricing, commute trip reduction programs, and bicycle infrastructure, to reduce the projected VMT. The calculator then provides estimates of daily vehicle trips, VMT, household VMT per capita, and work VMT per employee. It also shows how much the mix of land uses and context of the location affected VMT, as well as the TDM measures selected.

VMT is also used for addressing safety considerations by California Office of Planning & Research (OPR).[42] Use of VMT as a primary mobility measure was adopted by California Metropolitan Planning Organizations (MPOs) as a result of Senate Bill 743 with the intent to shift focus away from congestion management to infill development, public health promotion through active transportation, and reduction of greenhouse gas emissions through VMT reduction.[76] VMT is included in the California Environmental Quality Act (CEQA) to review projects in travel efficient locations.[70] It is also included in the City of San Jose VMT Evaluation tool for proposed development: VMT is now being used throughout California as an alternative to v/c-based LOS measures. It is included as a performance measure by San Francisco County Transportation projects and in the environmental review process[5] and by the Pasadena Department of Transportation and San Bernardino County's TIS Guidelines to assess the transportation impacts of proposed developments.[63,23] VMT is used by the Florida Department of Transportation for system-wide reporting.[14]

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	●	
Transportation Choice	◖	
Reliability and Efficiency	○	
Climate Leadership	●	
Equitable Transportation	◖	
Mode		
Private motor vehicles	●	
Freight	●	
Transit	◖	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	◖	
Development Review	◖	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	VMT data for and private motor vehicles, large freight trucks, and transit are available through • Modeled trip tables[24] • Network-based distance skims[24] • Traffic volumes[8] • ODOT Highway Performance Monitoring System (HPMS)
Forecasts	VMT can also be forecasted by using VMT mapping and Travel Demand Model[8]

3.6 Person Hours of Travel (PHT)

Definition: PHT refers to the person hours of travel in a specific area during a specified period of time. PHT can measure increases of trip lengths, excess delay, and total travel time experienced individually, regardless of mode.[24] Outside of travel time, PHT can speak to the impact on productivity and quality of life of a proposed project through looking at changes in PHT.[8] PHT also has potential to identify inequitable access to transportation and destinations by considering excess PHT.

Spatial Scale: Segment, facility, multimodal corridor, and district to area-wide.[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: None identified.

Oregon: None identified.

Nationally: None identified.

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	◖	
Transportation Choice	●	
Reliability and Efficiency	◖	
Climate Leadership	◖	
Equitable Transportation	◖	
Mode		
Private motor vehicles	●	
Freight	○	
Transit	●	
Bicycles	◖	
Pedestrians	◖	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	◖	
Development Review	○	
Performance Monitoring	◖	

Data Analysis & Availability	
Existing conditions	PHT data for and private motor vehicles, transit, bicycles, and pedestrians are available through[24] • Modeled trip tables • Vehicle occupancy • Network based distance skims
Forecasts	PHT can be forecasted by using Travel Demand Model[24]

3.7 Person Throughput

Definition: Person throughput refers to the number of people, across modes, traveling through a segment, facility, mobility corridor, or specified point in one direction over a certain period of time.[24] By focusing on total number of persons across modes, person throughput takes the emphasis away from vehicular movement.[29] Person throughput also is a good assessment of user benefits for different transportation systems[24] and a means to focus on mitigating congestion and increasing performance through more efficient use of existing infrastructure.[78]

Spatial Scale: Point, segment, system, multi-modal corridor[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): Throughput is included in the ODOT Analysis Procedures Manual (APM) as a Facility Plan and Project Development measure, and a supplemental measure for Development Review[52].

Metro: None identified.

Oregon: None Identified

Nationally: Person throughout is used in Minneapolis, Minnesota instead of increasing capacity to mitigate congestion and enhance performance through using existing infrastructure of a shift to low-cost/high-benefits improvements.[78]

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	○	
Transportation Choice	●	
Reliability and Efficiency	◖	
Climate Leadership	◖	
Equitable Transportation	○	
Mode		
Private motor vehicles	●	
Freight	○	
Transit	●	
Bicycles	●	
Pedestrians	●	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	○	
Development Review	◖	
Performance Monitoring	◖	

Data Analysis & Availability	
Existing conditions	Person Throughput data for and private motor vehicles, transit, bicycles, and pedestrians are available through[24] • Auto counts with surveyed occupancy data • Transit passenger counts • Counts of cyclists and pedestrians
Forecasts	Estimated future person throughput can also be forecasted through use of calibrated travel modes[26]

3.8 Recurring Delay/Non-Recurring Delay

Definition: Recurring delay is a measure of typically repeated vehicle delay during a certain time of day and day of the week.[24] The vehicle hours of delay in excess of recurring delay is defined as non-recurring delay.[24] Using recurring delay as a measure for freight can help monitor performance and connection of goods to different markets.[57] Recurring delay speaks largely to the amount of demand on a certain system and resulting congestion affecting travel times, whereas non-recurring delay is a measure of variability in delay due to traffic incidents, weather, construction, and other unexpected events.[57] Data collection can be expensive for measuring both types of delay and dividing delay into recurring and non-recurring categories can be difficult as well.[29]

Spatial Scale: Point, segment, and system[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): Recurring delay and non-recurring delay are current components of the ODOT Key Performance Measures (KPM) #9 Traffic Congestion.[57]

Metro: None identified.

Oregon: None identified.

Nationally: None identified.

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	●	
Transportation Choice	○	
Reliability and Efficiency	●	
Climate Leadership	○	
Equitable Transportation	○	
Mode		
Private motor vehicles	●	
Freight	●	
Transit	●	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	○	
Development Review	○	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Recurring delay and non-recurring delay data for private motor vehicles, trucks, and transit are available through • Travel times by time segment[24]
Forecasts	Recurring delay and non-recurring delay can also be forecasted through use of Intelligent Transportation Systems (ITS) and Dynamic Traffic Assignment (DTA)[24]

3.9 Hours of Congestion/Duration of Congestion

Definition: Hours of congestion refers to the hours, typically within a weekday, during which a facility exceeds its congestion level target.[8] The congested periods measured with hours of congestion speak to the excess or unserved demand during the studied time period.[54] This measure speaks largely to system performance and is typically used for long-term planning.[39]

Spatial Scale: Segment and facility[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): Hours of congestions is currently used as a Corridor Performance Indicator for Region 1 top corridors in the ODOT Traffic Performance Report.[55] It is also used by ODOT in Project Atlas as part of an evaluation of congestion bottlenecks on Region 1 corridors.[51] Hours of congestion is also included in the ODOT Analysis Procedures Manual (APM) as a TSP and Facility Plan measure and supplemental measure for Development Review.[52]

Metro: Congestion is used in the 2018 RTP as a key performance measure for addressing Goal 3, Reliability and Efficiency.[39]

Oregon: None identified.

Nationally: Duration of congestion is used by the Florida Department of Transportation (FDOT) as a measure for system-wide performance.[14]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	◖	
Transportation Choice	◖	
Reliability and Efficiency	●	
Climate Leadership	○	
Equitable Transportation	○	
Mode		
Private motor vehicles	●	
Freight	●	
Transit	◖	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	○	
Development Review	◖	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Hours of congestion data for private motor vehicles, trucks, and transit are available through • Travel speeds per time interval[24]
Forecasts	Hours of congestion can also be forecasted using Travel Demand Models[24]

3.10 Volume-to-Capacity Ratio (V/C) and Level of Service

Definition: V/C is defined as the ratio of traffic volume to the capacity of a roadway or intersection.[8] V/C ratios are clear and precise and can be used to set objective thresholds for comparison.[8] Calculating v/c is standardized and v/c is easily applied and forecasted with a travel model.[54] Calculated v/c thresholds can also be adapted to set alternative mobility targets.[64] However, v/c is not a multimodal measure, does not reflect the number of users affected or user experience[54], and work against density-related development goals.[29]

LOS is a system of letter grades A through F used as a measure of performance typically in relation to v/c, delay, and density.[24] LOS was the primary measure of mobility in Oregon until the Oregon Highway Plan adopted v/c as a primary measure since LOS is not a specifically defined, consistent standard and was more legally defensible.[48] LOS is still widely used, however, the Federal Highway Administration (FHWA) does not have regulations or policies for the National Highway System (NHS) to be measured with LOS values.[43] Similarly, cities and counties in California are able to opt out of LOS standards, especially in infill areas, due to SB 743.[76] V/C-based LOS does not address modern planning goals like emission reduction, multimodal transportation systems, infill, and the optimization of existing motor vehicle facilities and can be expensive to calculate for intended projects.[69] LOS has also been criticized for being biased against additional developments in already developed areas. Congestion in developed areas is already approaching thresholds so infill development will be deemed unacceptable due to the impact on LOS.[69]

Spatial Scale: Point, segment, and facility[24, 52]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): V/c is currently the principal performance measure for evaluating the Oregon state highway system.[50] V/c is also included in the ODOT Analysis Procedures Manual (APM) as a TSP, Facility, Development Review, and Project Development measure.[52] Motor vehicle LOS is included in ODOT Analysis Procedures Manual (APM) as a TSP, Facility Plan, Development Review, and Project Development measure.[52]

Metro: V/c is currently the principal performance measure for evaluating the Oregon state highway system and city and county-owned arterial streets designated in the RTP. V/c is also included in Metro's Regional Transportation Functional Plan.

Oregon: In order to evaluate congestion statewide, the Oregon Department of Transportation uses v/c targets of 0.70 to 1.0 at the state level using the 30th highest annual hour and 0.99-1.1 within the Portland Metropolitan Area using the highest two consecutive hours of weekday traffic volumes, as detailed in the Oregon Highway Plan (OHP).[31] However, for areas where these targets were unachievable, alternative targets have been developed and approved by the Oregon Transportation Commission:

- Oregon City/Metro Area, OR 213 at Beavercreek Rd (2018) – existing v/c ratio target of 0.99 changed to 1.0[64, 22]

- Salem/Keizer, Interstate-5/Chemawa Road Interchange (2019) – v/c ratio targets for seven intersections modified from 0.85-0.87 to 0.89-0.97 using non-seasonally adjusted volumes and hourly peaking rather than 15-minute peaking for analysis.[58]
- Rogue River, Rogue River Interchange on Interstate 5 (2019) – maximum v/c ratio was changed from 0.85 to four hours/day at or above a v/c ratio of 1.0[56]
- Seaside, US 101 (2011) – v/c ratio targets for four intersections adjusted from 0.80-0.85 at the 30th Highest Hour to 1.0 using average annual weekday peak hour conditions[17]
- Salem, Oregon 22 / 25th Street to Gaffin Road (2018) – Existing OHP v/c target ratios for six intersections were changed from 0.85 to 0.85-0.95 for average weekday volumes or 30th highest hour volume conditions[21]
- Clatsop County, U.S. 101: Camp Rilea to Surf Pines (2014) – Alternative v/c targets of 0.90 for the Sunset Beach Lane approach and 0.60 for six intersections on U.S. 101 through use of Average Annual Daily Traffic (AADT) rather than 30th highest hour volume[20]
- Newport, Oregon Coast Highway (U.S. 101) at South Beach (2013) – Alternative v/c ratio targets for four intersections changed from OHP targets of 0.80-0.90 to 0.85-0.99 using annual average weekday PM peak hour[18]
- The Dalles, Chenoweth Interchange at I-84 (2006) – v/c ratio target was lowered from 0.85 to 0.75 to reserve capacity for future development[61]
- Portland Metropolitan Region (2000) – OHP v/c ratio targets modified for the Portland Metropolitan Region for peak hour operating conditions to 0.99-1.1 at the 1st hour and 0.99 at the 2nd hour, 1.0 as reflected in Table 7 of the OHP (see Figure 3) and Table 2.4 of the RTP.[47,39]

Oregon Department of Transportation (ODOT): Motor vehicle LOS is included in ODOT Analysis Procedures Manual (APM) as a TSP, Facility Plan, Development Review, and Project Development measure.[52]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	◖	
Transportation Choice	○	
Reliability and Efficiency	●	
Climate Leadership	○	
Equitable Transportation	○	
Mode		
Private motor vehicles	●	
Freight	●	
Transit	○	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	●	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	V/C and LOS data for private motor vehicles and large freight trucks are available through[24] • Traffic counts • Model data • Signal timing • Facility capacity
Forecasts	V/C and LOS can also be forecasted using the Highway Capacity Manual (HCM) and Travel Demand Model[8, 24]

3.11 Congestion Extent

Definition: Congestion extent is defined as the length of a freeway segment, in a certain direction, for which average travel times are a percentage longer than free flow.[24] Using congestion extent allows for the assessment of how motorists might change their travel behavior in order to void peak congestion.[29]

Spatial Scale: Segment, facility, district to area-wide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: None identified.

Oregon: None identified.

Nationally: None identified.

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	◖	
Transportation Choice	○	
Reliability and Efficiency	●	
Climate Leadership	○	
Equitable Transportation	○	
Mode		
Private motor vehicles	●	
Freight	●	
Transit	◖	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	○	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Congestion extent data for private motor vehicles and large freight trucks are available through[24] • Travel speeds by time intervals • Lengths of segments
Forecasts	Congestion extent can also be forecasted by using travel forecast models and Dynamic traffic assignment (DTA)[24]

3.12 Queuing

Definition: Queuing, also referred to as motor vehicle queuing, queues, and queue length, measures the extent of vehicles queued on intersection approach lanes, including on and off ramps, during peak hour.[8]. Queuing can also be measured by setting a specific threshold and measuring the proportion of time when the queue is beyond the threshold or by measuring the percentage of intersections where queues are beyond the specified threshold.[24] In addition, queuing in excess of capacity indicates safety risks. Using queuing as a measure allows for a good assessment of operations as intersections approach capacity.[8] Queuing measures are typically made during peak period and can measure queuing due to oversaturation, where demand exceeds capacity, or undersaturation, when there is an interrupted flow.[54]

Spatial Scale: Point, segment, district, area-wide, and facility[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): Queue length is included in the ODOT Analysis Procedures Manual (APM) as a measure for TSP, Designated MMA, Facility Plan, Development Review, and Project Development.[52]

Metro: None identified.

Oregon None identified.

Nationally: None identified

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	◖	
Transportation Choice	○	
Reliability and Efficiency	●	
Climate Leadership	○	
Equitable Transportation	○	
Mode		
Private motor vehicles	●	
Freight	●	
Transit	◖	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	●	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Queuing data for private motor vehicles, large freight trucks, and transit are available through • Segment lane geometry[24] • access/egress points[24] • traffic control operations[24] • directional volumes[24] • field measurements[29]
Forecasts	Queuing can also be forecasted using Synchro/SimTraffic[24] or other micro-level modeling tools[8]

3.13 Percent of Congested Traffic

Definition: Percent of Congested Traffic measures the ratio of congested vehicle miles traveled (VMT) to total VMT. Congestion in this context could be measured using v/c ratio or another measure. Congested VMT is defined as traffic volume multiplied by the length of road section, for a certain period of time that occurs below a certain threshold. Total VMT is defined as the total volume of traffic multiplied by the length of road section during a specific time.[24] Using percent of congested traffic can be a useful measure for evaluating and comparing different improvement alternatives for TSP and corridor projects.[29]

Spatial Scale: District to area-wide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: None identified.

Oregon None identified.

Nationally: None identified

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	◖	
Transportation Choice	○	
Reliability and Efficiency	●	
Climate Leadership	○	
Equitable Transportation	○	
Mode		
Private motor vehicles	●	
Freight	●	
Transit	◖	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	○	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Percent of congested traffic data for private motor vehicles, large freight trucks, and transit are available through • Measures of traffic volumes and speeds by time period • Segment lengths[24]
Forecasts	This measure could be forecast using travel demand models.

3.14 Vehicle Hours of Delay (VHD)

Definition: VHD is the measurement of the total hours of delay per trip or during peak periods.[50] VHD is primarily used for setting goals for congestion reduction.[30] The use of VHD is of particular interest for freight since reductions in VHD can increase freight reliability[29] and VHD can be used for calculating freight delay costs.[50]

Spatial Scale: System-wide and facility[7, 29]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): VHD is used as a Region 1 Corridor Performance Indicator by the ODOT Traffic Performance Report.[55] VHD is also included in the ODOT Analysis Procedures Manual (APM) as a Project Development measure and as a supplemental measure for Facility Plan.[52]

Metro: VHD is a current Metro RTP Monitoring Performance Measure.[29] Annual Hours of Peak Hour Excessive Delay Per Capita is also a MAP-21/FAST Act Performance Measure reported on by Metro.[40] Freight truck vehicle hours of delay is used in the 2018 RTP as a key performance measure for addressing Goal 4 (Reliability and Efficiency).[39]

Oregon: Use of VHD was also suggested as an alternate mobility measure in a 2014 consultant report for Washington County.[30]

Nationally: Vehicle delay is used by the Florida Department of Transportation (FDOT) as a system-wide reporting measure.[14]

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	●	
Transportation Choice	○	
Reliability and Efficiency	●	
Climate Leadership	○	
Equitable Transportation	○	
Mode		
Private motor vehicles	●	
Freight	●	
Transit	◖	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	○	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	VHD data for private motor vehicles, large freight trucks, and transit are available through • Travel speeds[50] • Traffic volume[50] • National Performance Management Research Data Set (NPMRDS)[40]
Forecasts	VHD can also be forecasted using travel forecast models[50], Highway Capacity Manual[50], and Synchro/SimTraffic, PPEAG, HERS-ST, and microsimulation.[54]

3.15 Multimodal Level of Service (MMLOS)

Definition:

MMLOS is a level of service (LOS) system that measures the quantity and quality of facilities per mode[2] reflection the traveler's perceptions and user experience.[50] MMLOS is considered a quality of service measure or a level of comfort measure, reflected by its ability to assess factors that impact pedestrian, bicycle, and transit mobility from the perspectives of pedestrians, cyclists, and transit riders, respectively.[54] The measures, as defined in the Highway Capacity Manual, are based on the physical characteristics of the facility or transit service, not the amount of use of the facility or service. MMLOS has primarily been used for urban facilities and can be used to set standards by mode, while also considering the impact of other, adjacent modes and facilities.[50] MMLOS can be used to consider improvement strategies for non-motorized modes, such as bike and pedestrian infrastructure, as well as transit.[29] MMLOS also assesses the quality of connection of links between intersections to further identify areas of needed improvement.[11] For example, Modified Pedestrian LOS, a subset of MMLOS, evaluates the perception and user experience of pedestrian facilities and identifies areas of needed improvement, which has the potential to identify differences in experience geographically.[8] However, MMLOS only measures mobility around a potential project rather than for the entire system and it can be difficult to calculate.[69]

Spatial Scale: Point, segment, and facility.

Current Examples of Usage:

Oregon Department of Transportation (ODOT): MMLOS is included in the ODOT Analysis Procedures Manual (APM) as measure for Facility Plans, Development Review, Project Development, and as a supplemental measure for Designated Multimodal Mixed-Use Area (MMA).[52]

Metro: None identified.

Oregon: Modified pedestrian LOS was used in the Bend Central District Multimodal Mixed-Use Area (MMA) for long-range planning.[8] Use of MMLOS was also suggested as an alternate mobility measure in a 2014 consultant report for Washington County.[30]

Nationally: MMLOS was included in the 2010 edition of the Highway Capacity Manual, which is used by most jurisdictions in the U.S., though use of MMLOS is not a requirement. Bicycle LOS was used in the Pedestrian Master Plan in Spartanburg, South Carolina to locate areas of needed updates in the bicycle network.[11] Florida Department of Transportation (FDOT) uses both bicycle and pedestrian LOS as current mobility measures[77] and to review actions that impact the State Highway System for planning and permitting processes.[11] Bicycle and pedestrian LOS are used by the City of Fort Collins, Colorado for shaping plans and mitigating traffic.[1] Bicycle and pedestrian LOS are also used in the Urban Street Design Guidelines (USDG) in Charlotte, North Carolina, to assess the quality of bike and pedestrian comfort, safety, and design.[1] Bellevue, Washington also used MMLOS in the Transportation Element component of their 2014 Comprehensive Plan.[12]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	◖	
Transportation Choice	●	
Reliability and Efficiency	◖	
Climate Leadership	◖	
Equitable Transportation	◖	
Mode		
Private motor vehicles	●	
Freight	◖	
Transit	●	
Bicycles	●	
Pedestrians	●	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	●	
Performance Monitoring	◖	

Data Analysis & Availability	
Existing conditions	MMLOS data for private motor vehicles, transit, bicycles, pedestrians, and freight are available through • Cross-section/geometric measurements • Auto and pedestrian volumes • Signal timing data • Transit service/amenity information[50]
Forecasts	MMLOS can be forecasted through use of using data on facility improvements

3.16 Level of Traffic Stress (LTS)

Definition: Primarily suited for bicycles and pedestrians, level of traffic stress classifies points and segments on routes into different categories of stress ranging from 1 (low stress) to 4 (high stress). These level of stress measures correlate to the comfort and safety of the bicyclist or pedestrian.[8] Calculating level of traffic stress can help to assess network connectivity[30] and the quality of connection between different intersections[11], with potential to identify differences in experience geographically. Level of traffic stress also factors in ADA accessibility into measurements of user experience.[54] Level of traffic stress scores can also be interpreted by the level of experience of the cyclist, meaning that LTS 1 would be suitable for children, LTS 2 would be suitable for most adults, LTS 3 would be suitable for confident and enthused cyclists, and LTS 4 would be recommended for only strong and fearless riders.[30] With these standards in mind, creating a low stress, connected bicycle network is defined by never exceeding a level of traffic stress score of 2 and ensuring that cyclists do not diverge more than 25% from the shortest origin-destination path.[30]

Spatial Scale: Segment and point[8]

Current Examples of Usage:

Oregon Department of Transportation: Bicycle and Pedestrian level of traffic stress is included in the ODOT Analysis Procedures Manual (APM) as a RTP and Transportation System Plan (TSP) measure and as a supplemental measure for Designated Multimodal Mixed-Use Area (MMA), Facility Plan, and Project Development.[52]

Metro: None identified.

Oregon: Level of traffic stress is included in the Scappoose TSP as a performance measure.[8]

Nationally: The Federal Highway Administration (FHWA) calculated level of traffic stress for a case study in Fort Collins, Colorado to assess low-stress networks and route directness.[11] Florida Department of Transportation (FDOT) sanctioned the use of bicycle level of traffic stress for when designing multimodal streets.[77]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	○	
Transportation Choice	◖	
Reliability and Efficiency	○	
Climate Leadership	◖	
Equitable Transportation	◖	Can be estimated for different population groups comparing RTP equity focus areas with outside RTP equity focus.
Mode		
Private motor vehicles	○	
Freight	○	
Transit	○	
Bicycles	●	
Pedestrians	◖	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	◖	
Development Review	◖	
Performance Monitoring	◖	

Data Analysis & Availability	
Existing conditions	Level of traffic stress data for bicycles and pedestrians are available through • Bicycle facility data • Number of motor vehicle lanes • Traffic volumes, speeds, crossing types[8]
Forecasts	Because LTS is based on the physical characteristics of the street, it would be forecast based on plans for improving or changing infrastructure.

3.17 System Completeness

Definition: System completeness, or network completeness, is defined as the percent of planned facilities or services that are built and in place[50] and identifies the areas where there are gaps in transportation systems. Through monitoring the completeness of various facilities, system completeness is a good tool for measuring the progress of different transportation plans and projects.[8] System completeness can also be used for land use plan amendments and zone changes that could improve or hinder the completion of a planned transportation system.[29] Aside from mobility, system completeness can be a good safety metric through addressing the completeness of crossings, signal timing, detection/actuation, and lighting.[30] System completeness measures could be improved through including the quality of the system, such as allowing for the assessment of low-stress connectivity for bicycle networks.[11]

Spatial Scale: Facility, system[54]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): System completeness is included in the ODOT Analysis Procedures Manual (APM) as an RTP and TSP measure and a supplemental measure for Designated MMA, Facility Plan, and Project Development.[52]. System completeness was also identified as a recommended infrastructure measure in the ODOT Region 1 Accessibility Performance Measures report.[29] The Oregon Bicycle and Pedestrian Plan has a strategy to "identify and prioritize filling system gaps" which responded to a top issue (incompleteness of the walking and bicycling system) raised by stakeholders.[45]

Metro: Regional Bike and Pedestrian Network Completion is used by Metro to support Congestion Management Process (CMP) and Climate Smart Strategy implementation[40] monitoring and reporting.[40] System completeness was also used in the 2018 RTP as a performance target and a key performance measure for addressing Goal 3 (Transportation Choices) and Goal 9 (Equitable Transportation).[39]

Oregon: Pedestrian system completeness was used in the Sherwood TSP to assess existing and planned pedestrian facilities.[8] Bicycle system completeness was used in the Oregon City TSP to assess existing and planned bicycle facilities.[8] Use of system completeness was also suggested as an alternate mobility measure in a 2014 consultant report for Washington County.[30]

Nationally: System completeness was used by the Federal Highway Administration (FHWA) in a case study in Baltimore, Maryland to assess the level of completeness of sidewalks in the downtown area.[11]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	◖	Could be measured for freight routes/system
Transportation Choice	●	
Reliability and Efficiency	◖	
Climate Leadership	○	Could support this goal to the extent that the system improvements are designed to reduce GHG emissions
Equitable Transportation	●	Can be estimated for different population groups comparing RTP equity focus areas with areas outside of RTP equity focus areas.
Mode		
Private motor vehicles	●	
Freight	◖	
Transit	●	
Bicycles	●	
Pedestrians	●	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	●	
Performance Monitoring	◖	

Data Analysis & Availability	
Existing conditions	System completeness data for private motor vehicles, including large freight trucks, transit, bicycles, and pedestrians are available through • Inventory of constructed motor vehicle, bicycle, pedestrian, and multi-use facilities and other system improvements, though comprehensive accurate data for some infrastructure, such as sidewalks, can be problematic.[50, 45] • Metro RLIS[40]
Forecasts	Forecasts would be based on planned and programmed spending for new infrastructure

3.18 Accessibility to Transit

Definition: Accessibility to transit is defined as the number or percent of a population or households living within a defined distance or travel time from a transit stop.[8] Accessibility to transit also includes the time spent walking to and waiting for transit in addition to the frequency of transit.[8] Aside from distance or travel time to transit stops, accessibility to transit considers land use proximity, densification, addition of new routes, frequency, and span of service.[54] Accessibility to transit can be used to identify areas with inadequate, inequitable access and help to prioritize future transit development.[8] Higher accessibility to transit allows for more efficient energy consumption and greenhouse gas emission mitigation.[79]

Spatial Scale: Zonal, district, area-wide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): Accessibility for transit riders is included in the ODOT Analysis Procedures Manual (APM) as an RTP measure, a supplemental measure for TSP and Designated MMA, and as a screening measure for Facility Plan and Project Development.[52]

Metro: Accessibility to transit is used by Metro to support the Congestion Management Process (CMP) and Climate Smart Strategy implementation monitoring and reporting.[40] It is also used in the 2018 RTP as a key performance measure for addressing Goal 1 (Vibrant Communities), Goal 3 (Transportation Choices), and Goal 9 (Equitable Transportation).[39]

Oregon: Accessibility to transit was used to access travel sheds and network distance for the Milwaukie Tacoma Station Area Plan.[8]

Nationally: Accessibility to transit is a current mobility measure used by the Florida Department of Transportation (FDOT). Resident access to transit is measured as the percentage of the population within one-half mile of fixed route transit.[15]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	○	
Transportation Choice	◖	
Reliability and Efficiency	◖	
Climate Leadership	◖	
Equitable Transportation	●	Can be estimated for different population groups comparing RTP equity focus areas with areas outside RTP equity focus.
Mode		
Private motor vehicles	○	
Freight	○	
Transit	●	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	●	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Accessibility to transit data are available through • GIS-based housing and transit stop data[8] • Transit service data[8] • Geo-coded population data[24] • Metro RLIS[40]
Forecasts	This measure could be forecast using land use forecasts and planned transit service.

3.19 Accessibility to Employment

Definition: Accessibility to employment is typically defined as the number of jobs that can be reached within a certain travel time, cost or distance, by different modes.[24] Accessibility to employment is a good tool to assess employment opportunity geographically and therefore can be used to areas with inequitable access. Accessibility to employment is also a good measure for assessing different land use impacts by assessing the change in employment access due to various projects. [8]

Spatial Scale: Zonal, district to area-wide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: Access to jobs used in the 2018 RTP as a key performance measure for addressing Goal 2 (Shared Prosperity) and Goal 9 (Equitable Transportation).[39]

Oregon: None identified.

Nationally: Accessibility to employment by is used by the Florida Department of Transportation as a current mobility measure. There are separate measures for access by auto and transit.[16]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	●	
Transportation Choice	●	
Reliability and Efficiency	○	
Climate Leadership	◖	
Equitable Transportation	●	Can be estimated for different population groups comparing RTP equity focus areas with areas outside RTP equity focus.
Mode		
Private motor vehicles	●	
Freight	○	
Transit	●	
Bicycles	●	
Pedestrians	●	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	●	Development that impacts jobs and/or housing location would impact this accessibility measure
Performance Monitoring	◖	Accurate job location data may not be available in a timely manner

Data Analysis & Availability	
Existing conditions	Accessibility to employment by private motor vehicles, transit, bicycles, and pedestrians can be measures using • Employment, street network, and transit data[24] • Travel time skims[24]
Forecasts	Accessibility to employment and population can also be forecasted through use of forecasting tools (GIS, travel demand models) to evaluate the number of current and future employment and population within a specific proximity to transit[8]

3.20 Accessibility to Destinations

Definition: Accessibility to destinations is defined as number of essential destinations within a certain travel time or distance. For the purpose of this measure, essential destinations can be grocery stores, medical centers and clinics, schools, public spaces, transit stations, etc.[50] Accessibility to destinations can be measured across all modes[8] and contributes to the argument that measuring accessibility rather than mobility may be a more appropriate measure for urban areas. However, the measurement of travel times for both mobility and access suggests that these two measures may be more intertwined and bidirectional.[24] Additionally, access to destinations allows for the assessment of the connection between origin and destination. Projects that benefit people walking and bicycling for transportation, i.e. to access destinations, rather than for recreation, are more likely to impact mode shift.[11] Bike, walk, and transit "scores" are some measures of a accessibility to destinations known by the general public that can be used.[54] While accessibility to destinations does not address the adequacy of a facility[54], it is able to measure access on a large scale. Accessibility to destinations also assess distinct factors that impact transportation access for specific areas and populations by conducting needs assessments, gap identifications, and scenario analysis.[11]

Spatial Scale: Zonal, district to area-wide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): Accessibility for motor vehicles, pedestrians, and bicyclists is included in the ODOT Analysis Procedures Manual (APM) as an RTP measure, a supplemental measure for TSP and Designated MMA, and a screening measure for Facility Plan and Project Development.[52]

Metro: Access to community places used in 2018 RTP as a key performance measure for addressing Goal 1 (Vibrant Communities) and Goal 9 (Equitable Transportation).[39]

Oregon: Use of accessibility to destinations was also suggested as an alternate mobility measure in a 2014 consultant report for Washington County.[30]

Nationally: Accessibility to destinations was used by the Federal Highway Administration (FHWA) and the Atlanta Regional Council in Atlanta, Georgia in a case study to create travelsheds addressing number of homes and jobs within specified areas.[11]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	◖	
Transportation Choice	●	
Reliability and Efficiency	○	
Climate Leadership	◖	
Equitable Transportation	●	Can be estimated for different population groups comparing RTP equity focus areas with areas outside RTP equity focus.
Mode		
Private motor vehicles	●	
Freight	○	
Transit	●	
Bicycles	●	
Pedestrians	●	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	●	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Accessibility to destinations data for private motor vehicles, transit, bicycles, and pedestrians are available through • Data for population, employment, transit networks, and street networks[24] • Travel time skims[24] • Data sets showing the location of specified destinations[50]
Forecasts	Can be forecast using travel demand models and sketch planning tools, using planned or projected transportation improvements and land use forecasts

3.21 Accessibility to Freight Terminals

Definition: Accessibility to freight terminals, or referred to as accessibility to a freight network, is a measure of the number of freight-specific jobs within a certain distance or truck travel time of ports and intermodal facilities.[24] This measure is used to assess the connection of jobs to freight.[8]

Spatial Scale: District, area-wide, and statewide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: Access to industry and freight facilities was identified in the 2018 RTP as a performance measure for addressing Goal 2 (Shared Prosperity). However, the measure was "not fully implemented or evaluated." The intent was "to measure the number of trucks that are coming from or going to freight intermodal facilities or industrial land within each of the Regional Mobility Corridors, and determine the hours of truck delay they are experiencing on the regional freight network.[39] As described, this measure is more of a travel time reliability or congestion measure.

Oregon: None identified.

Nationally: None identified

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	●	
Transportation Choice	○	
Reliability and Efficiency	○	
Climate Leadership	○	
Equitable Transportation	○	
Mode		
Private motor vehicles	○	
Freight	●	
Transit	○	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	○	
Performance Monitoring	○	

Data Analysis & Availability	
Existing conditions	Accessibility to freight terminals data are available through • Geo-coded locations of port and intermodal facilities • Employment data • Network travel times[24]
Forecasts	This measure could be forecast using a travel demand model.

3.22 Trip Length Distributions

Definition: Trip length distribution is defined as the distribution of trips by different 1-mile segments, modes, and purposes. This measure can directly assess the changing trip lengths resulting from changes in land use.[24] Trip length distributions can also assess whether trips are occurring consistent with the functional classification of a facility.

Spatial Scale: Zonal, district to area-wide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: None identified.

Oregon: None identified.

Nationally: None identified

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	○	
Transportation Choice	●	
Reliability and Efficiency	○	
Climate Leadership	◖	
Equitable Transportation	◖	Would need to be measured & estimated by population groups
Mode		
Private motor vehicles	●	
Freight	○	
Transit	◖	
Bicycles	◖	More trips in shorter distance categories can indicate great *potential* for walking and bicycling
Pedestrians	◖	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	◖	
Development Review	◖	
Performance Monitoring	◖	Actual performance could be measured using new "big data" sources (e.g. cell phone data), though accuracy by mode may be limited

Data Analysis & Availability	
Existing conditions	Trip length distributions for private motor vehicles, transit, bicycles, and pedestrians are available through • Household and establishment surveys • Modeled network trip tables[24]
Forecasts	Could be forecast with a regional travel demand model.

3.23 Bicycle/Pedestrian Network Directness/Connectivity

Definition: Bicycle/Pedestrian network directness, also referred to as bike/pedestrian network circuitousness and bike/pedestrian route directness, is a measure of the shortest and most direct path between origin and destination for bicyclists and pedestrians.[24] This measure is used to assess whether or not nonmotorized facilities are planned to allow for travel via direct routes.[11] Through the measurement of directness, bicycle/pedestrian network directness acts a good promoter for walking and biking[29] and can be an indicator of connectivity for non-motorized facilities.[11] Bicycle/Pedestrian network directness can be implemented in scenario analyses, gap identification, project prioritization, and benchmarking.[11]

Spatial Scale: Zonal, district, and area-wide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: None identified.

Oregon: None identified

Nationally: Bicycle/pedestrian network directness was used by the City of Fort Collins, Colorado to evaluate the directness of pedestrian walkways to destinations.[1]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	○	
Transportation Choice	◖	
Reliability and Efficiency	○	
Climate Leadership	◖	
Equitable Transportation	◖	Would need to be measured separately by comparing RTP equity focus areas with areas outside RTP equity focus areas.
Mode		
Private motor vehicles	○	
Freight	○	
Transit	○	
Bicycles	●	
Pedestrians	●	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	◖	
Performance Monitoring	◖	

Data Analysis & Availability	
Existing conditions	Bicycle/pedestrian network directness data are available through • Street network data, transit routes, bike and sidewalk facilities[24] • Datasets showing location of destinations[29]
Forecasts	Would be forecast using planned and programmed improvements

3.24 Pedestrian Crossing Index

Definition: Pedestrian crossing index is a measure of the distance between pedestrian crossings compared to a target maximum distance. Through identifying where current crossings are, locations where crossings are needed most or where crossings do not meet a certain standard can be identified. Pedestrian crossing index can also be a useful tool for considering the placement of transit stops.[8]

Spatial Scale: Point, facility.

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: None identified.

Oregon: None identified.

Nationally: None identified.

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	○	
Transportation Choice	◖	
Reliability and Efficiency	○	
Climate Leadership	○	
Equitable Transportation	○	Would need to be measured separately by comparing RTP equity focus areas with areas outside RTP equity focus areas.
Mode		
Private motor vehicles	○	
Freight	○	
Transit	○	
Bicycles	○	
Pedestrians	●	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	
Development Review	◖	
Performance Monitoring	◖	

Data Analysis & Availability	
Existing conditions	Pedestrian crossing index data are available through • GIS-based database of intersection and crossing characteristics and signal cycle lengths[8] However, the availability of these data for the whole region is unclear.
Forecasts	Would be forecast using planned and programmed improvements

3.25 Mode Share

Definition: Mode share is defined as the percent of trips taken by various modes. Mode share is typically used to compare the percent of trips using public transit, walking, bicycling, carpool, and single occupancy vehicles (SOV).[50] Factors that can impact mode share are trip purpose, level of service, level of stress, travel time and directness of route, and accessibility.[54] Mode share can be used to encourage bicycling and walking and set desired mode share percentages as targets for each mode and desired reductions in the percentage of SOV trips for environmental and health policy and as a means to reduce traffic congestion.[79]

Spatial Scale: System, area-wide.

Current Examples of Usage:

Oregon Department of Transportation (ODOT): Mode share is included in the ODOT Analysis Procedures Manual as an RTP and TSP measure and as a supplemental measure for Designated MMA.[52]

Metro: Mode share is a current Metro RTP measure[29] and Metro adopted non-SOV mode share targets by mode and 2040 land use type as RTP system performance measures. Percent of non-SOV travel is also a MAP-21/FAST Act Performance Measure reported on by Metro.[40] Mode share was also used in the 2018 RTP as a key system performance measure for addressing Goal 3 (Transportation Choices). Multimodal travel was also used in the 2018 RTP as a key system performance measure for addressing Goal 2 (Shared Prosperity) and Goal 4 (Reliability and Efficiency).[39]

Oregon: Use of mode share was also suggested as an alternate mobility measure in a 2014 consultant report for Washington County.[30]

Nationally: Mode share was also included in both Seattle, Washington's Seattle 2035 plan and the Los Angeles Mobility Plan 2035 in Los Angeles, California as a means to decrease SOV trips and greenhouse gas emissions.[42]

	Applicability	Notes/Explanation
RTP Goal		
Shared Prosperity	◖	
Transportation Choice	●	
Reliability and Efficiency	◖	
Climate Leadership	●	
Equitable Transportation	○	
Mode		
Private motor vehicles	●	
Freight	○	
Transit	●	
Bicycles	●	
Pedestrians	●	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	●	When used with additional measures, mode share can assess small land use plan amendments or changes in zoning code due to its use in setting multimodal transportation goals[1].
Development Review	○	
Performance Monitoring	◖	Data on actual mode share for all trips is not collected on a frequent basis. New "big data" sources (e.g. cell phone data) might provide estimates, though accuracy by mode is unclear

Data Analysis & Availability	
Existing conditions	Mode share data are available through • American Community Survey (ACS) data for commuting[40] • Travel surveys[26] such as the Oregon Household Activity Survey (OHAS)[40] • Transit data[26] could be used to estimate the share of trips by that mode
Forecasts	Mode share can be forecasted through use of travel demand models[8]

3.26 Transit Supply

Definition: Transit supply refers to the average frequency of service, revenue hours, or miles of service provided.[24] Typically, transit supply is used to assess how well transit is serving the needs of a population and through doing so can identify gaps within the system.[8]

Spatial Scale: Facility, segment, zonal, district, and area-wide[24]

Current Examples of Usage:

Oregon Department of Transportation (ODOT): None identified.

Metro: Transit revenue hours and boarding rides per revenue hour are used by Metro in the 2018 RTP as a system-wide performance measure and Climate Smart Strategy implementation monitoring and reporting. The RTP also includes Transit Asset Management Targets that measure the condition of transit vehicles for use in service.[40, 39]

Oregon: None identified.

Nationally: The Florida Department of Transportation has guidance on three transit service measures: transit revenue miles, transit revenue miles between failures, and transit weekday span of service (number of hours).[16]

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	○	
Transportation Choice	◐	
Reliability and Efficiency	○	
Climate Leadership	◐	
Equitable Transportation	◐	Can be estimated for different population groups comparing RTP equity focus areas with areas outside RTP equity areas.
Mode		
Private motor vehicles	○	
Freight	○	
Transit	●	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	○	
Development Review	○	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Transit supply data are available through transit operations data[24]
Forecasts	Would be forecast using data on planned and programmed service

3.27 Transit Ridership

Definition: Transit ridership can be defined in a number of ways, including the average number of transit rides per person per year[57] and total ridership (e.g. boardings). Transit ridership can also be forecasted.[29] This measure can be used to measure the change in ridership after different transit-related projects and investments and can be used to identify inequitable access to transit through decreased ridership in geographic areas.

Spatial Scale: System, areawide.

Current Examples of Usage:

Oregon Department of Transportation (ODOT): Transit ridership is included in the ODOT Key Performance Measures (KPM) with the goal of expanding services to low-income populations.[57]

Metro: Transit ridership is used by Metro in the 2018 RTP to support the Congestion Management Process (CMP) monitoring and reporting.[40] It is measured as total daily boardings and boardings per revenue hour. Transit efficiency and ridership was used in the 2018 RTP as a system evaluation measure for addressing Goal 1 (Vibrant Communities), Goal 3 (Transportation Choices), and Goal 4 (Reliability and Efficiency).[39]

Oregon: None identified.

Nationally: Transit passenger trips and trips per revenue mile are used by the Florida Department of Transportation for system-wide reporting.[14]

	Applicability	**Notes/Explanation**
RTP Goal		
Shared Prosperity	○	
Transportation Choice	◖	
Reliability and Efficiency	◖	
Climate Leadership	◖	
Equitable Transportation	◖	
Mode		
Private motor vehicles	○	
Freight	○	
Transit	●	
Bicycles	○	
Pedestrians	○	
Planning Applicability		
TSP/Corridor	●	
Plan Amendment	○	
Development Review	○	
Performance Monitoring	●	

Data Analysis & Availability	
Existing conditions	Transit ridership data are available through TriMet, SMART, and C-TRAN performance reports[40]
Forecasts	Transit ridership can also be forecasted through use of a regional travel demand model by transit mode[39]

4 Conclusions

This review of measures presented a broad overview of 27 measures. The measures are organized into four categories:

- Measures that focus on travel time delay and congestion, including volume/capacity (v/c) ratio (commonly referred to as LOS), travel time reliability, and other measures of congestion;
- Measures of how and how much people are using the system, such as VMT, VHT, transit ridership, and mode share;
- Accessibility measures, which focus on what places or activities people or businesses can access; and
- Measures of the quality or amount of the system, which focus on the provision of facilities or service, such as MMLOS and transit supply.

Table 1 presents the assessment of how each measure supports five of the RTP goals, applies to different modes, and applies to different contexts. From this summary some patterns are made clear:

- Measures focusing on delay and congestion do not support the RTP goals related to climate leadership, equitable transportation, and transportation choices. This is partly because those measures do not apply well to bicycling and walking, and only marginally well to transit use. These measures are also not as useful in development review.
- Measures that focus on the use of the system do a better job at supporting the five RTP goals examined, though less so for equitable transportation. Beyond private motor vehicles, these measures are more easily applied to transit than the delay/congestion measures. Applicability to freight varies, as does applicability to active transportation modes. These measures are also not very easily applied to development review.
- The accessibility-based measures are best at supporting the RTP goals of equitable transportation and transportation choices and an adequate job addressing climate leadership. They do not, however, address the goal related to reliability and efficiency of the system. Overall, they are more multimodal than the other types of measures, except their limited application to freight. These measures are more easily applied to the development review process than the other categories.
- The measures assessing the amount or quality of the system overall do the poorest job of supporting the RTP goals examined. This is due, in part, to the fact that the amount and quality of the system is an interim step towards mobility. These measures tell us, for example, how much transit service is available or how many streets have adequate sidewalks, but they do not tell us whether people are using the system, nor who is using the system. These measures might be best viewed as inputs to improved mobility. They could be used to measure progress towards implementing a system that should help meet larger mobility goals.

The measures also vary with respect to the data and tools needed to use them in planning practice and in performance monitoring. Our current v/c measure, as well as other measures focused on delay and congestion, rely on a fairly robust traffic monitoring system that has developed over decades. The measures that focus more on people's travel and access, rather than motor vehicle movement on roads, face greater limitations with respect to data and tools. These measures may require some new investment in data collection and improvements in modeling and forecasting tools. Metro is already a leader nationally in demand modeling that incorporates land use and active transportation modes, so it is well positioned to make this transition. In addition, tools being developed for similar efforts in California and other states could be adapted. Finally, is it quickly becoming more feasible to collect multimodal data using passive sources (e.g. cell phones) and technology (e.g. sensors).

This overview of alternative mobility measures, while comprehensive, acts mainly as a starting point for further research and as a resource for the eventual update to the Regional Mobility Policy. Comprehensively measuring mobility is complex and this report suggests that there is no single measure that easily meets all objectives. Our existing volume-to-capacity standards are limited and, in order to meet the desired outcomes of the 2040 Growth Concept vision and Regional Transportation Plan, a more comprehensive framework of mobility measures is needed. Our current analysis tools are limited, though improving, in their ability to quantify the complex nature of mobility or the benefits of individual actions, such as compact urban form, timing traffic signals, providing financial incentives and civic infrastructure in centers, or building sidewalks and bike facilities. However, these actions can help improve mobility in the metropolitan area and support the identified RTP policy priorities of equity, safety, climate, and congestion, and goal of shared economic prosperity.

Through the review of the existing literature, we have identified other MPOs and state DOTs throughout the country that are making the shift towards more performance-based planning, measuring a broader set of outcomes, and using these outcomes to inform planning and investment decisions. Overall, there seems to be a consensus that additional measures and tools are needed to fully measure mobility, many of which are tools that have been used or are currently used by Metro, local governments in the region, and by ODOT. While the grouping of measures used may be different based on location, scale, and stage in the planning process, the underlying use of a variety of measures and tools offers a robust, multifaceted picture of mobility better suited to contemporary, multimodal transportation. In addition, as noted in the beginning of this report, mobility measures are just one part of measuring the overall quality or impact of the transportation system. They should be used alongside measures of safety and health, for example, to obtain a more comprehensive assessment of the system.

Table 1: Measures by type

	RTP Goal					**Mode**					**Planning Applicability**			
Measure	Shar. Prosp.	Transp. Choice	Reliability & Effic'y	Climate Leadership	Equit. Transp.	Priv. Motor Veh.	Freight	Transit	Bike	Ped	TSP/ Corridor	Plan Amendment	Devt. Review	Perf. Mon.
Delay/Congestion														
Travel Time Reliability (Planning and Buffer Travel Time Indexes)	●	◖	●	○	○	●	●	●	○	○	●	◖	○	●
Waiting Time	○	◖	○	○	◖	○	○	●	○	○	◖	○	○	◖
Recurring Delay/Non-Recurring Delay	●	○	●	○	○	●	●	●	○	○	●	○	○	●
Hours of Congestion/Duration of Congestion	◖	◖	●	○	○	●	●	◖	○	○	●	○	◖	●
Volume-to-Capacity Ratio (V/C) and Level of Service	◖	○	●	○	○	●	●	○	○	○	●	●	●	●
Congestion Extent	◖	○	●	○	○	●	●	◖	○	○	●	●	○	●
Queuing	◖	○	●	○	○	●	●	◖	○	○	●	●	●	●
Percent of Congested Traffic	◖	○	●	○	○	●	●	◖	○	○	●	●	○	●
Vehicle Hours of Delay (VHD)	●	○	●	○	○	●	●	◖	○	○	●	●	○	●
Use of the system														
Travel Time	●	◖	●	◖	○	●	●	●	◖	◖	●	◖	○	●
Vehicle Hours Traveled (VHT)	●	◖	●	◖	○	●	●	●	○	○	●	◖	○	●
Vehicle Miles Traveled (VMT)	●	◖	○	●	◖	●	●	◖	○	○	●	◖	◖	●
Person Hours of Travel (PHT)	◖	●	◖	◖	◖	●	○	●	◖	◖	●	◖	○	◖
Person Throughput	○	●	◖	◖	○	●	○	●	●	●	●	○	◖	◖
Trip Length Distributions	○	●	○	◖	◖	●	○	◖	◖	◖	●	◖	◖	◖
Mode Share	◖	●	◖	●	○	●	○	●	●	●	●	●	○	◖
Transit Ridership	○	◖	◖	◖	◖	○	○	●	○	○	●	○	○	●

	RTP Goal					Mode					Planning Applicability			
Measure	Shar. Prosp.	Transp. Choice	Reliability & Effic'y	Climate Leadership	Equit. Transp.	Priv. Motor Veh.	Freight	Transit	Bike	Ped	TSP/ Corridor	Plan Amendment	Devt. Review	Perf. Mon.
Accessibility														
Accessibility to Transit	○	◖	◖	◖	●	○	○	●	○	○	●	●	●	●
Accessibility to Employment	●	●	○	◖	●	●	○	●	●	●	●	●	●	◖
Accessibility to Destinations	◖	●	○	◖	●	●	○	●	●	●	●	●	●	●
Accessibility to Freight Terminals	●	○	○	○	○	○	●	○	○	○	●	●	○	○
Quality/Amount of the System														
Multimodal Level of Service (MMLOS)	◖	●	◖	◖	◖	●	◖	●	●	●	●	●	●	◖
Level of Traffic Stress (LTS)	○	◖	○	◖	◖	○	○	○	●	◖	●	◖	◖	◖
System Completeness	◖	●	◖	○	●	●	◖	●	●	●	●	●	●	◖
Bicycle/Pedestrian Network Directness/Connectivity	○	◖	○	◖	◖	○	○	○	●	●	●	●	◖	◖
Pedestrian Crossing Index	○	◖	○	○	○	○	○	○	○	●	●	●	◖	◖
Transit Supply	○	◖	○	◖	◖	○	○	●	○	○	●	○	○	●

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