Most Promising Mobility Measures: Methodologies & Preliminary Evaluations

October 2021

Introduction

Metro and the Oregon Department of Transportation (ODOT) are working together to update the regional mobility policy and related mobility measures for the Portland Metropolitan Area. The mobility policy guides the development of regional and local transportation plans and studies, and the evaluation of potential impacts of plan amendments and zoning changes on the transportation system.

The goal of this update is to better align the policy and measures with shared regional values, goals, and desired outcomes identified in Metro's Regional Transportation Plan (RTP) and 2040 Growth Concept as well as with local and state goals, and define expectations about mobility by travel mode, land use context, and roadway functional classification.

The updated policy will describe the region's desired mobility outcomes and more robustly and explicitly define mobility for transportation system users in the Portland area.

Metro has identified six key elements integral to achieving the region's desired mobility outcomes. These, along with a draft mobility definition, were developed with input from project stakeholders and through workshops with the Transportation Policy Alternatives Committee (TPAC) and Metro Technical Advisory Committee (MTAC).

Elements of mobility: Equity, Access, Efficiency, Safety, Options

> **Draft mobility definition:** People and businesses can safely, affordably, and efficiently reach the goods, services, places and opportunities they need to thrive by a variety of seamless and well-connected travel options and services that are welcoming, convenient, comfortable, and reliable.

The TPAC and MTAC followed the four-step process shown in **Figure 1** to narrow a list of 38 measures identified through a review of best practices to the 12 most promising. These 12 measures were advanced for further evaluation and testing through case studies.

The aim of this approach is to reveal the implications of different measures, allowing policymakers and practitioners to select the ones that will capture progress and areas for improvement most clearly.

Figure 1. Screening Process to Inform Selection of Most Promising Measures for Testing

1	2	3	4
• Identify potential measures related to policy elements *(completed in the Best Practices Memorandum)*	• Evaluate measures using screening criteria • Rank measures based on screening score	• Identify top scored measures for each policy element	• Further filter top scoring measures to identify most promising for testing
38 measures	**38 measures**	**17 measures**	**12 measures**

Table 1. Mobility Measures Being Evaluated and Tested

Current mobility policy measure	**V/C Ratio**	The ratio of traffic volume to the capacity of a roadway link or intersection during a specified analysis period.
Vehicle-focused measures*	**Duration of Congestion**	Hours of congestion (HOC) is the number of hours within a time period, most often within a weekday, where a facility's congestion target (such as v/c ratio or acceptable speed) is exceeded or not met.
	Queuing	The extent of vehicles queued on intersection approach lanes, including on and off ramps, during a specified analysis period (typically a peak hour).
	Throughput (Person and Goods)	Number of people (across modes), and/or amount of freight, traveling through a segment, facility, or specified point in one direction over a specified time period (typically a weekday peak period or 24 hours).
	Travel Speed	Average or a percentile speed between origin-destination pairs, during a specific time period.
	Travel Time	Average or a percentile time spent traveling between origin-destination pairs, during a specific time period.
*These measures impact travel by bus transit and may be able to evaluated for transit trips specifically, such as travel time and speed.	**Travel Time Reliability**	Measure of congestion severity that assesses on-time arrival and travel time variability caused by unexpected events, such as crashes, vehicle breakdowns, work zones, and inclement weather causing delay and stop-n-go conditions.
	VMT/Capita	Compares the number of miles traveled by motorists within a specified time period and study area to the number residents or employees in the area. VMT/capita can indicate how much people who live and work in a study area must drive to meet their obligations and daily needs.
Multimodal measures	**Access to Destinations/ Opportunity** (all modes)	The number of essential destinations within a certain travel time or distance, by different modes.
	Level of Traffic Stress (LTS) (bike and pedestrian)	Level of traffic stress (LTS) classifies points and segments on routes into different categories of stress ranging from 1 (low stress) to 4 (high stress) based on factors that correlate to the comfort and safety of the bicyclist or pedestrian using that facility.
	Multimodal Level of Service (MMLOS) (all modes)	MMLOS describes a group of performance measures that evaluate the quality and level of comfort of facilities for different travel modes based on factors that impact mobility from the perspectives of pedestrians, cyclists, and transit riders, respectively.
	Pedestrian Crossing Index (bike and pedestrian)	The percent of a corridor or roadway segment meeting the pedestrian crossing target spacing.
	System Completion (all modes)	The percent of planned facilities that are built within a specified network or on a specified corridor/roadway segment.

An overview of methodologies, data needs, and tools for these performance measures is included in the attached fact sheets (Attachment A) on each measure and the supplemental information in Attachment B.

In this Memorandum

This memorandum is designed as an easy reference to help stakeholders and policymakers understand each of the performance measures being evaluated, review the preliminary evaluation, and confirm what additional information is needed from the case studies to determine which performance measures are best suited for inclusion in the updated regional mobility policy.

This memo includes the following:

- Preliminary evaluation summary
- Conclusions and recommendations: What should advance to the draft mobility policy and what needs to be answered through the case studies?
- Fact sheets about each performance measure (Attachment A)
- An attachment (Attachment B) providing detailed information for each measure, documenting the preliminary evaluation

Evaluating the Potential Performance Measures

The performance measures were put through a preliminary evaluation based on the criteria that follow. The performance measures that passed these criteria will be further evaluated through the case study analysis.

To determine which performance measures to advance for further consideration, the study team needed to answer three major questions.

Question 1:
Which performance measures best support the region's desired mobility outcomes?

Question 2:
Which performance measures best meet the region's technical needs?

Question 3:
Which performance measures work best for different planning applications?

Question 1: Which performance measures best support the region's desired mobility outcomes?

Six key elements identified as integral to achieving the region's desired mobility outcomes were developed with input from project stakeholders and through workshops with the TPAC and MTAC in fall 2020.

Figure 3. Draft Mobility Policy Elements

EQUITY

Black, indigenous and people of color (BIPOC) community members; people with low incomes; youth; older adults; people living with disabilities; and other historically-marginalized and underserved community members experience equitable mobility.

ACCESS

People and businesses can conveniently and affordably reach the goods, services, places and opportunities they need to thrive.

EFFICIENCY

People and businesses efficiently use the public's investment in our transportation system to travel where they need to go.

RELIABILITY

People and businesses can count on the transportation system to travel where they need to go reliably and in a reasonable amount of time.

SAFETY

People are able to travel safely and comfortably and feel welcome.

OPTIONS

People and businesses can choose from a variety of seamless and well-connected travel modes and services that easily get them where they need to go.

Table 2: Mobility measure support of region's desired mobility outcomes

	Measure	Equity	Access	Efficiency	Reliability	Safety	Options
Current mobility policy measure	V/C Ratio	◖	N/A	◖	●	N/A	○
Vehicle-focused measures*	Duration of Congestion	◖	N/A	◖	●	N/A	○
	Queuing	N/A	N/A	◖	●	●	○
	Throughput (Person and Goods)	◖	◖	●	●	N/A	◖
	Travel Speed	◖	N/A	◖	●	◖	○
	Travel Time	◖	N/A	◖	●	N/A	○
	Travel Time Reliability	◖	N/A	N/A	●	N/A	○
	VMT/Capita	◖	●	●	N/A	●	●
Multimodal measures	Access to Destinations/Opportunity (all modes)	●	●	●	N/A	N/A	●
	LTS (bike and pedestrian)	●	●	N/A	N/A	●	●
	MMLOS (all modes)	●	●	N/A	N/A	●	●
	Pedestrian Crossing Index (bike and pedestrian)	●	●	●	N/A	●	●
	System Completion (all modes)	●	●	●	N/A	●	●

○ = Negative impacts ◖ = Somewhat supports ● = Supports N/A = No relationship

Summary:

- **Equity:** All measures that can be evaluated and compared for different geographic areas such as Equity Focus Areas (EFA) vs non-Equity Focus Areas can be used to advance equity through the planning and project prioritization process. This includes all the measures being evaluated, depending on how they are applied. Measures that further help plan and prioritize a multimodal system, not a system for people that own or travel in vehicles only, further enhance equity if still comparing outcomes for EFAs and non-EFAs
- **Multimodal measures:** Best suited to evaluating and enhancing people's access to destinations and opportunity, improving safety for all travelers and ensuring travel options are available.
- **Vehicle-focused measures:** The vehicle-focused measures are the only measures that address the mobility outcome related to reliability.
- **VMT/Capita:** A vehicle-focused measure that if used for planning and project prioritization has positive impacts on accessibility, efficiency, safety, and travel options.

See page 3 for a full description of the draft policy elements and Attachment B for additional details on the elevation.

*These measures impact travel by bus transit and may be able to evaluated for transit trips specifically, such as travel time and speed.

Question 2: Which performance measures best meet the region's technical needs? The performance measures were vetted against the following evaluation criteria developed based on TPAC and MTAC feedback in fall 2020. The evaluation criteria cover a wide variety of desires that may be addressed by a combination of measures. Each measure must be technically feasible (potentially with addition of new data or tools) and legally defensible. To narrow the focus of the case studies, Metro modeling and technical resource staff and the project team preliminarily assessed these criteria to determine what is known and unknown about how the measures will work.

Figure 4. Evaluation Criteria

1 Relationship to the mobility policy elements and ability to address multiple elements

- See Question 1 on pages 4-5

2 Technical Feasibility

- Is the performance measure reasonably simple to analyze?
- Is it easy for both the public and practitioners to understand?
- Does it rely on readily-available data and a proven analysis process?

3 Flexibility for intended planning applications and different contexts

- Can it be focused on people, goods, or both?
- Is it flexible enough to be used for different facility types such as throughways vs. arterials?
- Can it consider land use context?
- Can it be used for one or all intended applications (system planning, plan amendments and development review)?
- Can it be used at different scales to compare scenarios and alternatives?

4 Legal defensibility

- Are the measures able to be applied as a standard and legally defensible?
- Can they document incremental changes or impacts and be compared to a standard?

5 Current uses of the measures by ODOT, Metro, local governments and other states and metropolitan planning organizations (MPOs)

- Is the measure in use by other states, MPOs or jurisdictions?
- Is the measure already in use by ODOT?
- Is the measure already in use by Metro?

6 Ability to show impact or progress toward desired mobility elements

- Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?
- Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?

7 Supportive of planned land uses and compact urban form

- Does the measure help evaluate support for compact, urban form and planned land uses (including mixed-use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?
- Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?
- Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?

8 Leads to financially achievable solutions

- Does the measure allow solutions or mitigation measures, i.e., projects, services and programs that ODOT, Metro, cities, counties, and transit providers can afford to build, operate and maintain?

Table 3: Mobility measure ability to meet the region's technical needs

	Measure	Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
Current mobility policy measure	V/C Ratio	●	●	●	●	●	◖	○
Vehicle-focused measures*	Duration of Congestion	●	◖	●	●	●	◖	○
	Queuing	●	◖	●	●	●	◖	○
	Throughput (Person and Goods)	●	○	○	◖	●	◖	◖
	Travel Speed	●	◖	●	●	●	◖	○
	Travel Time	◖	○	○	●	●	◖	○
	Travel Time Reliability	◖	○	○	●	◖	◖	○
	VMT/Capita	●	◖	●	●	●	●	◖
Multimodal measures	Access/Opportunity (all modes)	●	●	◖	●	●	●	◖
	LTS (bike and pedestrian)	◖	●	◖	●	●	●	◖
	MMLOS (all modes)	◖	◖	○	●	◖	◖	◖
	Pedestrian Crossing Index (bike & ped)	◖	●	●	●	●	●	●
	System Completion (all modes)	●	●	◖	●	●	●	◖

○ = Does not meet need ◖ = Somewhat meets need ● = Meets need

*These measures impact travel by bus transit and may be able to evaluated for transit trips specifically, such as travel time and speed.

Summary:

The evaluation criteria cover a wide variety of desires that may be addressed by a combination of measures. Each measure must be technically feasible (potentially with addition of new data or tools) and legally defensible.

V/C Ratio: As the current measure, it meets all technical needs but has negative impacts on some of the desired mobility policy elements when applied in practice. Solutions that improve the v/c-ratio often have negative impacts on people walking, biking and accessing transit which are more efficient modes and necessary to support a compact, urban environment. Peak hour v/c-based standards are frequently a barrier to implementing planned land uses if the standard cannot be met and is implemented by local agencies during development review.

Legal Defensibility[1]: In evaluating the legal defensibility of a specific measure, two criteria were applied: 1) Can the measure be quantified so that a standard can be set, tied to a factual basis, and can it be applied objectively and consistently in most circumstances? 2) Once set as a standard or target, can the measure be used to describe incremental changes or impacts resulting from a proposed plan amendment?

1. Legal defensibility was considered through the lens of Oregon land use law, including Goal 2, Land Use, and Goal 12 Transportation. Goal 2 requires that decisions related to land use be founded on a factual basis. Goal 12, as implemented through the Transportation Planning Rule (TPR, OAR 660-012), requires coordinated land use and transportation planning and balancing land use and transportation goals to ensure that transportation plans reflect the system needed to implement land use plans. When a plan amendment is proposed, the TPR requires demonstrating that the proposed change would not degrade the performance of existing or planned transportation facilities, based on performance standards identified in the TSP or comprehensive plan. Historically in Oregon, performance standards have been based on vehicular mobility and system capacity. For state facilities, transportation system performance standards are adopted in the Oregon Highway Plan (OHP) and in the Regional Transportation Plan (RTP) and are quantified as volume to capacity (v/c) targets. For purposes of this evaluation, the Legal Defensibility criteria provide an indication of whether the measure can be a standard to determine a plan amendment's significant effect.

The following measures received poor evaluations for Legal Defensibility because they would be difficult to apply as a standard. These measures are also insensitive to specific land use changes (such as plan amendments) but can be good for use in broader corridor planning and when evaluating alternatives and trade-offs.

- **Throughput:** A standard cannot be set for throughput as it varies for the same facility based on congestion levels. At the system level, maximizing throughput is likely to result in increasing VMT and VMT/capita.
- **Travel Time:** Requires an origin and a destination to be defined making it difficult to set a standard. Travel time is calculated using distance and average speed and therefore average speed could be used to measure similar outcomes.
- **Travel Time Reliability:** Travel time reliability can be calculated for existing conditions, but it cannot be easily forecast. It calculates how significant non-recurring congestion is, such as from weather events and crashes, and is useful for identifying locations and areas where projects or actions can be identified to mitigate these types of events.
- **Multimodal Level of Service:** Difficult to set a standard as a standard for each mode can rarely be met at the same time given limited right-of-way. It produces counterintuitive results for the bicycle mode when comparing alternatives such as four-lane to three-lane conversions. It is also difficult to apply across an entire system due to the data requirements.

The following measures "somewhat meet needs" for Legal Defensibility as they can have an established standard but the measure is minimally or not impacted by the additions of trips of any mode. This is currently an important element in looking at how a plan amendment (land use change) impacts performance.

- Access to Destinations/Opportunity
- Level of Traffic Stress (LTS)
- System Completion

LTS received higher evaluation scores than MMLOS in several criteria: flexibility, legal defensibility, showing impact/progress, and supportiveness of land use. As discussed in ODOT's Analysis Procedures Manual (APM, see page A-17), LTS is recommended for use at the system-planning level and as a potential option for applications from refinement area planning, project development and development review. MMLOS is a more detailed evaluation tool better suited for project development and development review only.

Achievable Solutions: The vehicle focused measures received poor evaluations for achievable solutions as they require vehicle capacity enhancements to improve the metric which is typically achieved through additional roadways, additional travel lanes, and wider intersections. These are expensive improvements that frequently require right-of-way and property acquisition. The measures that lead toward less expensive solutions such as reducing peak hour vehicle volumes, reducing trip lengths through better land use planning, and increasing opportunities for trips to be completed by walking, biking, taking transit received medium evaluations as these improvements can also be expensive in constrained environments. Pedestrian Crossing Index received the only good evaluation as the addition of pedestrian crossings are relatively inexpensive and often do not require right-of-way.

Question 3: Which performance measures work best for different planning applications?

The graphic below summarizes the various planning applications where the mobility policy is applied. The current mobility policy measure (v/c ratio) is applied as a target during system planning and as a standard during plan amendments.

Figure 5. Applications of the Current Mobility Policy

Focusing in on the applications related to system planning and evaluating plan amendments, the project team looked at the measures' usability for the following specific applications:

System Planning	Plan Amendments
• Applying a Target to Identify Needs and Develop a Plan • Setting a Standard based on a Plan	• Show measurable impact • Identify mitigations if the standard is exceeded

Table 4. Mobility measure effectiveness for different planning applications

	Current mobility policy measure	Evaluating Outcomes for Equity Focus Areas	System Planning: Applying a Target to Identify Needs and Develop Plan	System Planning: Setting Standard based on Plan	Plan Amendments: Large-Scale/ Areawide: Show measurable impact (from added trips, any mode)	Plan Amendments: Large-Scale/ Areawide: Identify mitigations if standard exceeded	Plan Amendments: Small-Scale/Site-Specific: Show measurable impact (from added trips, any mode)	Plan Amendments: Small-Scale/Site-Specific: Identify mitigations if standard exceeded
	V/C Ratio	A	▌▌✚	▌▌✚	▌▌✚	▌▌✚	▌▌✚	▌▌✚
Vehicle-Focused	Duration of Congestion	A	▌▌✚	▌▌✚	Unknown*	Unknown*	Unknown*	Unknown*
Vehicle-Focused	Queuing		▌▌[1]✚	▌▌[1]✚	▌▌[1]✚	▌▌[1]✚	▌▌[1]✚	▌▌[1]✚
Vehicle-Focused	Throughput (Person/ Goods)	A	▌▌[3]✚[3]	No	▌▌[3]✚[3]			
Vehicle-Focused	Travel Speed	A	▌▌✚[6]	▌▌✚[6]	▌▌✚	▌▌✚[6]	Unknown*	Unknown*
Vehicle-Focused	Travel Time	A	▌▌✚	No	▌▌✚			
Vehicle-Focused	Travel Time Reliability	A	▌▌✚	▌▌✚	No[5]		No[5]	
Vehicle-Focused	VMT/Capita[11]	AB	▌▌✚	▌▌✚	▌▌✚	▌▌[2]✚[2]	Unknown*	Unknown*
Multimodal	Access to Destinations[11]	AB	▌▌✚	▌▌✚	▌▌[7]✚[7]		▌▌[7]✚[7]	
Multimodal	LTS	AB	✚	✚	✚[8]	✚[8]		
Multimodal	MMLOS	AB	✚[3]	No	▌▌[3]✚[3]			
Multimodal	Ped. Crossing Index	AB	✚	✚	✚[9]	✚	✚[9]	✚
Multimodal	System Completion	AB	▌▌✚	▌▌✚	✚[10]	✚	✚[10]	✚

▌▌=Thruway ✚=Arterial/Collector

*Need to test

A. Measure can be evaluated and compared for different geographic areas related to concentrations of disadvantaged populations and can be used to evaluate equity.

B. Measure relates to increased access to non-auto modes which are accessible to people without access to vehicles.

1. Off-ramps only
2. Mitigations would need to be changes in land use or significant travel demand management (TDM) measures
3. Difficult to set standards, best for corridor studies and comparing alternatives
4. Difficult to set standard as origin-destination based
5. Cannot be forecast and is not impacted by land use, impacted by non-recurring congestion such as from weather events and crashes
6. The target travel speed on arterials/collectors should have a maximum consistent with area context and the desired posted speed and a minimum thresholder for congestion
7. Land use changes would increase or decrease the number of destinations that are accessible but not how far the area of accessibility is
8. Only sensitive to large changes in volumes or looking at access to LTS routes
9. Can document impact on warrants for a protected crossing
10. Can document impact on signal warrants, and number of trips added to system by mode, and if they are impacting an incomplete mode, but difficult to calculate their impact or proportionate share
11. VMT/Capita and Access to Destinations are both measures related to the efficiency of the land use pattern and are impacted by land use changes more than transportation changes based on the current methodologies and models. VMT/capita is more useful for evaluating the transportation impacts of a land use change than Access to Destinations.

Conclusion/Recommendations

What measures do we preliminarily recommend and what do we need to learn from the case studies?

Based on the preliminary evaluation of measures, the following describes the potential measures still under consideration for including in the mobility policy for system planning and plan amendments. It also identifies questions to be further evaluated through the case studies.

Table 5. Potential measures still under consideration by application

Application	Measure[1]
System Planning • Apply as target in planning • Define the planned complete system • Set standard based on what the plan achieves	• Travel Speed » V/C and Queuing: Recommended to be used in tandem with travel speed, not as a standard except for off-ramp queuing, but to identify intersection needs and solutions to improve the corridor travel speed • Duration of Congestion (based on speed) • VMT/Capita (or per resident or per worker)[7] • Access to Destinations (by mode)[7] • Level of Traffic Stress (bikes and pedestrians) • Pedestrian Crossing Index • System Completion (define complete for each mode, including roads and intersections)
Plan Amendments • Determine if the amendment reduces VMT/ capita • Determine if amendment changes what's needed in the TSP (Does it change what may be considered the complete system in the area? If so, may need to apply the system planning measures.)	• VMT/Capita (or per resident or per worker)[2,3,4,5, 7] • System Completeness[6] • Queuing (off-ramps only)

1. Some measures only apply to the RTP, TSPs, or both

2. Increasing housing density in developed areas likely to reduce VMT/capita compared to new housing in undeveloped areas

3. Diversifying land uses and adding essential destinations in developed areas likely to reduce VMT/capita as goods and services and jobs are located closer to existing housing

4. Adding regional destinations in developed areas likely to increase VMT/capita unless mitigated with transit and TDM

5. Land use plans for undeveloped areas should have a target VMT/capita or VMT/worker encouraging mixed use and transit connectivity. Amendments to that plan should result in reduced VMT/capita unless mitigated

6. Increased trips of any mode does not impact System Completeness but could impact travel speed and queuing. This could be irrelevant if the auto system is complete with regard to number of lanes and turn lanes (exception for off-ramp queuing).

7. VMT/Capita and Access to Destinations are both measures related to the efficiency of the land use pattern and are impacted by land use changes more than transportation changes based on the current methodologies and models. VMT/capita is more useful for evaluating the transportation impacts of a land use change than Access to Destinations.

What we want to learn from the case studies

- How well does the measure help compare outcomes in Equity Focus Areas (EFAs) to other areas?
- How sensitive is the measure to changes in land use?
- How could measures that are not sensitive to land use changes be applied in plan amendments?
- Does Metro's Dynamic Traffic Assignment (DTA) model identify different needs than the travel demand model at the system level?
- Does the DTA model result in significantly different post-processed intersection volumes for use at the intersection level?

Attachment A: Mobility Measure Fact Sheets

Table of Contents

Current mobility policy measure

Vehicle-focused measures

Multimodal measures

Volume to Capacity (v/c) Ratio

The ratio of traffic volume to the capacity of a roadway link or intersection during a specified analysis period.

How is it calculated and is there a goal, standard or target?

It is calculated by dividing the traffic volumes during a 1-hour period, typically the peak hour of the day, by the capacity of the road or intersection.

Calculation of existing conditions is based on current traffic counts. Calculation of forecast conditions is based on future volumes generated through Metro's Regional Travel Demand Model and planned intersection or facility improvements.

Most jurisdictions have a standard that is based on the peak 15-minutes, peak hour, or peak 2-hours of the day during either an average month or a peak month. In the Metro area, ODOT's standards and the RTP standards range from 0.90 to 1.1. depending on the facility's functional classification and land use context.

What data and tools does it require?

Existing traffic volumes and/or forecast traffic volumes along with information about the road or intersection geometry and the signal timing required. The calculation is typically done using computer software.

What policy elements can it help measure?

EQUITY

EFFICIENCY

RELIABILITY

How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
●	●	●	●	●	◖	○

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

As the current measure, it meets all our technical objectives but has negative impacts on some of the desired mobility policy elements. Peak hour v/c-based standards are frequently a barrier to implementing planned land uses if the standard cannot be met and is implemented by local agencies during development review.

What are the best uses of the measure?

It works well as a performance target for identifying capacity limitations under existing and future conditions. This can be helpful when planning the system and determining the best way to address the capacity issue either by reducing demand, providing alternative routes or modal options, or by increasing capacity with additional lanes or changes in traffic control such as a signal.

Once there is a planned system that accounts for financial constraints, physical constraints, the roles of other modes in meeting travel demand, and demand management, it should not be applied as a regulatory standard as it becomes a barrier to planned land use.

What do we still need to learn about the measure?

Would the location and severity of forecast capacity limitations be different if we used a Dynamic Traffic Assignment (DTA) model to project future traffic volumes?

Duration of Congestion (Hours)

Hours of congestion (HOC) is the number of hours in a time period where a facility's congestion target (e.g., v/c ratio, average travel speed) is exceeded or not met. HOC measures the severity of recurring congestion.

How is it calculated and is there a goal, standard or target?

Variations of the measure and methodology rely on how the term "congestion" is defined. ODOT's APM Chapter 9 lists several potential measures that could be used to evaluate duration of congestion including:

- v/c ratio above 1.0
- Speed below an agreed-upon threshold
- Excess or unserved demand
- Queue on uninterrupted flow facility
- Annual Daily Traffic/Capacity (ADT/C) ratio

No standard or target has been used in the Metro Region for HOC.

What data and tools does it require?

The data needs depend on how "congested" is defined. See the v/c and travel speed fact sheets for further details related to those two potential measures for defining congestion.

What policy elements can it help measure?

EQUITY

EFFICIENCY

RELIABILITY

How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
●	◖	●	●	●	◖	○

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

This measure is helpful in that it does not focus solely on the most congested hour of the day and describes the available capacity of a roadway throughout the day. By identifying areas of sustained congestion instead of peak hour congestion, potential vehicular mitigations and improvements create less negative impacts on other modes sharing the roadway.

What are the best uses of the measure?

Hours of congestions is best used as a performance target and evaluation tool in system plans.

What do we still need to learn about the measure?

Is the location and severity of forecast congestion different using a speed-based definition for congestion versus v/c ratio?

Would the location and severity of forecast congestion be different if we used a Dynamic Traffic Assignment (DTA) model instead of the travel demand model to project future traffic volumes?

What definition of "congested" is best suited for use throughout the metro region and at different application scales?

Queuing

The extent of vehicles queued on intersection approach lanes, including on and off ramps, during a specified analysis period (typically a peak hour).

How is it calculated and is there a goal, standard or target?

It is calculated using microsimulation models (e.g. Synchro/SimTraffic) with intersection geometry and operational data, often reported as 95th percentile queue length which means the queue length only exceeds that 5 percent of the time for the reported period. Queuing can be calculated for existing conditions and can also be forecast for future conditions if there are projected or planned changes in volumes or intersection geometry.

The target for queuing is often set as the existing storage area. The queue storage area is the length of space for storing vehicles in a turn lane after the transition area. For a through lane, the storage area is the distance to the preceding intersection. At highway offramp terminals, it's the storage area up to the off-ramp deceleration area from the freeway.

What data and tools does it require?

Existing traffic volumes and/or forecast traffic volumes along with information about the road or intersection geometry and the signal timing is required. The calculation is typically done using computer software.

What policy elements can it help measure?

How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
●	◖	●	●	●	◖	○

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

Queuing provides an important intersection-level view for areas that are highly congested or experiencing safety issues.

What are the best uses of the measure?

Queuing is useful to evaluate transportation project alternatives and to evaluate access and safety concerns. It has not traditionally been a good broad-based metric for regional plans or local jurisdiction TSPs and plan amendments unless looking at the intersection level. Intersection level queuing analysis in system plans is typically focused where there is concern about the v/c ratio. High v/c ratios have a strong correlation to longer queues that could exceed storage capacity, which is a safety concern.

What do we still need to learn about the measure?

Would the location and severity of forecast storage limitations be different if we used a Dynamic Traffic Assignment (DTA) model to project future traffic volumes?

Fact Sheet

Throughput (Person and Goods)

Person throughput is the number of people, across modes, traveling through a segment, facility, or specified point in one direction over a specified time period (typically a weekday peak period or 24 hours). Goods throughput is the amount of freight carried through a segment, facility, or specific point in one direction over a specified time period (typically 24 hours). These measures indicate how efficiently a transportation facility serves passenger and/or freight travel.

How is it calculated and is there a goal, standard or target?

Person throughput and goods throughput are both calculated based on vehicle throughput, as described below.

Person throughput

Person throughput is typically calculated by multiplying vehicle throughput within a given time period by vehicle occupancy and can be calculated separately for different travel modes (such as auto, transit, bicycle, etc.). Seat utilization (for individual modes or across all modes) can provide a similar measure of efficiency on a corridor.

While vehicle occupancy for individual travel modes can be observed in the field, vehicle occupancy values are typically derived from regional data in household travel surveys, transit providers, and/or travel demand models. This means that person throughput forecasted using a travel demand model would reflect changes in mode share (for example, a shift from single-occupant vehicles to carpools) but not changes in vehicle occupancy (such as an increase in the average occupancy of a carpool).

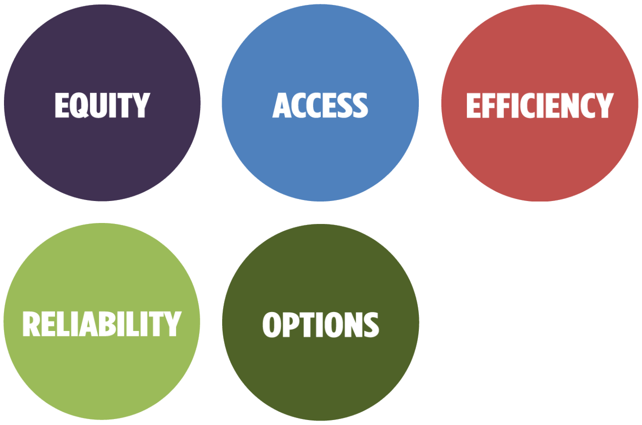
Goods throughput

Goods throughput is calculated by multiplying freight vehicle throughput by the value of goods carried on each freight vehicle. Freight vehicle throughput as a share of total vehicle throughput can be measured in the field or adapted from travel model inputs. Data on the value of goods carried by freight vehicles, however, is not readily available at a granular level. As a result, local and regional freight studies often rely on related performance measures. Freight vehicle throughput can be used to evaluate goods throughput at a specific location. At a regional or corridor level, the ratio of commercial vehicle VMT to total VMT can be used to indicate the relative importance of freight to passenger travel. Metro's travel demand model can evaluate commercial vehicle VMT/total VMT and includes a freight model that outputs existing and forecasted truck trips. Metro's dynamic traffic assignment model or a microsimulation model can be used to assess changes in vehicle throughput under forecasted future conditions, which would affect freight throughput.

What data and tools does it require?

Both person throughput and goods throughput are based on a calculation of vehicle throughput at a specific time and location on a transportation facility. Vehicle throughput is measured for specific modes in a specified location and direction on a study segment (e.g., "northbound at mile marker 37 on State Highway 6") and can be reported for an entire facility or by travel lane. It can be measured in the field or using big data (for the existing conditions) or forecasted (for existing and future conditions) using Metro's travel demand model. To reflect the effects of traffic congestion on vehicle throughput, travel model outputs should be post-processed using Metro's dynamic traffic assignment model or a microsimulation model (such as Synchro/SimTraffic) that reflects anticipated future conditions. Converting vehicle throughput to person or goods throughput requires additional information about vehicle occupancy and commodity loads.

What policy elements can it help measure?



How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
●	○	○	◖	●	◖	◖

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

Person and goods throughput are helpful for comparing alternatives and evaluating before/after conditions, with the ability to incorporate all modes as available data allows. However, a standard cannot be set for throughput as it varies for the same facility based on congestion levels and at the system level, maximizing throughput is likely to result in increasing VMT and VMT/capita.

What are the best uses of the measure?

Person throughput can be used for corridor studies, particularly to show how mode shifting or investments in transit or high-occupancy vehicle infrastructure can be an effective way to increase mobility. Evaluating person throughput by all modes before and after transportation system changes, such as a road diet, bus-only lane conversion, or light rail expansion, can inform the selection of project alternatives.

Goods throughput is difficult to measure directly, since data on the volume and value of commodities is limited. Freight vehicle throughput can be used as a proxy at the corridor level, and the share of commercial vehicle VMT/total VMT can be evaluated at the regional and sub-area levels. These metrics could be used to assess the potential effects of changes to corridor operations and transportation system investments on freight travel.

What do we still need to learn about the measure?

What data are readily available to access goods throughput? *(This measure is not recommended for further testing.* *See p. 8.)*

Travel Speed

Average or a percentile speed for a network segment or between key origin-destination pairs, during a specific time period.

How is it calculated and is there a goal, standard or target?

Travel speed can be directly measured on the ground, assessed through probe data, or modeled via a travel demand model or dynamic traffic assignment (DTA) model.

ODOT sets a congestion threshold based on travel speed of 75 percent or lower of the roadway's free flow speed.

What data and tools does it require?

For measured travel speed in large areas, probe data such as INRIX, HERE, and Wejo are commonly used to directly provide travel time and speed output. ODOT utilized HERE data for the 2018 Portland Region Traffic Performance Report (PRTPR) and 2020 Statewide Congestion Overview.

For modeled travel speed, Metro's travel demand model and dynamic traffic assignment (DTA) model generate outputs that include travel speeds by segment by hour.

What policy elements can it help measure?

EQUITY

EFFICIENCY

RELIABILITY

SAFETY

How well does it meet our needs?

Travel speed can be used as a proxy measure for both congestion and for safety, depending on the targets set. When considering congestion, speeds close to free flow speed speeds are favorable. In uncongested areas or times of day, travel speed above the posted speed can have adverse effects on safety. Travel speed is also a measure easily understood by the public with the rise of apps like Google Maps.

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
●	◖	●	●	●	◖	○

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

What are the best uses of the measure?

Travel speed is growing in its use since the public is now familiar with Google maps and similar sites reporting this type of data. Big data providers are also making this a much more available existing conditions dataset. If Metro or others define speed thresholds for different roadway types, transit facilities, freight routes, etc., this could be an easily applied performance target. In practice, a realistic arterial corridor speed considering expected delay at traffic signals, can appear low to the public, who might argue that a defined speed threshold is too low.

Travel speed is already in use as a performance target. ODOT uses travel speed to determine if a freeway segment is congested. For ODOT's PRTPR, the congestion threshold was defined as travel speed 75 percent or lower of the roadway's free flow speed. For the freeway network, this is generally equivalent to speeds of 45 miles per hour or lower. For system plans and plan amendments, travel speed may be used as an evaluation tool or as a performance monitoring measure.

What do we still need to learn about the measure?

Would locations forecast for travel speeds outside of a desirable range be different if we used a Dynamic Traffic Assignment (DTA) model instead of the regional travel demand model?

How sensitive is modeled travel speed to land use or transportation system changes?

Travel Time

Average or a percentile time spent traveling between key origin-destination pairs, during a specific time period.

How is it calculated and is there a goal, standard or target?

Travel time can be measured on the ground, assessed through probe data, or modeled via a travel demand model or dynamic traffic assignment (DTA) model. The reported statistic for travel speed could be the average, percentile, free-flow, etc.

For the RTP, no target was set for travel time, but the desired direction is typically to maintain or decrease travel times for passenger vehicle, bicycle, transit, and truck modes in 2040 compared to 2015 levels.

What data and tools does it require?

For measured travel times in large areas, probe data such as INRIX, HERE, and Wejo are commonly used to directly provide travel time and speed output. ODOT utilized HERE data for the 2018 Portland Region Traffic Performance Report (PRTPR) and 2020 Statewide Congestion Overview. Measured datasets may be costly for local agencies if they do not currently collect this data or cannot utilize ODOT's data for a project.

For modeled travel speed, Metro's travel demand model or dynamic traffic assignment (DTA) model generate outputs that include vehicular travel times for designated origin-destination pairs. Only the travel demand model is able provide other modal travel times for bicycle, transit, and freight modes.

What policy elements can it help measure?

EQUITY

EFFICIENCY

RELIABILITY

How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
◖	○	○	●	●	◖	○

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

Travel time is an easily understood measure, especially when comparing capacity-based or travel demand management alternatives. However, it requires an origin and a destination to be defined making it difficult to set a standard. Travel time is calculated using distance and average speed and therefore using an average speed rather than travel time is more easily applied to a variety of facilities.

What are the best uses of the measure?

Travel demand models have historically been developed with vehicles in mind first, so bike and transit travel times via the travel demand model may not align as closely to field conditions as vehicular travel times. With this in mind, travel time and travel time reliability measures are most relevant for autos, freight, and transit.

The measure is difficult to use for setting a target or standard because it requires a defined origin and destination pair. It is best applied for comparing alternatives and the relative change in travel time for the study area corridor between existing and future years and for different treatments.

What do we still need to learn about the measure?

Would locations forecast for travel times outside of a desirable range be different if we used a Dynamic Traffic Assignment (DTA) model instead of the regional travel demand model?

How sensitive is modeled travel time to land use or transportation system changes? *(This measure is not recommended for further testing.* *See p. 8.)*

Fact Sheet

Travel Time Reliability

Travel time reliability measures, such as Planning Time Index and Buffer Travel Time Index, are indicators of congestion severity that assess probability of on-time arrival and travel time variability.

Planning Time Index is the ratio of the 95th percentile travel time to the free-flow travel time. Buffer Travel Time Index is the ratio of the 95th percentile travel time to the average travel time. These indices measure variation in travel time caused by unexpected events, such as crashes, vehicle breakdowns, work zones, and inclement weather causing delay and stop-n-go conditions.

How is it calculated and is there a goal, standard or target?

Travel time reliability measures utilize travel time datasets that can be measured on the ground, specifically assessable through probe data. To determine a percentile travel time dataset that cover non-recurring congestion, the measured data ideally covers a longer time period, such as a year.

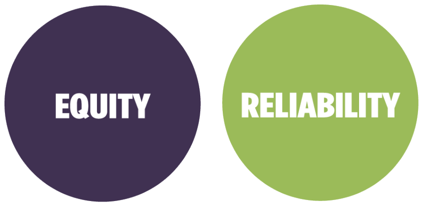
PTI is the 95th percentile travel time divided by the free-flow travel time. Buffer Travel Time Index is the 95th percentile travel time divided by the average travel time.

What data and tools does it require?

For measured travel times in large areas, probe data such as INRIX, HERE, and Wejo are commonly used to directly provide travel time and speed output or full probe datasets.

Based on discussions with Metro staff, travel time reliability metrics are not forecastable using existing regional models. Although the dynamic traffic assignment (DTA) model has a temporal aspect, it does not create percentile travel times that could be incorporated into travel time reliability metrics because the model is representative of recurring congestion only. The tools and methodologies that are available for forecasting travel time reliability metrics are focused on limited-access highways and freeways only.

What policy elements can it help measure?



How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
◖	○	○	●	◖	◖	○

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

Travel time reliability measures capture the variability of congestion over a longer period of time, most commonly over a year. Because of this, the congestion described by travel time reliability measures encapsulates both recurring congestion (such as what peak hour v/c conveys) as well as non-recurring congestion that cannot be predicted (due to crashes, weather, road work, etc). Travel time reliability cannot be easily forecast. The best forecasts are derived from statistical relationships of how planning and/or buffer time relate to congestion or alternative routes. Simulation-based modeling of this is expensive and impractical for many types of studies. Although reliability is very important to the public, the indexes for reporting it are difficult for the public to understand and relate to.

What are the best uses of the measure?

Travel time reliability measures are valuable for agencies like DOTs and transit operators as it does a good job of succinctly summarizing "worst case conditions" for operations. It is most beneficial for evaluating existing conditions as it can be difficult to forecast. Existing conditions can show where there are large degrees of unreliability related to non-recurring events such as crashes and weather events. It is a good measure for identifying locations and areas where projects or actions can be identified to mitigate these types of events.

What do we still need to learn about the measure?

Do travel time reliability measures highlight different needs for system planning under existing conditions than other congestion-based performance measures? *(This measure is not recommended for further testing.* *See p. 8.)*

Fact Sheet

Vehicle Miles Traveled (VMT) per Capita

Vehicle miles traveled (VMT) is the number of miles traveled by motorists within a specified time period and study area. VMT/capita compares this number to a defined population, such as total number of residents or employees within a specific study area.

VMT/capita can be calculated to include or exclude different types of trips, such as trips that start or end within the study area, commute trips, freight and delivery trips, etc. VMT/capita can indicate how much people who live and work in a study area must drive to meet their obligations and daily needs.

How is it calculated and is there a goal, standard or target?

VMT/capita can be measured in several ways depending on the application. At the Regional Transportation Plan (RTP) and Transportation System Plan (TSP) planning levels, VMT/capita can be used to evaluate how efficiently a transportation system serves its users. Appropriate metrics include (* indicates a measure used in the 2018 RTP):

- **Total VMT/capita***, which measures all vehicle trips on the network within the region or analysis area, divided by the service population. When calculated using a travel model or multi-zone big data analysis, pass-through trips (such as trips on the Interstate system that do not start or end in the Metro Region) can be included or excluded. This metric is most suitable for planning efforts where it is important to capture potential changes in visitor and commercial travel.
- **VMT/resident or VMT/household**, which measures the rate of vehicle travel per person living in the plan area. This can be calculated using a travel model by dividing VMT from all home-based trips by the number of residents or households in the planning area. This is appropriate for plans and development projects where strategies are being considered that would reduce household reliance on auto travel. However, it excludes commercial and non-home-based travel, and therefore may underestimate the VMT associated with home deliveries and trips made by residents while away from home.
- **VMT/worker**, which measures work-related VMT/worker. This is appropriate for plans and development projects where strategies are being considered that would reduce auto commuting.
- **VMT exposure/capita**, which measures Total VMT/capita or Total VMT by speed bin/capita within a defined area, including pass-through trips. This is suitable for analysis in areas where traffic safety and air quality are concerns, particularly for residents, students, or employees whose VMT makes up only a small portion of the total VMT in the area.

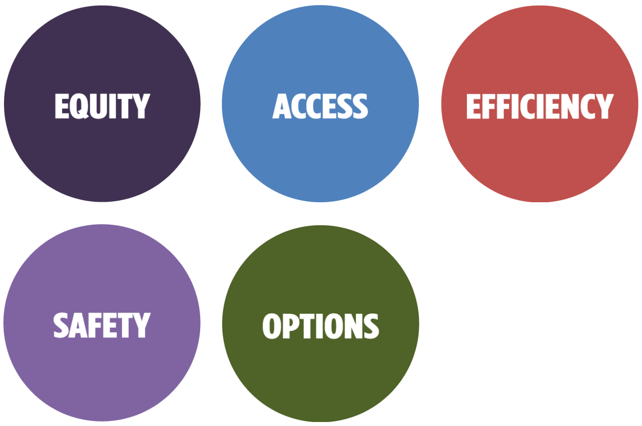
At the facility or corridor level, vehicle miles traveled can be compared to person miles traveled **(PMT/VMT)** to evaluate project alternatives that would expand transit service and/or roadway capacity.

Since most vehicles are powered by internal combustion engines, GHG emissions tend to rise and fall with VMT; however, this relationship is likely to weaken as electric vehicles become more common.

What data and tools does it require?

Metro's travel demand model can be used to evaluated existing and forecast future VMT/capita measures.

What policy elements can it help measure?



How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
●	◖	●	●	●	●	◖

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

VMT/capita measures are being used more and more throughout the country, with agencies in California setting standards around the measure for new development.

What are the best uses of the measure?

For RTPs, TSPs, and transportation infrastructure programs, VMT per capita is the preferred way to evaluate VMT as a transportation planning metric as it is not skewed by population or employment growth and helps support land use and transportation strategies that reduce household reliance on auto travel. In undeveloped areas, it can be used to compare land use and transportation scenarios. It can have a target VMT/capita or per worker to encourage mixed land use and transit connectivity.

To evaluate plan amendments, VMT/capita at the sub-area level can be used to evaluate if the land use change increases or decreases the VMT/capita for the subarea. In developed areas, plan amendments that increase densities and diversify land use are likely to reduce VMT/capita and increasing housing density in a developed area is likely to result in less VMT/capita compared to new housing in an undeveloped area. However, adding regional destinations in developed areas or major job centers is likely to increase VMT/capita unless mitigated with transit and TDM.

What do we still need to learn about the measure?

What is the existing and forecasted VMT/capita for the region and each jurisdiction within Metro's Planning Area? Do approved plan alternatives meet the 5% VMT/capita reduction target identified in Oregon's Transportation Planning Rule?

At what scale of change (in terms of land use density and diversity) does a sub-area plan show differences in forecasted VMT/capita?

For multi-modal corridors, how different must plan alternatives be to shift forecasted PMT/VMT?

Access to Destinations/Opportunity

The number of essential destinations within a certain travel time or distance, by different modes. Metro's 2018 RTP defines accessibility as "the ability to reach desired goods, services, activities and destinations with relative ease, within a reasonable time, at a reasonable cost and with reasonable choices... Locations that can be accessed by many people using a variety of modes of transportation generally have a high degree of accessibility."

How is it calculated and is there a goal, standard or target?

Access to destinations is typically modeled in terms of the number of destinations accessible from a single origin point within a defined travel time at a defined time of day, using Metro's travel demand model. In the 2018 RTP, Metro calculated a weighted average of the number of community places reached from different locations in the planning area by different travel modes (automobile, transit, bicycle, and walking) in a given travel time window for the entire region, equity focus areas, and non-equity focus areas. The travel times used to determine access by mode were:

- 20 minutes by auto (including access and egress times)
- 30 minutes by transit (including access and egress times)
- 20 minutes by bike
- 20 minutes by walking

Defining key destinations and opportunities is essential to evaluating access to destinations and opportunity in a meaningful way. Access to jobs is one component of access to opportunities, which can also include access to destinations that provide education and training. Community destinations are typically understood as places where people can access key services and meet their daily needs. Typically, they include public agency offices, healthcare providers, libraries, community centers, schools, places of worship, and grocery stores and other essential shopping destinations; they can also be defined more narrowly or broadly depending on the community of focus. For example, when evaluating how well members of an immigrant community can access destinations and opportunities, emphasis could be placed on destinations that are culturally relevant and on jobs in sectors where community members are most likely to work.

Specific targets were not set through the RTP, although a trend of increased access is the goal over time.

What data and tools does it require?

To evaluate existing conditions for access to destinations and opportunities, a GIS dataset is first created that specifies how many destinations of each defined type is located in each TAZ. A travel demand model can then determine which TAZs can be reached from a study area within the defined travel times by mode and by time of day. The cumulative destinations for those TAZs within the modal travel sheds are then reported for the study area, which can range in size from a single TAZ to the whole region. For future scenarios, impacts to modal travel sheds and the destinations that can be reached from the study area can either be modeled using the travel demand model or estimated based on project characteristics.

What policy elements can it help measure?

EQUITY

ACCESS

EFFICIENCY

OPTIONS

How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
●	●	◖	●	●	●	◖

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

Access is an important part of mobility that is not often accounted for in historic mobility measures. Through the last RTP update process, Metro modeling staff have methodologies in place for determining access to destinations. It could have a performance target but would be challenging to have a standard as it’s a measure about land use more than transportation. It is not impacted by changes in number of trips by any mode which makes looking at the proportionality of a transportation improvement for a plan amendment difficult.

What are the best uses of the measure?

This measure is suited to comparing alternative land use and/or transportation scenarios that would increase jobs and/or housing or that would expand multimodal transportation options and increase the number of locations that can be reached within 20-30 minutes depending on the mode of travel.

What do we still need to learn about the measure?

How sensitive is the measure to land use plan changes? Can it demonstrate increases in accessibility through additional accessible destinations or show a reduction resulting in increased travel times?

Level of Traffic Stress

Classifies points and segments on routes into different categories of stress ranging from 1 (low) to 4 (high) based on factors that correlate to the comfort and safety of the bicyclist or pedestrian using that facility.

How is it calculated and is there a goal, standard or target?

LTS can be calculated for bicyclists or pedestrians, as described below:

Bicycle Level of Traffic Stress

Nationally, there are several methodologies used to calculate bicycle level of traffic stress (BLTS). ODOT's methodology is outlined in the APM and utilizes matrices that assign a BLTS value based on facility characteristics. Some matrices use average daily traffic (ADT) as a factor and can be forecast based on future volumes. Other matrices do not use ADT as a factor and do not change between an existing conditions analysis and a future no-build analysis. Here is an example BLTS matrix for a bike lane facility adjacent to a parking lane:

BLTS Criteria for Segment with Bike Lane and Adjacent Parking Lane

Prevailing or Posted Speed	1 Lane Per Direction			≥ 2 lanes per direction	
	≥ 15' bike lane + parking	14'–14.5' bike lane + parking	≤ 13' bike lane + parking or frequent blockage*	≥ 15' bike lane + parking	≤ 14.5' bike lane + parking or frequent blockage*
<25 mph	BLTS 1	BLTS 2	BLTS 3	BLTS 2	BLTS 3
30 mph	BLTS 1	BLTS 2	BLTS 3	BLTS 2	BLTS 3
35 mph	BLTS 2	BLTS 3	BLTS 3	BLTS 3	BLTS 3
≥ 40 mph	BLTS 2	BLTS 4	BLTS 4	BLTS 3	BLTS 4

*Typically occurs in urban areas (i.e., delivery trucks, parking maneuvers, stopped buses).

Pedestrian Level of Traffic Stress

ODOT's methodology for pedestrian level of traffic stress (PLTS) utilizes matrices based on key facility characteristics, differing from the BLTS matrices based on facility type. For segment-level PLTS evaluations, four characteristic matrices are used to consider PLTS values, and the larger value is assigned to the segment. Here is an example matrix for PLTS based on sidewalk condition:

PLTS Based on Sidewalk Conditions[1,3]

Actual/Effective Sidewalk Width (ft)[2]		Sidewalk Condition				
		Good	Fair	Poor	Very Poor	No Sidewalk
Actual	<4	PLTS 4	PLTS 4	PLTS 4	PLTS 4	PLTS 4
	≥ 4 to ≥ 5	PLTS 3	PLTS 3	PLTS 3	PLTS 4	PLTS 4
	≥ 5	PLTS 2	PLTS 2	PLTS 2	PLTS 4	PLTS 4
Effective	≥ 6[4]	PLTS 1	PLTS 1	PLTS 2	PLTS 3	PLTS 4

1. Can include other facilities, such as walkways and shared-used paths.

2. Effective width is the available/usable area for pedestrians free of obstructions. Does not include areas occupied by storefronts or curbside features.

3. Consider increasing PLTS one level higher (max PLTS 4) for segments that do not have illumination. Darkness requires more awareness, especially if sidewalk is in fair or worse condition.

4. Effective width should be proportional to volume, as higher-volume sidewalks should be wider than the base six feet. Use a minimum PLTS 2 for higher-volume sidewalks that are not proportional (include documentation).

In Oregon, the target for a low-stress facility is often LTS 2 but may be dropped to LTS 1 if the land use context supports major bicycle and pedestrian generators like schools, downtown cores, retirement centers, and transit stops. Typically not all facilities in a network are targeted as low-stress facilities.

What data and tools does it require?

The calculation is typically done using computer software such as ArcGIS or Microsoft Excel and requires existing traffic volumes and/or forecast traffic volumes, roadway and intersection characteristic information, ideally at the link-level.

What policy elements can it help measure?

EQUITY

ACCESS

SAFETY

OPTIONS

How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
◖	●	◖	●	●	●	◖

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

LTS is a well-used measure in Oregon system plans, but data is not always readily available. It is not impacted by changes in number of trips by any mode which makes looking at the proportionality of a transportation improvement for a plan amendment difficult.

What are the best uses of the measure?

It works well as an evaluation tool for identifying gaps and deficiencies under existing conditions and for planning a network of connected a low-stress pedestrian and bicycle facilities.

It is not sensitive to land use changes and changes to trip volumes.

What do we still need to learn about the measure?

Would system planning outcomes be impacted if LTS is set as a target or if there was a target percentage of the network or destinations that needed to be served by low-stress facilities?

Multimodal Level of Service (MMLOS)

MMLOS describes a group of performance measures that evaluate the quality and level of comfort of facilities for different travel modes based on factors that impact mobility from the perspectives of pedestrians, cyclists, and transit riders, respectively. It is intended to provide a parallel to automobile LOS at intersections.

How is it calculated and is there a goal, standard or target?

Multiple approaches to evaluating MMLOS have been tested and applied around the US. Typically, MMLOS measures are used to evaluate transportation project alternatives that would affect conditions for people walking, bicycling, or taking transit.

The best-known MMLOS methodology was developed for the Transportation Research Board's Highway Capacity Manual (HCM 2010) and includes performance measures at the street segment and intersection level for vehicle, transit, bike, and pedestrian modes separately. ODOT has adapted both qualitative and quantitative versions of the HCM 2010 MMLOS methodology:

- **Quantitative MMLOS methodologies:** Adaptation of HCM 2010 methodologies. Best applied at the corridor or facility level where alternatives are defined in detail.
- **Qualitative Multimodal Assessment (QMA) methodology:** Adaptation of ODOT's quantitative MMLOS methodologies. This is best applied at the TSP level where alternatives are not defined in detail and/or data are limited.

ODOT has developed Excel-based calculator tools to streamline analysis for its quantitative methodology – see **Exhibit 14-30** from the ODOT APM.

Many other methods for calculating MMLOS have been developed, generally by and for individual agencies and jurisdictions.

What data and tools does it require?

The calculation is typically done using computer software such as ArcGIS or Microsoft Excel and requires existing traffic volumes and/or forecast traffic volumes, roadway and intersection characteristic information, ideally at the link-level.

What policy elements can it help measure?

EQUITY

ACCESS

SAFETY

OPTIONS

How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
◖	◖	○	●	◖	◖	◖

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

MMLOS provides detailed evaluations of quality of service for different travel modes, in addition to the more widely used vehicular LOS metric. It is difficult to set a standard for MMLOS as a standard for each mode can rarely be met at the same time given limited right-of-way.

What are the best uses of the measure?

Regardless of which methodology is applied, quantitative MMLOS performance measures require substantial amounts of data on pedestrian and bicycle facilities; since these data are not consistently available at a regional level, MMLOS is most suited to corridor studies where field data can be collected and where differences between alternatives may not be captured by other bike and pedestrian measures such as Level of Traffic Stress.

While ODOT's qualitative MMLOS performance measure requires less data than quantitative measures and therefore can be applied at a larger scale of analysis, it overlaps substantially with system completeness performance measures. At the segment level, pedestrian and bicycle MMLOS scores evaluate many of the same variables as PLTS and BLTS, which can be easier and more intuitive to evaluate using widely collected data.

One challenge to applying MMLOS is that pedestrian and bicycle segment LOS are heavily influenced by the volume of adjacent vehicle traffic. Substantial improvements to pedestrian and bicycle infrastructure may not produce meaningful changes to the pedestrian and bicycle LOS scores if they are adjacent to high volume and high-speed roadways. Additionally, some applications of MMLOS have counterintuitive results when comparing 3-lane and 5-lane cross-sections due to the measure being highly impacted by the volumes in the lane adjacent to the bike lane only.

Although MMLOS is not suited to a standard for system planning, it is applied by some local agencies in development review to quantify impacts to each mode that can then be mitigated with improvements to any mode.

What do we still need to learn about the measure?

MMLOS evaluates many of the same variables that are evaluated using the system completeness and bicycle/pedestrian level of traffic stress performance measures. Although MMLOS can be helpful for reviewing alternatives, the more complex and detailed evaluation process make it a less desirable measure for system planning and large-scale plan amendments. *(This measure is not recommended for further testing.* *See p. 8.)*

Multimodal Analysis Tool Applications

Increasing Detail →

Increasing Project Complexity ↓

	Qualitative Multimodal Assessment (QMA)	Level of Traffic Stress (LTS)[1]	Multimodal Level of Service (MMLOS)
Regional Transportation Plan (RTP)	○	○	
Transportation System Plan (TSP)	●	●	
Facility Plan/ Interchange Area Management Plan (IAMP)	○	○	●
Project Development		○	●
Development Review		○	●

● = Preferred Methodology ○ = Methodology Can Also Be Used

1. Use of LTS for project development and development review should be limited to screening-based analysis to quickly identify existing and future needs.

Fact Sheet

Pedestrian Crossing Index

The percent of a corridor or roadway segment meeting the pedestrian crossing target spacing.

How is it calculated and is there a goal, standard or target?

How is it calculated and is there a goal, standard or target?

ODOT recently conducted a project to begin to include this measure in their annual key performance measures report. The ODOT methodology includes the following steps:

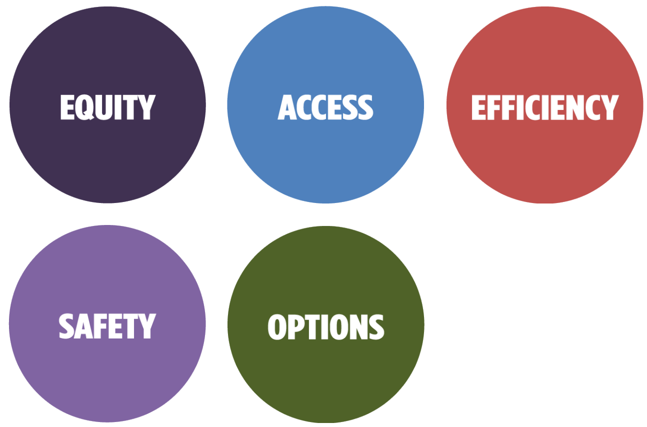
1. Identify the corridors to be included in the analysis
2. Identify the marked crossings, including crossings with and without ADA ramps, along each corridor and locate marked crossings.
3. Create a buffer area around each marked crossings equivalent to the target maximum crossing spacing.
4. Calculate the length of corridor that is covered by the marked crossing buffer area.
5. Summarize the length and calculate the percentage of each corridor or all corridors that are covered by the marked crossing buffer area.

$$\textit{Percent bicycle and pedestrian corridors meeting target crossing spacing} = \frac{\textit{Center Lane Miles Covered by Marked Crossing Buffer Area}}{\textit{Center Lane Miles}}$$

What data and tools does it require?

This measure relies on ArcGIS or similar computer software, with the methodology applied at the facility level. The needed data includes roadway centerlines and locations of marked crossings. Open Streetmap includes marked crossings that could be used but it is unknown how accurate the data is.

What policy elements can it help measure?



How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
◖	●	●	●	●	●	●

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

Sufficient pedestrian crossing locations is a major barrier for pedestrian connectivity, accessibility, and mobility. This measure can provide a clear means to evaluate needs and determine low-cost projects.

What are the best uses of the measure?

This is a relatively new measure being used by ODOT that may be used as a target to identify needs for additional crossings and as an evaluation tool in system plans and plan amendments. This is a good metric to identify crossing gaps in corridor plans. For transportation planning, the existing conditions and future no-build conditions will be the same although the land use could change the need for crossings if the target crossing spacing is tied to land use.

Although this measure is not impacted by additional vehicle traffic or bicycle and pedestrian crossing movements, this data can be used to look at if and what type of crossing treatment is needed.

What do we still need to learn about the measure?

What is the best way to set crossing spacing targets?

Would this measure have influenced plan or project identified crossing needs and locations?

System Completion

The percent of planned facilities that are built within a specified network or on a specified corridor/roadway segment.

How is it calculated and is there a goal, standard or target?

System completion measures for the different modes may include:

- **Pedestrian**
  - » Built facilities compared to Regional Pedestrian Network
  - » Built facilities compared to a Low-Stress Pedestrian Network (not currently defined)
- **Bicycle**
  - » Built facilities compared to Regional Bicycle Network
  - » Built facilities compared to a Low-Stress Bicycle Network (not currently defined)
- **Transit**
  - » Built facilities compared to Regional Networks (pedestrian, bike, and trail) within a walking distance to transit. Walking distance to transit was defined as:
    - Within 1/2-mile from light rail stops
    - Within 1/3-mile from streetcar stops, and
    - Within 1/4-mile from bus stops for existing and planned stops.
- **Roadway**
  - » Built lanes compared to lanes for roadway classification cross-section.
  - » Intersection density compared to RTP recommended spacings.
  - » Built turn lanes compared to plan (not currently defined but TSPs and corridor plans could define areas where turn lanes are desirable and where they are not)
- **TSMO**
  - » Built ITS/communication network compared to planned network.
- **TDM Services**
  - » Provided services compared to planned services.

A threshold or target is not established for the region, but the goal is for an increasing percent complete trend over time. Percent complete can be a difficult measure because the planned system does change as agencies and jurisdictions refine their TSPs and other plans to reflect growth, development/redevelopment, or other changes.

What data and tools does it require?

Data on the planned and completed/planned systems is needed. This measure relies on ArcGIS or similar computer software.

What policy elements can it help measure?

EQUITY

ACCESS

EFFICIENCY

SAFETY

OPTIONS

How well does it meet our needs?

Technical Feasibility	Flexibility	Legal Defensibility	Currently Used	Show Impact/ Progress	Supportive of Land use	Achievable Solutions
●	●	◖	●	●	●	◖

○ = Negative Impacts ◖ = Somewhat supports ● = Supports

System completeness can provide a view of mobility and access for all modes, depending on the measures used. When there is a clearly defined plan, these metrics can show whether progress is made. It is not impacted by changes in number of trips by any mode which makes looking at the proportionality of a transportation improvement for a plan amendment difficult.

What are the best uses of the measure?

From an implementation tracking standpoint, system completeness is a very strong metric. If the transportation system planning process has already considered the best way to accommodate future travel demand, the maximum capacity that will be provided for vehicles, and the comfort or performance for other modes, then the plan should articulate the future cross-section for each roadway and this can be used to identify gaps and projects. This can then be used over time, coupled with other performance measures to determine timing, to determine if additional vehicle capacity should be provided or if the vehicle system is already complete and to determine if there are gaps for the bicycle and pedestrian modes. For cities that are densifying or transitioning to a more urban form, system completeness is becoming more widely implemented.

System Completeness could be applied as a performance target and a regulatory standard. It could be used as performance monitoring measure in system plan implementation, such as for a dashboard. It is not as directly useful for plan amendments as the measure is not likely to be impacted by changes in travel demand from a potential land use change. However, the plan amendment would trigger a review as to whether the planned system is adequate.

What do we still need to learn about the measure?

What are the impacts of different targets when determining needs and identifying projects/mitigations?

- Targets based on presence of a planned facility (gaps)
- Targets based on characteristics of a planned facility (deficiencies)
    - Example: Reconstruct a buffered bike lane where there is an existing standard bike lane to meeting LTS 2 on a planned bicycle corridor.

How could the measure be applied to plan amendments for undeveloped areas and developed areas?

For locations where there are conflicts in providing a "complete" network for each mode, how will modal priorities impact what is considered "complete"?

Attachment B: Supporting Materials

Table of Contents

Volume to Capacity Ratio (V/C)

The ratio of traffic volume to the capacity of a roadway link or intersection during a specified analysis period.

Relationship to Elements

EQUITY	A v/c ratio-based standard can be evaluated for facilities or intersections in Equity Focus Areas and compared to other areas to identify disparities in outcomes. The historic emphasis of focusing on maintaining a v/c standard has resulted in inequitable outcomes.
ACCESS	
EFFICIENCY	Can indicate how efficiently goods and people can travel through an intersection or interchange in a vehicle. However, the focus on a one hour period can lead to investments that may not be the most efficient for the overall transportation system.
RELIABILITY	Maintaining a v/c ratio standard helps reduce vehicular delay and increase reliability.
SAFETY	
OPTIONS	Maintaining v/c ratio-based standard can result in negative outcomes for other modes when standards for the other modes are not upheld such as system completeness, safe crossings, and level of traffic stress in areas where bicycles and pedestrians should be prioritized.

Variations of the Measure and Methodology

The v/c calculation itself is well documented in the Highway Capacity Manual (HCM) and widely accepted, but the analysis period and volume development can vary between agencies. For example whether volumes should be for an average month vs peak month or based on the peak 15-minutes, peak hour, or peak 2-hours. ODOT's Analysis Procedures Manual (APM) requires volume adjustments to replicate the 30th highest volume hour of the year (thought to be a peak hour within the peak traffic month of the year) on top of peak hour factors to replicate the peak 15-minute period of that hour occurring for an entire hour.

Current Applications and Thresholds/Targets

V/C is utilized nation-wide. PSU's research paper discussed these current applications of the measure:

Oregon Department of Transportation (ODOT): V/C is currently the principal performance measure for evaluating the Oregon state highway system. V/C is also included in the ODOT Analysis Procedures Manual (APM) as a Transportation System Plan (TSP), Facility, Development Review, and Project Development measure. 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). However, for areas where these targets were unachievable, alternative targets have been developed and approved by the Oregon Transportation Commission.

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 Regional Transportation Plan (RTP). V/C is also included in Metro's Regional Transportation Functional Plan.

The 2018 RTP analysis uses vehicle volumes from the regional travel demand model for specified times of the day, including 1:00-2:00 PM (mid-day one-hour) and 4:00 – 6:00 PM (PM two-hour peak period). The analysis was conducted for a base year (2015) as well as five additional investment scenarios to allow for comparison (2027 No Build, 2027 Constrained, 2040 No Build, 2040 Constrained, 2040 Strategic).

Oregon Highway Plan (OHP) Policy 1F lists V/C performance targets for state facilities in the Portland metropolitan area in Table 7 which are intended to be applied at the intersection and corridor levels in development review, system planning, and plan amendment situations. The Metro Regional Mobility Policy (RMP) in the Regional Transportation Plan (RTP) includes the targets from OHP Table 7 and also identifies targets for non-ODOT roadways. The RMP targets are only applied at the corridor level in the development of the RTP.

Interim regional mobility policy from Chapter 2 of the 2018 RTP

Deficiency thresholds for peak hour operating conditions expressed as volume to capacity ratio targets as adopted in the RTP and Oregon Highway Plan.

Locations	Target Mid-day One-Hour Peak [A, B]	Target PM 2-Hour Peak [A, B] 1st hour	 2nd hour
Central City Regional Centers Town Centers Main Streets Station Communities	.99	1.1	.99
Corridors Industrial Areas Intermodal Facilities Employment Areas Neighborhoods	.90	.99	.99

Locations	Target Mid-day One-Hour Peak A, B	Target PM 2-Hour Peak A, B	
		1st hour	2nd hour
I-84 *(from I-5 to I-205)*	.99	1.1	.99
I-5 North *(from Marquam Bridge to Interstate Bridge)*	.99	1.1	.99
OR 99E *(from Lincoln Street to OR 224 interchange)*	.99	1.1	.99
US 26 *(from I-405 to Sylvan interchange)*	.99	1.1	.99
I-405 [C] *(from I-5 South to I-5 North)*	.99	1.1	.99
Other principal arterial routes [D] 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 Boulevard to Brookwood Avenue) [C, D] OR 47 OR 99W OR 212 [E] OR 224 OR 213 [F]	.90	.99	.99

Table Notes:

A. Unless the Oregon Transportation Commission has adopted an alternative mobility target for the impacted state-owned facility within the urban growth boundary, the mobility targets in this table (and Table 7 of the Oregon Highway Plan) are considered standards for state-owned facilities for purposes of determining compliance with OAR 660-012-0060.

B. The volume-to-capacity ratios in this table (and Table 7 of the Oregon Highway Plan) are for the highest two consecutive hours of weekday traffic volumes. The 2nd hour is defined as the single 60-minute period, either before or after the peak 60-minute period, whichever is highest. See Oregon Highway Plan Action 1.F.1 for additional technical details for state-owned facilities. The mid-day peak hour is the highest 60-minute period between the hours of 9 a.m. and 3 p.m.

C. A corridor refinement plan, which will likely include a tailored mobility policy, is required by the Regional Transportation Plan for this corridor.

D. Two facilities are not designated as principal arterial throughway routes in the RTP, including OR 8 between Murray Boulevard and Brookwood Avenue and portions of 99W, and are proposed to be removed from Table 7 of the Oregon Highway Plan in the next scheduled update.

E. OR 212 is designated as a throughway route in the RTP and is proposed to be amended into Table 7 of the Oregon Highway Plan in the next scheduled update.

F. In October 2018, the OTC approved an alternative mobility target that applies to the intersection of OR 213 and Beavercreek Road such that during the first, second and third hours, a maximum v/c ratio of 1.00 shall be maintained. Calculation of the maximum v/c ratio will be based on an average annual weekday peak hour.

Evaluation Criteria Findings

Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Yes. Requires computer software to efficiently calculate, however multiple software packages are readily available within the industry.
Is the measure easy for both the public and practitioners to understand?	Yes - Easy to explain and for the public to understand in part due to how long it's been in use
Does it rely on readily available data and a proven analysis process?	Yes – Agencies and contractors are accustomed to collecting traffic counts, calculating results, and following local and national guidance on how to conduct the analysis

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	Measures the combined v/c for all vehicles including people and goods. Cannot calculate a v/c for goods only. Can estimate the volume of people (throughput) by applying an estimated vehicle occupancy rate. Can also calculate a theoretical person capacity assuming an occupancy rate.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes – It can be calculated on all roadway facilities.
Can it consider land use context?	Yes - A different V/C standard/target can be applied/adopted for intersections/corridors in different land use contexts.
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes – It can be applied to system planning, plan amendment, and development review applications. The RTP calculates it at the link level. Local TSPs look at it at the link level and at the intersection level to determine adequacy, identify needs and evaluate mitigations.
Can it be used at different scales to compare scenarios or alternatives?	Yes – It can be used to compare scenarios and alternatives.

Legal Defensibility	
Are the measures able to be applied as a standard and legally defensible?	Yes – V/C standards are currently adopted in the OHP and have been broadly applied since 1999. They are also included in the RTP and many other local jurisdictions and adopted in local transportation system plans as an evaluation and mitigation measure.
Can they document incremental changes or impacts and be compared to a standard?	Yes – V/C is sensitive to volume and transportation infrastructure changes

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Yes – Broadly used across the country at the state, MPO, county, and local jurisdiction levels.
Is the measure already in use by ODOT?	Yes – Currently a widely used and applied mobility measure that is adopted in the OHP.
Is the measure already in use by Metro?	Yes – Currently the mobility measure in the RTP mobility policy.

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – Current mobility policy is to maintain acceptable and reliable levels of mobility on highways and arterials. The v/c measure helps identify deficiencies and solutions at the vehicle mode only.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – ODOT, Metro and local agencies are able to plan and fund projects individually and as a region to maintain/improve vehicle mobility.

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	No – V/C is not well suited as a standard or for identifying mobility solutions in compact, urban areas as it is vehicle focused only. Solutions that maintain current or increase vehicle mobility often have negative impacts on people walking, biking and accessing transit which are more efficient modes and necessary for a compact, urban environment. It can be supportive of some land uses such as industrial areas (I.e., facilitates freight movement) and is a useful tool for identifying mobility needs regionally but applying it as the only mobility measure by which to evaluate whether a standard has been met does not allow all modes or mobility solutions to be equally considered.
Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	Yes – It can help assess if the transportation system can support planned land uses if a standard has been set that can be met through the implementation of the financially constrained transportation system plan, which assumes the buildout of planned land uses within the planning horizon. In many urban areas, peak hour v/c-based standards can be difficult to achieve. In these instances, V/C can become a barrier to implementing planned land during development review, in cases where the standard must be met as a condition of land use approval, or mitigation

	to the standard is required but the improvement is cost prohibitive.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan (OTP) goals and policies?	No - Statewide Planning Goals require transportation plans to support land use plans. Although the Transportation Planning Rule and the OTP have many requirements for developing a balanced multi-modal system, the V/C ratio on its own over emphasizes the vehicle mode and does not help balance all planning goals. The OTP has goals related to reliability of the vehicle system which v/c does help evaluate.
Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	No - The solutions and mitigation measures are not always affordable for this measure. Capacity enhancements are typically achieved through additional roadways, additional travel lanes, and wider intersections. These are expensive improvements that frequently require right-of-way and property acquisition. This is why there is emphasis in transportation planning on less expensive solutions such as reducing peak hour vehicle volumes, reducing trip lengths through better land use planning, and increasing opportunities for trips to be completed by walking, biking, taking transit.

Advantages/Limitations (best suitability/difficult applications)

Advantages

As stated in ODOT APM Chapter 9: *ODOT uses v/c-based measures for reasons of application consistency and flexibility, manageable data requirements, forecasting accuracy, and the ability to aggregate into area-wide targets that are fairly easy to understand and specify. In addition, since v/c is responsive to changes in volume as well as in capacity, it reflects the results of demand management, land use and multimodal policies. Other advantages of v/c ratio include:*

- *Standardized calculation methodologies and tools*
- *Easily applied and forecasted*
- *Planning level methods are available to estimate segment v/c ratios. Volumes are estimated using AADTs along with K30 factors and directional factors. Capacity estimates can include the use of default values in estimating v/c ratios with the results reported out as below, near, or at capacity, as example, HERS-ST performs this level of v/c ratio analysis (refer to Chapter 7). For urban signalized arterials, segment capacity can be estimated using approximate green time to cycle time (g/c) ratio assumptions.*
- *Can be calculated for segments, intersections, approaches, and turn movements*
- *Travel demand models calculate a link-based demand to capacity ratio (d/c).*

Limitations

- *Does not directly apply to or address safety, non-motorized vehicle modes, operational improvements, and other policy objectives often under consideration because these aspects of the transportation system cannot be directly measured in terms of vehicle demand and vehicle capacity.*
- *Identifies when capacity is exceeded but does not address the extent or duration of congestion or queue spill-back effects. By definition, the volume of traffic using a roadway cannot exceed the roadway's capacity. When demand exceeds capacity, a demand-to-capacity (d/c) ratio may be used (see section on Demand to Capacity Ratio). A d/c ratio that exceeds 1.00 indicates that more vehicles would use a roadway in a given time period if capacity constraints were not present.*

The fact that demand shifts as congestion increases further complicates how this metric is estimated/forecasted since many tools tend to underestimate the actual demand on a major throughway/arterial and therefore underpredict the traffic volumes when capacity is expanded.

Best Suitability

Given the long history of this metric and its general familiarity, it warrants consideration for being used as a performance target since it can help to identify capacity limitations or when the volume needs to be better managed. However, once there is a planned system that accounts for financial constraints, physical constraints, the roles of other modes in meeting travel demand, and demand management, it should not be applied as a regulatory standard as it becomes a barrier to planned land use.

Duration of Congestion (Hours)

Hours of congestion (HOC) is the number of hours within a time period, most often within a weekday, where a facility's congestion target (such as v/c ratio or acceptable speed) is exceeded or not met.

HOC is a measure of recurring congestion versus travel time reliability measures which evaluate non-recurring congestion.

Relationship to Elements

EQUITY	Can be evaluated for facilities in Equity Focus Areas and compared to other areas to identify disparities in outcomes. The historic emphasis of focusing on maintaining a congestion-based standard has resulted in inequitable outcomes.
ACCESS	
EFFICIENCY	Can indicate how efficiently goods and people can travel through a corridor in a vehicle over an average weekday.
RELIABILITY	Maintaining a duration of congestion standard helps reduce vehicular delay and increase reliability.
SAFETY	
OPTIONS	Maintaining a congestion-based standard can result in negative outcomes for other modes when standards for the other modes are not upheld such as system completeness, safe crossings, and level of traffic stress in areas where bicycles and pedestrians should be prioritized.

Variations of the Measure and Methodology

Variations of the measure and methodology rely on how the term "congestion" is defined. ODOT's APM chapter 9 lists several potential measures that could be used to evaluate duration of congestion including:

- v/c ratio above 1.0
- Speed below an agreed-upon threshold
- Excess/unserved demand
- Queue on uninterrupted flow facility
- ADT/C ratio

Another potential variation is to use level of service (LOS) thresholds for defining congestion, as FDOT does in their annual source book. For freeway and two-lane highway segments, LOS is based on density. For urban street segments, LOS is based on speed. At intersections, LOS is based off of control delay per vehicle. Methodologies can be found in chapters 12, 15, and 19 through 22 of the HCM.

Current Applications and Thresholds/Targets

For ODOT's PRTPR, the congestion threshold was defined as travel speed 75 percent or lower of the roadway's free flow speed. For the freeway network, this is generally equivalent to speeds of 45 miles per hour or lower. The reported region-wide value is based on the cumulative HOC estimated for each freeway corridor as an average number of hours per workday, based on HERE data.

Metro recently conducted new work for this measure. Using a simplified approach, the analysis calculated the number of hours each weekday that throughways and arterials are expected to be approaching congested conditions (defined as a v/c ratio equal to or greater than 0.90 and less than 1.0), congested (defined as a v/c ration equal to or greater than 1.0 and less than 1.1) and severely congested (defined as a v/c ratio equal to or greater than 1.1). The analysis was performed for the RTP 2015 Base year, RTP 2040 No Build, RTP 2040 Constrained and RTP 2040 Strategic networks.

PSU's research paper discussed these current applications of the measure:

- *Oregon Department of Transportation (ODOT): Hours of congestion is currently used as a Corridor Performance Indicator for Region 1 top corridors in the ODOT Traffic Performance Report. It is also used by ODOT in Project Atlas as part of an evaluation of congestion bottlenecks on Region 1 corridors. 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.*
- *Metro: Congestion is used in the 2018 RTP as a key performance measure for addressing Goal 3, Reliability and Efficiency.*
- *Oregon: None identified.*
- *Nationally: Duration of congestion is used by the Florida Department of Transportation (FDOT) as a measure for system-wide performance.*

Evaluation Criteria Findings

Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Maybe – Metro's travel demand model and DTM model can both provide congestion outputs, such as v/c and travel speed, for roadway segments. If the travel demand model is recommended for use, reporting congestion outputs will be reasonably simple. If the DTM model is recommended for use, further exploration regarding calibration of the model is needed to understand effort of modeling base year and outputs. The output itself is simple to review with multiple software packages readily available within the industry.
Is the measure easy for both the public and practitioners to understand?	Yes - Easy to explain and for the public to understand because most vehicular road users can visualize congested time periods.
Does it rely on readily available data and a proven analysis process?	Yes – Metro has two potential models that can analyze segment-level congestion outputs that are already used for many planning and reporting needs in the region.

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	Measures the duration of congestion created by all vehicles, including those transporting both people and goods. Cannot calculate a for goods only.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes – It can be calculated on individual facilities.
Can it consider land use context?	Yes - Different congestion standards/targets can be applied/adopted for corridors in different land use contexts.
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes – It can be applied to system planning, plan amendment, and development review applications; however, trip generation for different hours of the day can be difficult to generate at the site level for small scale plan amendments and development review.
Can it be used at different scales to compare scenarios or alternatives?	Yes – It can be used to compare scenarios and alternatives.

Legal Defensibility	
Are the measures able to be applied as a standard and legally defensible?	Measure could be used to set a standard.
Can they document incremental changes or impacts and be compared to a standard?	Yes – If V/C is the congestion measure, it is sensitive to volume and transportation infrastructure changes Need to test sensitivity of the travel speed model output for incremental changes.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs

Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Yes – Broadly used across the country at the state, MPO, county, and local jurisdiction levels.
Is the measure already in use by ODOT?	Yes – ODOT reports hours of congestion based on travel speed for the Portland Region Traffic Performance Report.
Is the measure already in use by Metro?	Metro has not previously reported this metric but recently completed exploratory work for hours of congestion based on link v/c.

Ability to Show Impact or Progress Toward Desired Mobility Elements

Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – Duration of congestion relates to providing a reliable transportation system, especially over a whole day or specified time period.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – ODOT, Metro and local agencies are able to plan and fund projects individually and as a region to maintain/improve vehicle mobility.

Supportive of Planned Land Uses and Compact Urban Form

Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Yes – It can help assess if the transportation system can support compact, urban form and planned land uses if standards/targets for corridors are set based on land use contexts. More or less hours of congestion may be reasonable for a segment based on the facility type, use, and context.
Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	Yes – It can help assess if the transportation system can support planned land uses if a standard has been set that can be met through the implementation of the financially constrained transportation system plan, which is planned to support the buildout of planned land uses within the planning horizon. If travel speed is used as the basis for determining "congested" segments, need to test model sensitivity to land use changes.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	Yes – Travel speed and/or v/c can support evaluation of the OTP goals related to reliability of the vehicle system. If context-sensitive targets/standards are set, the Transportation Planning Rule and OTP goals for developing a balanced multi-modal system is supported as well. Need to test sensitivity of the model output for both land use and transportation system changes.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	No - The solutions and mitigation measures are not always affordable for this measure. Capacity enhancements are typically achieved through additional roadways, additional travel lanes, and wider intersections. These are expensive improvements that frequently require right-of-way and property acquisition. This is why there is emphasis in transportation planning on less expensive solutions such as reducing peak hour vehicle volumes, reducing trip lengths through better land use planning, and increasing opportunities for trips to be completed by walking, biking, taking transit.

Advantages/Limitations (best suitability/difficult applications)

Relatively common metric that is often used by DOTs to summarize traffic operations for the public. Hours of congestion is often an attention-grabbing data point, but it is difficult to relate to as there are no baselines about what is acceptable/affordable for a region. Duration of congestion is generally relatable to drivers and freight operators. Both hours of congestion and duration of congestion could serve as performance target as they can be forecasted reasonably well. These metrics work best on a corridor scale. This measure is also helpful in that it does not focus solely on the most congested hour of the day and does a better job of explaining the availability of off-peak capacity. The term "congestion" needs to be defined, particularly for arterial streets, however there is substantial guidance on congestion thresholds that relate to speed or V/C ratios from TRB and other national sources.

Hours of congestion is not recommended for regulatory standard but is a good candidate for a performance target and may be used as an evaluation tool in system plans and plan amendments.

The following describes how Duration of Congestion could be applied as a measure for the different applications in system planning.

identifying system needs and system adequacy in system planning	The travel demand model or the DTA model could be used to look at the hours of congestion across the model network for either a v/c or speed-based definition. The DTA model is able to more realistically model congestion over the course of a day, whether to capture v/c or travel speed. Both potential measures of “congestion” can be reported by roadway segment along corridors or within large or small subareas and used to identify needs or system adequacy in system planning.
evaluating the transportation/mobility impacts of land use decisions in plan amendments	Modeling v/c or travel speed can be useful for evaluating these impacts along adjacent roadway segments. If there is enough of a shift in demand, the DTA may capture changes.
Evaluating mitigations when a threshold of significance is exceeded	The TDM model and DTA model could both provide these evaluations when capacity-based mitigations are being reviewed, but the DTA is likely more realistic when capturing the temporal nature of this measure.

Queuing

The extent of vehicles queued on intersection approach lanes, including on and off ramps, during a specified analysis period (typically a peak hour).

Relationship to Elements

EQUITY	
ACCESS	
EFFICIENCY	Queue lengths can indicate how efficiently goods and people can travel through an intersection or interchange as long queues can indicate signal cycle failure and insufficient capacity. However, the focus on a 15-minute or one hour period can lead to investments that may not be the most efficient for the overall transportation system.
RELIABILITY	Consistent queue lengths that do not exceed storage capacity indicate a predictable and reliable transportation system for vehicles.
SAFETY	Queue lengths that exceed storage capacity for turn lanes can increase the probability of rear-end crashes and side swipe crashes.
OPTIONS	Maintaining queuing related standards can result in negative outcomes for other modes when standards for the other modes are not upheld such as system completeness, safe crossings, and level of traffic stress in areas where bicycles and pedestrians should be prioritized.

Variations of the Measure and Methodology

Typically used to measure whether vehicles at an intersection or on/off freeway ramp are exceeding the facility’s storage capacity during peak travel hours with capacity being the length of the turn lane or the distance to the next upstream intersection.

It is calculated using intersection geometry and operational data. and using microsimulation models (e.g. Synchro/SimTraffic). It can be calculated for existing conditions and can also be calculated for future conditions if there are projected or planned changes in volumes or intersection geometry.

For system planning, Metro uses Dynameq, a dynamic traffic assignment model, to post-process travel demand model outputs of vehicle volumes on roadways and at interchanges and intersections. Dynameq can be used to forecast peak hour demand under future year conditions and, with sufficient calibration to local conditions, it can be used to forecast queue lengths. Under most circumstances, however, Metro modeling staff recommend using Dynameq to forecast future vehicle demand for a specified facility and using Synchro/SimTraffic to estimate forecast queue lengths.

Current Applications and Thresholds/Targets

ODOT Analysis Procedures Manual (APM) identifies 95th percentile queue length as a measure for TSPs, Designated MMAs, Facility Plans, Development Review, and Project Development. 95th percentile queues mean that the calculated queue is equal to or less than all other queues 95% of the time and exceeded only 5% of the time. An acceptable queue is generally a queue that fits within the existing or proposed storage area 95% of the time during the peak hour. The queue storage area is the length of space for storing vehicles in a turn lane after the transition area. For a through lane, the storage area is the distance to the preceding intersection. At highway offramp terminals, it's the storage area up to the off-ramp deceleration area from the freeway.

Evaluation Criteria

Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Requires computer software, however multiple software package are readily available within the industry.
Is the measure easy for both the public and practitioners to understand?	Yes - Easy to explain and for the public to understand as it describes something they can observe themselves.
Does it rely on readily available data and a proven analysis process?	Yes – Agencies and contractors are accustomed to collecting traffic counts and geometric data, utilizing software for calculating, and following local and national guidance on how to conduct the analysis.

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	Measures the combined queue for all vehicles including those moving people and goods.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes – It can be calculated on individual facilities.
Can it consider land use context?	No – storage is either adequate or not. Some areas/facilities could be designated as not having a standard for queueing and queueing could be used for performance measure for optimizing operations only.
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes – It can be applied to all planning applications but is typically only looked at for intersections that are being evaluated for v/c.

Can it be used at different scales to compare scenarios or alternatives?	Metro's DTA could be used to compare queueing at the scenario level but would only be useful to visualize changes in travel demand and travel patterns for very distinct scenarios. Yes - At the intersection level, queuing can be compared for different sets of volumes, lane configurations, and operations changes for system planning, evaluation plan amendments, development review, and project development.

Legal Defensibility	
Are the measures able to be applied as a standard and legally defensible?	Measure could be used to set a standard.
Can they document incremental changes or impacts and be compared to a standard?	Yes – queuing is sensitive to small changes in volumes and changes to the transportation system and can be compared to a percentile standard.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Yes – Commonly used when looking at operations and safety at the intersection level in system plans, plan amendments, and development review.
Is the measure already in use by ODOT?	Yes - Commonly used when looking at operations and safety at the intersection level in system plans, plan amendments, and development review.
Is the measure already in use by Metro?	Yes - Commonly used when looking at operations and safety at the intersection level in system plans, plan amendments, and development review.

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Unknown – need to test
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – ODOT, Metro and local agencies are able to plan and fund projects individually and as a region that increase queue storage or operationally manage the queue through signal timing or demand management.

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	No – Queuing is not well suited as a standard or for identifying mobility solutions in compact, urban areas as it is vehicle focused only. Solutions that increase queue storage often have negative impacts on people walking, biking and accessing transit which are more efficient modes and necessary for a compact, urban environment. There are areas where evaluating queueing is important for safety reasons such as freeway off-ramps and turn lanes on high-speed arterials and providing adequate queue storage should be a target.
Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	It can help identify needs during system planning, specifically areas where the system plan should address deficiencies based on queuing targets for freeway off-ramps and arterial turn lanes. Once the system is planned, setting a standard for queuing is a barrier to implementing planned land uses (development review) as solutions tend be very expensive, sometimes undesirable, and in some locations, permitting the land use is part of the solution to reduce reliance on the freeways and arterials through shorter trip lengths and increased travel options.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	No - Statewide Planning Goals require transportation plans to support land use plans. While evaluating queuing has a role in system planning, in particular in refinement planning, it’s not a measure that should be used to help define/plan the transportation system to support the land use plan. The OTP does have goals related to safety of the vehicle system which queuing does help evaluate.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	No - The solutions and mitigation measures are not always affordable for this measure. Additional freeway auxiliary lanes, additional arterial turn lanes or through lanes (wider roadways and intersections) are the solutions to reduce queuing in system planning. These are very expensive improvements that frequently require right-of-way and property acquisition. In existing operations, queues can also be managed with changes to signal timing and operations. The solutions may be more affordable at the arterial level in areas that are not built out.

Advantages/Limitations (best suitability/difficult applications)

Queuing is useful to evaluate transportation infrastructure project alternatives and to address access and safety concerns but has not traditionally been a good broad-based metric for regional plans or local jurisdiction TSPs and plan amendments unless looking at the intersection level. Intersection level analysis is typically only done at locations where there is concern about the v/c ratio. High v/c ratios have a strong correlation to longer queues that could exceed storage capacity which is a safety concern.

Metro's DTA model is a newer modeling tool that allows for queues to be evaluated for the entire modeled roadway network at the subarea level of the regional travel demand model; however, the results are an indicator of where intersection capacity limitations are causing queue spillback that is having impacts on the greater network and cannot be used for calculating queues. The volumes from the DTA model can be put into microsimulation tools to calculate estimated queues in the same way that queues have traditionally been calculated at study intersections.

The following describes how queuing could be applied as a measure for the different applications in system planning.

identifying system needs and system adequacy in system planning	TSPs/Large SubAreas – DTA model calculates queues but they best for identifying vehicle bottle necks and congestion, not well calibrated to calculating queues Corridors/Smaller SubAreas – Use Synchro/SimTraffic or other microsimulation tool for calculating queues and determining if queue storage is adequate. Significant effort to apply systemwide. Well suited to facility level or TSP focus areas as it is calculated at the intersection level.
evaluating the transportation/mobility impacts of land use decisions in plan amendments	Syncho/SimTraffic or other microsimulation tool is useful for looking at changes in queuing for specific intersections based on changes in volumes.
Evaluating mitigations when a threshold of significance is exceeded	Syncho/SimTraffic or other microsimulation is useful for looking at changes in queuing for specific intersections based on changes in intersection geometry or operations.

Throughput (Person and Goods)

Person Throughput is the number of people, across modes, traveling through a segment, facility, or specified point in one direction over a specified time period (typically a weekday peak period or 24 hours). Goods Throughput is the amount of freight carried through a segment, facility, or specific point in one direction over a specified time period (typically 24 hours). These measures indicate how efficiently a transportation facility serves passenger and/or freight travel.

Relationship to Elements

EQUITY	Can be evaluated at specific locations within Equity Focus Areas.
ACCESS	Does not directly reflect access to destinations but can be used qualitatively to compare project alternatives in TSPs and corridor plans.
EFFICIENCY	Measures how efficiently the facility moves people and goods.
RELIABILITY	Consistent and predictable rates of person and goods throughput indicates a reliable system or facility.
SAFETY	
OPTIONS	Person throughput can be evaluated for different travel modes on the same facility (e.g., person throughput for transit users vs. auto users on the same corridor).

Variations of the Measure and Methodology

Both person throughput and goods throughput are based on a calculation of vehicle throughput at a specific time and location on a transportation facility. Vehicle throughput is measured for specific modes in a specified location and direction on a study segment (e.g., "northbound at mile marker 37 on State Highway 6") and can be reported for an entire facility or by travel lane. It can be measured in the field or using big data (for the existing condition) or forecasted (for existing and future conditions) using Metro's travel demand model. To reflect the effects of traffic congestion on vehicle throughput, travel model outputs should be post-processed using Metro's dynamic traffic assignment model or a microsimulation model (such as Synchro/SimTraffic) that reflects anticipated future conditions. Converting vehicle throughput to person or goods throughput requires additional information about vehicle occupancy and commodity loads.

Person throughput

Person throughput is typically calculated by multiplying vehicle throughput within a given time period by vehicle occupancy and can be calculated separately for different travel modes (such as auto, transit, bicycle, etc.). Seat utilization (for individual modes or across all modes) can provide a similar measure of efficiency on a corridor.

While vehicle occupancy for individual travel modes can be observed in the field, vehicle occupancy values are typically derived from regional data in household travel surveys, transit providers, and/or travel demand models. This means that person throughput forecasted using a travel demand model would reflect changes in mode share (for example, a shift from single-occupant vehicles to carpools) but not changes in vehicle occupancy (such as an increase in the average occupancy of a carpool).

Goods throughput

Goods throughput is calculated by multiplying freight vehicle throughput by the value of goods carried on each freight vehicle. Freight vehicle throughput as a share of total vehicle throughput can be measured in the field or adapted from travel model inputs. Data on the value of goods carried by freight vehicles, however, is not readily available at a granular level.[1] As a result, local and regional freight studies often rely on related performance measures. Freight vehicle throughput can be used to evaluate goods throughput at a specific location. At a regional or corridor level, the ratio of commercial vehicle VMT to total VMT can be used to indicate the relative importance of freight to passenger travel. Metro's travel demand model can evaluate commercial vehicle VMT/total VMT and includes a freight model that outputs existing and forecasted truck trips. Metro's dynamic traffic assignment model or a microsimulation model can be used to assess changes in vehicle throughput under forecasted future conditions, which would affect freight throughput.

Current Applications and Thresholds/Targets

Person throughput

ODOT: Person 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. ODOT's APM provides technical guidance on using vehicle throughput to evaluate corridor operations, evaluating either corridor segments or intersections along the corridor. ODOT Region 1 issues Traffic Performance Reports, which identify bottlenecks on regional travel routes that affect vehicle throughput and therefore person throughput.

[1] The Bureau of Transportation Statistics collects data on the partial value of freight carried in and out of the Portland-Vancouver-Salem region through its Commodity Flow Survey, and is experimenting with providing this data at the county level. Commodity flow data, however, reflects outbound shipments from survey respondents for one week of each quarter in a calendar year, and is unlikely to accurately reflect the value of goods carried by the average freight vehicle.

National: In **Utah**, the UDOT Wasatch Front Corridor Study evaluated person throughput and compared seat utilization on transit vs. freeways to evaluate transit vs. freeway expansion scenarios.

In **California**, the Caltrain Business Plan evaluated a range of commuter rail line service expansion scenarios by comparing the person throughput for added transit service to the number of freeway lanes that would be required to accommodate the same number of passengers.

In **Minneapolis-St. Paul**, **Minnesota**, the metropolitan planning organization measures person throughput (in terms of PMT/VMT by facility and lane type) to encourage the use of higher-occupancy modes on existing infrastructure rather than increasing capacity to mitigate congestion.

Goods throughput

ODOT's APM does not define metrics for evaluating goods movement specifically, although it provides technical guidance on using vehicle throughput to evaluate corridor operations, evaluating either corridor segments or intersections along the corridor. ODOT's Traffic Performance Report reports goods movement in trucks per day and truck share of total traffic for individual highways and freeways. ODOT's Freight Highway Bottlenecks Project identifies the hours of delay experienced by trucks on state facilities.

Metro's Regional Freight Strategy reports goods movement in trucks per day and truck share of total traffic for individual highways and freeways, along with qualitative data from freight stakeholders on the effects of congestion on their businesses.

PBOT's Freight Master Plan update (currently underway) reports truck volumes, truck VMT, and the share of trucks as a percentage of total traffic but does not report goods throughput specifically.

Washington State DOT recommends the use of freight vehicle throughput as a performance measure in its Practical Solutions Performance Framework, and reports both annual truck tonnage and average daily truck traffic for individual segments of the state highway system.

Evaluation Criteria

Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Yes - Both person and good throughput are fairly simple to analyze if data are available.
Is the measure easy for both the public and practitioners to understand?	Yes – Intuitive measure
Does it rely on readily available data and a proven analysis process?	Calculating vehicle throughput requires the same data and analytical tools as traditional measures and is clearly defined and well-understood; however, evaluating person and goods throughput requires data on vehicle occupancy and freight capacity and usage which are not readily available or are high level static estimates.

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	Can be focused on either goods or people.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes, it can distinguish between facility types and modes of travel.
Can it consider land use context?	Does not consider land use context.
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Not suited to system planning. Best used for corridor planning where changes to transportation infrastructure or operations are likely to affect mode choice and/or vehicle throughput.
Can it be used at different scales to compare scenarios or alternatives?	Able to compare different scenarios and project alternatives

Legal Defensibility	
Are the measures able to be applied as a standard and legally defensible?	The measure is difficult to use for setting a target or standard.
Can they document incremental changes or impacts and be compared to a standard?	Not recommended as a standard but can be used to compare project or plan alternatives.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Person throughput has been applied on corridor studies around the United States. Goods throughput is not measured directly due to a lack of available data; freight vehicle throughput can be used as a proxy.
Is the measure already in use by ODOT?	Person throughput is recommended for Facility Planning and Project Development. Goods throughput is not measured, but daily truck traffic is.
Is the measure already in use by Metro?	Not in the RTP but has been applied to corridor studies.

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – It measures efficiency of specific facilities in moving people and goods.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – ODOT, Metro, and local agencies can improve corridor operations to reduce delays, thereby increasing vehicle and goods throughput, and can support the development of space-efficient travel modes, thereby increasing person throughput.

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Unknown – need to test
Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	Increased person throughput due to improved transit access could indicate supportiveness of planned land uses. Increase person throughput via non-motorized modes could indicate the influence of a compact urban form.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	Yes - Increased person and goods throughput is consistent with OTP goals promoting improved transportation system efficiency and economic vitality.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	Yes – ODOT, Metro, and local agencies can improve corridor operations to reduce delays, thereby increasing vehicle and goods throughput, and can support the development of space-efficient travel modes, thereby increasing person throughput; although, the biggest increases in throughput come from vehicle capacity increasing projects.

Advantages/Limitations (best suitability/difficult applications)

Person throughput is occasionally used for corridor studies, particularly to show how mode shifting or investments in transit or high-occupancy vehicle infrastructure can be an effective way to increase mobility. Evaluating person throughput by all modes before and after transportation system changes, such as a road diet, bus-only lane conversion, or light rail expansion, can inform the selection of project alternatives. While not used on a wide-scale basis, person throughput on key multimodal corridors (including via bicycle and pedestrian modes) can evaluate whether transportation and land use plans and plan amendments will induce more use of transit, walking and biking trips.

Person throughput is strongly affected by transit ridership and carpooling, both of which may decline for reasons outside the control of Metro and ODOT R1, such as transit service or fuel price changes. This creates the potential risk of non-attainment if the RMP defines a standard for travel corridors that transportation projects and land use plans must achieve. Metro's travel demand model assumes a constant vehicle occupancy rate for high-occupancy vehicles; therefore, forecasted person throughput will reflect shifts between modes (such as a shift from driving alone to carpooling) but not changes to vehicle occupancy within modes (such as a trend toward 3-person carpools as opposed to 2-person carpools).

Goods throughput is difficult to measure directly since data on the volume and value of commodities is limited. Freight vehicle throughput can be used as a proxy at the corridor level, and the share of commercial vehicle VMT/total VMT can be evaluated at the regional and sub-area levels. These metrics could be used to assess the potential effects of changes to corridor operations and transportation system investments on freight travel.

The following describes how Person and Goods Throughput could be applied as a measure for the different applications in system planning.

Identifying system needs and system adequacy in system planning	TSPs/Large Subareas – See below; best evaluated at the corridor level. Applying to all corridors in a TSP likely to be cost prohibitive. Corridors/Smaller Subareas – Person throughput on key corridors can be evaluated for existing and future conditions using Metro's travel demand model. (Freight) vehicle throughput on specific corridors could be evaluated to qualitatively assess the effects of corridor changes on freight traffic.
Evaluating the transportation/mobility impacts of land use decisions in plan amendments	Does not measure land use decisions directly, although land use changes could impact mode choice in the travel demand model, possibly increasing or decreasing trips by non-auto modes. Added congestion due to land use changes could also affect vehicle throughput.
Evaluating mitigations when a threshold of significance is exceeded	Forecasted person throughput can be measured for different mitigation alternatives that would expand transportation options or affect vehicle throughput on the corridor.
Identifying system needs and system adequacy in system planning	TSPs/Large SubAreas – See below; best evaluated at the corridor level. Applying to all corridors in a TSP likely to be cost prohibitive. Corridors/Smaller SubAreas – Person throughput on key corridors can be evaluated for existing and future conditions using Metro's travel demand model. (Freight) vehicle throughput on specific corridors could be evaluated to qualitatively assess the effects of corridor changes on freight traffic.
Evaluating the transportation/mobility impacts of land use decisions in plan amendments	Does not measure land use decisions directly, although land use changes could impact mode choice in the travel demand model, possibly increasing or decreasing trips by non-auto modes. Added congestion due to land use changes could also affect vehicle throughput.

Evaluating mitigations when a threshold of significance is exceeded	Forecasted person throughput can be measured for different mitigation alternatives that would expand transportation options or affect vehicle throughput on the corridor.

Travel Speed

Average or a percentile speed for a network segment or between key origin-destination pairs, during a specific time period.

Relationship to Elements

EQUITY	Travel speed can be evaluated for facilities in Equity Focus Areas and compared to other areas to identify disparities in outcomes. High speed corridors in residential areas can result in inequitable outcomes and risk exposure.
ACCESS	
EFFICIENCY	Travel speed can indicate how efficiently goods and people can travel through a corridor and the level of congestion experienced by vehicles. However, a focus on solely increasing travel speed can lead to safety concerns and increased stress for road users who are walking or cycling.
RELIABILITY	Travel speed close to the posted speed indicates a predictable and reliable transportation system for vehicles.
SAFETY	High vehicular travel speeds increase the probability of fatal and serious injury crashes, especially for crashes involving pedestrians and bicyclists.
OPTIONS	Maintaining competitive travel speeds for transit can increase its attractiveness as an option. Maintaining free flow travel speeds during peak periods can result in negative outcomes for other modes when standards for the other modes are not upheld such as system completeness, safe crossings, and level of traffic stress in areas where bicycles and pedestrians should be prioritized.

Variations of the Measure and Methodology

- Measured:
  - For large areas, probe data such as INRIX, HERE, and Wejo are commonly used to directly provide travel time and speed output or full probe data sets. ODOT utilized HERE data for the 2018 Portland Region Traffic Performance Report and 2020 Statewide Congestion Overview.
- Modeled:
  - Metro's travel demand model outputs include travel speeds by segment.

- In addition to the regional travel demand model, Metro also uses Dynameq mesoscopic models, which include an additional level of detail.

Current Applications and Thresholds/Targets

ODOT uses travel speed to determine if a freeway segment is congested. For ODOT's PRTPR, the congestion threshold was defined as travel speed 75 percent or lower of the roadway's free flow speed. For the freeway network, this is generally equivalent to speeds of 45 miles per hour or lower.

Evaluation Criteria Findings

Technical Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Metro's travel demand model and DTM model can both provide travel speed for roadway segments. If the travel demand model is recommended for use, reporting congestion outputs will be reasonably simple. If the DTM model is recommended for use, further exploration regarding calibration of the model is needed to understand effort of modeling base year and future year outputs. The output itself is simple to review with multiple software packages readily available within the industry.
Is the measure easy for both the public and practitioners to understand?	Yes - Easy to explain and for the public to understand.
Does it rely on readily available data and a proven analysis process?	Yes – If using measured data for existing conditions, ODOT has access to INRIX data. If proceeding with modeling, Metro has two potential models that can analyze travel time outputs that are already used for many planning and reporting needs in the region. Measured and modeled travel speed for non-vehicular modes does not have models that would be sensitive to show changes in travel speed associated with different conditions.

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	Measures or models travel speed for all vehicles, including those transporting both people and goods. Cannot calculate for goods only.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes – It can be calculated on individual facilities.
Can it consider land use context?	Yes - Different standards/targets can be applied/adopted for corridors in different land use contexts.
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes – It can be applied to system planning, plan amendment, and development review applications. The measure is analyzed at the link level. For plan

	amendments and development review, need to test sensitivity of the model output for both land use and transportation system changes.
Can it be used at different scales to compare scenarios or alternatives?	Need to test sensitivity of the model output.

Legal Defensibility	
Are the measures able to be applied as a standard and legally defensible?	Measure could be used to set a standard.
Can they document incremental changes or impacts and be compared to a standard?	Impacted by added trips. Unknown - need to test model sensitivity.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Yes – Broadly used across the country at the state, MPO, county, and local jurisdiction levels.
Is the measure already in use by ODOT?	Yes – ODOT uses travel speed to determine congested roadway segments for the Portland Region Traffic Performance Report.
Is the measure already in use by Metro?	Yes – Metro model outputs include travel speed.

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – Travel speed relates to providing a reliable transportation system.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – ODOT, Metro and local agencies are able to plan and fund projects and programs individually and as a region to maintain travel speeds. It is unknown if the model will be sensitive enough to show changes for these projects and/or programs. Need to test this through case studies.

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Yes – It can help assess if the transportation system can support compact, urban form and planned land uses if standards/targets for corridors are set based on land use contexts. The travel speed target is not to increase travel speed but to maintain safe and reliable travel speeds that correspond to the facility type, use, and context.

Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	Unknown - Need to test model sensitivity to land use changes.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	Need to test sensitivity of the model output for both land use and transportation system changes. Yes – Travel speed can support evaluation of the OTP goals related to reliability of the vehicle system. If context-sensitive targets/standards are set, the Transportation Planning Rule and OTP goals for developing a balanced multi-modal system is supported as well.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	No - The solutions and mitigation measures are not always affordable for this measure. Capacity enhancements are typically achieved through additional roadways, additional travel lanes, and wider intersections. These are expensive improvements that frequently require right-of-way and property acquisition. This is why there is emphasis in transportation planning on less expensive solutions such as reducing peak hour vehicle volumes, reducing trip lengths through better land use planning, and increasing opportunities for trips to be completed by walking, biking, taking transit. It is unknown if the model will be sensitive enough to show changes for projects and/or programs that are not capacity enhancements.

Advantages/Limitations (best suitability/difficult applications)

Travel speed is not recommended to be applied as a regulatory standard, but it is a good candidate for a performance target. It may be used as an evaluation tool or as a performance monitoring measure in system plans and plan amendments.

This is metric that is growing in its use since the public is now fairly familiar with Google maps and similar sites reporting this type of data. Big data providers are also making this a much more available existing conditions dataset. If Metro or others defined speed thresholds for different roadway types, transit facilities, freight routes, etc., this could be a credible performance target. In practice, a realistic arterial corridor speed under typical suburban traffic congestion can appear low to the public, who might argue that a defined speed threshold is too low. This metric has some challenges to forecast without sophisticated analysis tools and the regional travel demand model's challenges forecasting latent demand can also pose a challenge. However, this could be a more modern alternative to V/C, particularly since it is easier to collect existing conditions data. Widespread speed data is increasingly available. Average travel speed on corridors or areas could be summarized as a performance dashboard metric.

The following describes how Travel Speed could be applied as a measure for the different applications in system planning.

identifying system needs and system adequacy in system planning	Travel speed can be measured or modeled on roadway segments along corridors or within large or small subareas with thresholds specific to each roadway functional classification and land use context used to define needs and adequacy.
evaluating the transportation/mobility impacts of land use decisions in plan amendments	Modeling travel speed can be useful for evaluating these impacts along adjacent roadway segments. If there is enough of a shift in demand, the DTA may capture changes in travel speed.
Evaluating mitigations when a threshold of significance is exceeded	The TDM model and DTA model could both provide these evaluations when capacity-based mitigations are being reviewed.

Travel Time

Average or a percentile time spent traveling between key origin-destination pairs, during a specific time period.

Relationship to Elements

EQUITY	Travel time measures can be evaluated for facilities in Equity Focus Areas and to compare trends to other areas to identify disparities in outcomes.
ACCESS	
EFFICIENCY	Travel time can indicate whether a user can efficiently travel from a specified origin or destination, especially when compared over serval hours to capture changes due to congestion and demand. However, if the analysis focuses on only one hour period, it can lead to investments that may not be the most efficient for the overall transportation system.
RELIABILITY	Maintained or decreasing travel times indicate a predictable and reliable transportation system for users.
SAFETY	
OPTIONS	Maintaining competitive travel times for non-vehicular modes can allow for realistic travel options within the region. Maintaining travel times during peak periods can result in negative outcomes for other modes when standards for the other modes are not upheld such as system completeness, safe crossings, and level of traffic stress in areas where bicycles and pedestrians should be prioritized.

Variations of the Measure and Methodology

The major methodology variations for travel time are whether the output is measured or modeled and which summary statistic used (average, percentile, free-flow, etc).

- Measured:
  - For large areas, probe data such as INRIX, HERE, and Wejo are commonly used to directly provide travel time and speed output or full probe data sets. ODOT utilized

HERE data for the 2018 Portland Region Traffic Performance Report (PRTPR) and 2020 Statewide Congestion Overview.

  - Measured datasets may be financially limiting for local agencies if they do not currently collect this data or cannot utilize ODOT's data for a project
- Modeled:
  - Metro RTP methodology states: *Metro evaluated average weekday travel times for passenger vehicle, truck, transit, and bike for the 2018 RTP. The analysis was conducted on corridors between key regional origin-destination pairs. Passenger vehicle, bicycle, and transit travel times are for the one-hour mid-day and one hour PM peak travel times and are based on a zone-to-zone analysis. Truck travel times are not zone-to-zone based. Freight truck travel times add a mid-day hour for trucks (2-3 PM), use the regional freight network, and start and/or end at a major freight destination (e.g., rail yard, intermodal facility, industrial site). This analysis utilizes the Metro Travel Demand Model.*
  - The methodology documents that the base year model was validated against third-party GPS data sources (such as INRIX, HERE, NPMRDS) and verified by local agency partners to reflect local traffic characteristics.
  - In addition to the regional travel demand model, Metro also uses Dynameq mesoscopic models, which include an additional level of detail with time of day and capacity-restricted modeling.

ODOT APM Chapter 9 outlines different travel time summary statistics that could be reported:

- *Free-flow Travel Time*
  - *Free-flow travel time is the time required to travel a roadway section under low-volume conditions. It is preferably calculated as the average vehicle speed during low-volume periods (i.e., 500 pc/h/lane or less), with good weather and no* construction *activity or incidents. Alternatively, when the study roadway is a freeway, multilane highway, or two-lane highway (i.e., uninterrupted flow without traffic signals), and the distribution clearly contains congestion-free periods, free-flow travel time can also be estimated as the 5th-percentile travel time, as shown in Exhibit 9-8. Typically, free-flow travel time is not reported by itself, but is used instead to calculate other reliability measures, such as the travel time index, discussed later. Highway Capacity Manual (HCM) methods also calculate delay based on the difference between the actual travel time and the free-flow travel time.*
- *Travel Time at the Speed Limit*
  - *The time required to travel a roadway section at the speed limit can be used as an alternative starting point for calculating delay, and as an input to reliability measures based on the percentage of time the roadway operates at or above a target percentage of the posted speed. This value can also be used as a check that the free-flow travel time estimate is accurate; the free-flow travel time will normally be slightly less (i.e., faster) than the travel time at the speed limit.*

- *Average (Mean) Travel Time*
  - *This is the average time to travel a roadway section during a given time period. HCM segment and facility methods predict average 15-minute travel times for a particular set of conditions.*
- *Percentile Travel Time*
  - *A percentile travel time is the travel time over a roadway section achievable a given percentage of the time. Percentile travel times may be reported by themselves but are also often used in calculating other reliability measures. The most common percentile travel times are:*
    - *50th-percentile (median) travel time—this time typically will be slightly lower than the mean travel time, due to the influence of exceptionally long (outlier) travel times on the mean travel time;*
    - *80th-percentile travel time—the travel time achievable 80% of the time; research has shown that the 80th-percentile time is more sensitive to roadway operational changes than the 95th-percentile time, making it useful for evaluating project effects on reliability; and*
    - *95th-percentile (planning) time—for a segment or facility, the travel time achievable 95% of the time; for a trip, the travel time one would need to budget to ensure an on-time arrival 95% of the time (e.g., late to work approximately once a month when commuting).*

Current Applications and Thresholds/Targets

Vehicle travel time and travel speed on state freeways were reported for ODOT's PRTPR as peak period averages for the AM peak, mid-day, and PM peak. The average vehicle travel times and travels speeds were calculated using 5-minute interval data for the 24-hour workday, based on HERE data. Multi-modal travel times is a system evaluation measure in Chapter 7 of the 2018 RTP. No target was set but the desired direction is to maintain or decrease travel times for passenger vehicle, bicycle, transit, and truck modes in 2040 compared to 2015 levels.

PSU's research paper discussed these current applications of the measure:

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

Evaluation Criteria Findings

Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Maybe – Metro's travel demand model and Dynamic Traffic Assignment (DTA) model can both provide travel time outputs for determined O-D pairs. If the travel demand model is recommended for use, reporting travel time output will be reasonably simple. If the DTA model is recommended for use, further exploration regarding calibration of the model is needed to understand effort of modeling base year and future travel times for determined O-D pairs. The output itself is simple to review with multiple software packages readily available within the industry.
Is the measure easy for both the public and practitioners to understand?	Yes - Easy to explain and for the public to understand in part due to the popularity of navigation apps such as Google Maps.
Does it rely on readily available data and a proven analysis process?	Yes – If using measured data for existing conditions, ODOT has access to INRIX data. If proceeding with modeling, Metro has two potential models that can create travel time outputs that are already used for many planning and reporting needs in the region. Measured and modeled travel time for non-vehicular modes do not have readily available data or realistic models. Travel demand models have historically focused on vehicular traffic, and Metro has noted the need to further develop their model to better reflect walking and biking.

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	Measured travel time data is for all vehicles including people and goods. For modeled travel times, need to test the ability to separate out freight trips from all vehicle trips.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes – It can be calculated on individual facilities.
Can it consider land use context?	No – Travel time is not sensitive to land use context. The O-D pairs selected to review may be related to their land uses.
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes – It can be applied to system planning, such as in the 2018 RTP. For plan amendments and development review, need to test sensitivity of the model output for both land use and transportation system changes.

Can it be used at different scales to compare scenarios or alternatives?	Unknown - Need to test sensitivity of the model output. Metro did use travel time as a comparison between build and no-build scenarios in the 2018 RTP.

Legal Defensibility

Are the measures able to be applied as a standard and legally defensible?	Cannot set a standard as it's dependent upon the origin and destination. The measure is difficult to use for setting a target or standard because it requires a defined origin and a destination.
Can they document incremental changes or impacts and be compared to a standard?	Unknown - need to test sensitivity of the model output.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs

Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Yes – Broadly used across the country at the state, MPO, county, and local jurisdiction levels.
Is the measure already in use by ODOT?	Yes – ODOT reports travel time for the Portland Region Traffic Performance Report.
Is the measure already in use by Metro?	Yes – Metro modeled travel time for the 2018 RTP and also uses it as a RTP Monitoring Performance measure.

Ability to Show Impact or Progress Toward Desired Mobility Elements

Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – Travel time relates to providing a reliable transportation system.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – ODOT, Metro and local agencies can plan and fund projects and programs individually and as a region that maintain or decrease travel times for different modes, including travel demand management programs. It is unknown if the model will be sensitive enough to show changes for these projects and/or programs.

Supportive of Planned Land Uses and Compact Urban Form

Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Depending on the analysis time period and analyzed O-D pairs, travel time may provide support for compact, urban form by showing competitive travel times for non-vehicular modes when there is congestion and reduced average travel times as trip lengths shorten in high density mixed-use areas.

Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	Unknown - Need to test model sensitivity to land use changes.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	Yes – Travel time can support evaluation of the OTP goals related to reliability of the vehicle system. Need to test sensitivity of the model output for both land use and transportation system changes. If realistic non-vehicular travel times can also be modeled, the Transportation Planning Rule and OTP goals for developing a balanced multi-modal system is supported as well.

Leads to Financially Achievable Solutions

Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	No - The solutions and mitigation measures are not always affordable for this measure. Capacity enhancements could be explored, which are typically achieved through additional roadways, additional travel lanes, and wider intersections. These are expensive improvements that frequently require right-of-way and property acquisition. This is why there is emphasis in transportation planning on less expensive solutions such as reducing peak hour vehicle volumes, reducing trip lengths through better land use planning, and increasing opportunities for trips to be completed by walking, biking, taking transit. It is unknown if the model will be sensitive enough to show changes for projects and/or programs that are not capacity enhancements.

Advantages/Limitations (best suitability/difficult applications)

Clarifications are needed when comparing modeled travel times between modes. Travel demand models have historically been developed with vehicles in mind first, so bike and transit travel times via the travel demand model may not align as closely to field conditions as vehicular travel times. Travel time and travel time reliability measures are most relevant for autos, freight, and transit. Bike travel time is not a focus for most travel time measures. It is most impacted by signal cycle lengths and directness/connectivity of the bike network; therefore other measures may better capture bicycle and pedestrian mobility.

The following describes how Travel Time could be applied as a measure for the different applications in system planning.

Identifying system needs and system adequacy in system planning	Travel time can be measured or modeled between O-D pairs along corridors or within large or small subareas. Needs and adequacy identification would rely on comparison of existing and future travel times to identify corridors needing improvements or establishing an average travel speed threshold, applying it to the O-D pair length to develop a travel time threshold for each O-D pair.
Evaluating the transportation/mobility impacts of land use decisions in plan amendments	Modeling travel time is less useful for evaluating these impacts. If there is enough of a change or shift in demand, the DTA model may capture changes in travel time. One challenge for a given land use change would be determining the relevant O-D pairs for evaluation.
Evaluating mitigations when a threshold of significance is exceeded	The travel demand model and DTA model could both provide these evaluations when capacity-based mitigations are being reviewed. One challenge would be determining the relevant O-D pairs for evaluation.

Travel Time Reliability

Travel time reliability measures, such as planning time index and buffer travel time index, are indicators of congestion severity that assess on-time arrival and travel time variability.

Planning Time Index (PTI) is the ratio of the 95th percentile travel time to the free-flow travel time. As noted in the ODOT 2020 statewide Congestion Overview, PTI measures variation in travel time caused by unexpected events, such as crashes, vehicle breakdowns, work zones, and inclement weather causing delay and stop-n-go conditions.

Buffer Travel Time Index is the ratio of the 95th percentile travel time to the average travel time.

Relationship to Elements

EQUITY	Travel time reliability can be evaluated for facilities in Equity Focus Areas and to compare trends to other areas to identify disparities in outcomes.
ACCESS	
EFFICIENCY	
RELIABILITY	Maintained or decreasing travel time reliability measures, such as Planning Time Index or Buffer Time Index, indicate more consistent service for roadway users.
SAFETY	
OPTIONS	Travel time reliability measures are traditionally applied for vehicular modes. Focusing on vehicular-based measures such as travel time reliability can result in negative outcomes for other modes when standards for the other modes are not upheld such as system completeness, safe crossings, and level of traffic stress in areas where bicycles and pedestrians should be prioritized.

Variations of the Measure and Methodology

- Measured datasets are available to support reporting travel time reliability measures:
  - For large areas, probe data such as INRIX, HERE, and Wejo are commonly used to directly provide travel time and speed output or full probe data sets. ODOT utilized HERE data for the 2018 Portland Region Traffic Performance Report and 2020 Statewide Congestion Overview, reporting PTI.
  - ODOT APM chapter 9 lists four primary sources of travel time data that ODOT has access to, listed below. Section 9.3.5 includes links to access data.
    - Iteris Performance Measurement System (iPeMS)
    - HERE Traffic Analytics
    - National Performance Management Research Data Set (NPMRDS)
    - Portland, Oregon Regional Transportation Archive Listing (PORTAL)
  - This ODOT APM section also mentions that travel time data can be obtained through other devices such as Bluetooth or Wi-Fi readers if deployed over extended periods of time.
  - As of May 2020, ODOT has access to INRIX data through the Regional Integrated Transportation Information System (RITIS) system. Through ODOT's agreement, all public agencies in Oregon and their project teams can gain access to this data.

ODOT APM Section 9.3.3 discusses recommended Reliability Performance Measures

The following performance measures provide a good starting point for evaluating reliability:

- 80th-percentile TTI_P—this measure reports the upper limit of commonly occurring (e.g., once a week) travel conditions. This measure is more sensitive to roadway operations strategies such as ramp metering and road patrols than is the 95th-percentile TTIP. This is because the longest travel times in the travel time distribution tend to be associated with major crashes and/or severe weather, both of which are less affected by operations strategies.
- 95th-percentile TTI_P—this measure reports uncommonly poor, but not worst-case, conditions that roadway users would account for as part of their trip planning (e.g., a once-a-month occurrence on a commute trip). The planning time associated with this measure can be valued in terms of commuter time that could have been spent at home, extra freight shipment time that must be planned for, and longer transit trips that must be scheduled (possibly requiring additional vehicles and drivers). However, the use of an index rather than a pure travel time allows facilities with different lengths and different free-flow speeds to be compared on an apples-to-apples basis. Additional reliability measures, such as TTIP50, person delay, and reliability rating, can also be evaluated, depending on the specific needs of the analysis. For example, the FHWA national performance management measures would be forecasted if the purpose of the analysis was to investigate the potential contribution of different project alternatives toward meeting state or metropolitan system performance targets.

Travel Time Index (TTI)

A TTI is calculated as a travel time divided by the free-flow travel time. A TTI value of 1.00 indicates travel at the free-flow speed, while a TTI value of 2.00 indicates travel that is twice as long, compared to free-flow conditions. Commonly reported TTIs include the 50th-percentile TTI (TTI_{50}, the 50th-percentile travel time divided by the free-flow travel time), the 80th-percentile TTI (TTI_{80}), the 95th-percentile TTI (TTI_{95}, also known as the planning index), and the mean (or average) TTI (TTI_{mean}).

Policy Travel Time Index (TTI_P)

ODOT's policy TTI is calculated as a travel time divided by the travel time at the posted speed limit. A TTI_P value of 1.00 indicates travel at the posted speed, while a TTI_P value of 2.00 indicates travel that is twice as long as travel at the posted speed limit. Like the TTI, a variety of percentile values can be reported, including TTI_{P50} (the 50th-percentile travel time divided by the travel time at the posted speed limit), TTI_{P80}, and TTI_{P95}. ODOT uses TTI_P instead of TTI for ODOT reporting purposes. Analysts should be aware that software packages may report TTI by default.

ODOT APM Chapter 9 discusses Reliability Reporting Periods.

"Reliability quantifies the uncertainty in travel times that a traveler might experience from day to day, across different times of day, over a period of time from a few months up to a year. Key reliability time periods are defined below.

1. *The reliability analysis period is the smallest time unit for which the analysis procedure is applied. In the case of freeway and urban street facility analysis, the analysis period is Analysis Procedure Manual Version 2 9-38 Last Updated 12/2019 typically 15 min, although it can be of greater or lesser duration, at the discretion of the analyst. Alternative tools may define different analysis period lengths.*
2. *The study period is the sum of the consecutive analysis periods for which the facility analysis procedure is applied (e.g., an a.m., midday, or p.m. peak period). The study period is defined by the analyst for each specific application. A study period of multiple hours is preferred, as a single congested peak hour could be very reliable but with poor travel times, while the shoulder hours could be much less reliable but with better travel times.*
3. *The reliability reporting period is the period over which reliability is to be estimated (e.g., the 250 non-holiday weekdays in a year). In essence, the reliability reporting period specifies the days within the year for which the reliability analysis is to be performed."*

Forecasting Reliability Measures

ODOT APM Chapter 9 states:

"When performing a detailed forecast of travel time reliability, the majority of the effort involves coding and calibrating the facility in the analysis tool. The analysis tool then takes care of creating various reliability scenarios, generating the travel time database, and reporting reliability performance.

Reliability forecasting methods can be divided into three main groups: (1) sketch-planning methods developed through the SHRP 2 program, (2) the detailed HCM freeway and urban streets reliability methods, and (3) Oregon's implementation of HERS-ST, which incorporates elements of the other two methods. Although in theory microsimulation can also be used to estimate reliability, it is not currently practical to do so in a way that addresses the multitude of potential scenarios the way the HCM or HERS-

ST can, because of the time required to develop, code, run, and analyze the many different reliability scenarios that would be required to accurately estimate reliability."

Exhibit 9-12. Comparison of Travel Time Reliability Analysis Methods

	SHRP 2 C11	PPEAG	Oregon HERS-ST	Simulation	HCM
Scenarios used	1	1	1/100s*	≤10	100s to 1,000s
Scenario generation process	NA	NA	NA/Manual*	Manual	Automated
Facility types covered	All	Freeways (extendable to all)	All	All	Freeways, urban streets
Required inputs	FFS, v/c, # lanes	FFS, v/c, # lanes, average speed	Obtained from HPMS	All required by simulation tool	All required for freeway facility analysis
Local adjustment capability	No	Values used to generate input data	Scenario generation	Inputs, scenario generation	Inputs, scenario generation
Reliability measures output	Most common	Most common	Most common/ any*	Any	Any
Creates travel time distribution	No	No	No/Yes*	Creates sub-distributions for each scenario	Yes
Reliability reporting period	Single analysis hour for all weekdays in one year**	1–24 analysis hours for all weekdays in one year	Weekday peak hour for one year	Typically, 1+ analysis hours for all weekdays in one year	Any, up to one year
Models weather impacts	No	No	No/Yes*	No	Yes
Models incident impacts	Indirectly	Indirectly	Indirectly/Yes*	If included as scenarios	Yes
Models work zone impacts	No	No	No/Yes*	If included as scenarios	Yes

Notes: NA = not applicable, FFS = free-flow speed, v/c = volume-to-capacity ratio.
*In a batch-processing application using multiple scenarios.
**Calculations can be repeated for additional weekday analysis hours if desired.

SHRP 2 Project C11 Method

This method estimates delay due to recurring and nonrecurring congestion using just two inputs: volume-to-capacity ratio and facility type (freeway, arterial, collector, ramp, local road). Facility type is used as a proxy for free-flow speed. Predictive equations are then used to estimate common reliability performance measures. The method is capable of forecasting reliability impacts and costs for individual projects and can be applied to any roadway type.

Roadway segments are the basic unit of analysis. Segments can be of any length, but it is recommended that they not be so long that their characteristics change dramatically along their length. Reasonable segment lengths would be:

- *Freeways: between interchanges;*
- *Signalized highways: between signals; and*
- *Rural highways (non-freeways): 2–5 miles.*

The method first estimates the mean TTI. The mean TTI then becomes an input to other predictive equations for estimating:

- *Recurring delay (hours)*
- *Incident delay (hours)*
- *Total delay (hours)*
- *95th-percentile TTI*
- *80th-percentile TTI*
- *50th-percentile TTI*
- *Percent of trips < 45 mph*
- *Percent of trips < 30 mph*
- *Cost of recurring delay*
- *Cost of unreliability*
- *Total congestion cost*

The reported reliability values apply to a single weekday analysis hour (the hour used in calculating the volume-to-capacity ratio supplied to the method) over the course of a year. The results from multiple calculations can be combined and weighted to produce reliability values for longer weekday study periods

Oregon HERS-ST Method

The HERS-ST software does not directly calculate reliability performance measures. However, ODOT has used HERS-ST to generate the inputs required for the SHRP 2 C-11 mean TTI equation, namely: free-flow speed, recurring delay rate, and incident delay rate. Once the mean TTI has been determined, all of the other performance measures described above for the SHRP 2 C11 method can also be predicted.

ODOT has also demonstrated the application of HERS-ST for developing reliability scenarios combining a variety of severe weather, incident, and work zone events. Appropriate demand and capacity, and free-flow speed adjustments for a given scenario are made in HERS-ST before rerunning the model. The individual scenario results are then weighted by their probability of occurrence when calculating an overall performance measure result. Because HERS-ST results apply to individual roadway sections, they may not fully reflect the delay associated with queue spillback from one section into other upstream sections. The HERS-ST method can be applied to any roadway type, for a reliability reporting period consisting of the weekday peak hour over an entire year.

Exhibit 9-14 SHRP 2 C11 Implementing Tool Comparison

Overview	SHRP 2 C11 Reliability Tool	PPEAG Tool	ODOT HERS-ST
Tool Overview			
Source	tpics.us/tools	hcmvolume4.org	ODOT
Cost	Free	Free	Free
Operating system	Windows/Mac	Windows/Mac	Windows
Installation required	No (need Excel)	No (need Excel)	Yes
Widespread use	Low	Low	Low
Data source for reliability inputs	Defaults or another tool	Calculated	Imported from HPMS
Reliability calculations	Automated	Manual or separate spreadsheet	Manual or separate spreadsheet
Staff and Support Needs			
Learning curve	Low	Low	Medium
Complexity	Low	Medium	Medium
Training available	○	○	
User guide	●	◐	
Instructional videos	○	○	○
Technical support	○	○	
Specialized Features			
Congestion cost estimates	●	○	○

Notes: ● = fully supported, ◐ = partially supported, ○ = not supported.

Current Applications and Thresholds/Targets

ODOT's 2020 Statewide Congestion Overview utilized the thresholds below to categorize segments of the interstate highway, from Table 10 of the document:

Reliability Level	Planning Time Index Value	Interpretation
Reliable	Less than 1.33	Average travel speed is no less than 25 percent below posted speed
Moderately Unreliable	1.33 ≤ PTI < 2.0	Average travel speed is between 25 to 50 percent below posted speed
Highly or Extremely Unreliable	Greater than or equal to 2.0	Average travel speed is at least 50 percent below the posted speed limit

National: The final rule implementing federal MAP-21 and FAST Act transportation funding legislations requires states and MPOs to measure roadway performance, including four reliability-related system performance measures as part of the National Performance Management Measures (*Federal Register*, Vol. 82, No. 11, January 18, 2017, 23 DRF Part 490).

PSU's research paper discussed these current applications of the measure:

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.

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. Transit on-time performance is used by Metro to support the Congestion Management Process monitoring and reporting.

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

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. Ontime performance and travel time reliability are used by FDOT as current mobility measures.

ODOT APM Chapter 9's comparison of reliability forecasting tools lists widespread use as low for the SHRP 2 C11 Reliability Tool, PPEAG Tool, and ODOT HERS-ST. HCM-implementing tools that are focused primarily on freeway segments are more common with HCS listed as high use, FREEVAL as medium use, and TTR/ATDM as low use.

Evaluation criteria findings

Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Yes – Existing conditions are reasonably simple with use of probe data. Forecasting is more complicated. Most tools available for forecasting travel time reliability are focused on freeways and highways, such as FREEVAL and SHRP 2 C11. As the industry moves forward, there is potential to integrate travel time reliability analyses into DTA modeling by determining travel time distributions.
Is the measure easy for both the public and practitioners to understand?	No – Travel time reliability is not intuitive for the public. Practitioners continue to gain understanding due to national reporting requirement for states and regional agencies.
Does it rely on readily available data and a proven analysis process?	Yes – The data and process are available for calculating existing conditions. Forecasting is more complicated. Most tools available for forecasting travel time reliability are focused on freeways and highways, such as FREEVAL and SHRP 2 C11. As the industry moves forward, there is potential to integrate travel time reliability analyses into DTA modeling by determining travel time distributions. Additional data such as crash/incident data and weather data are needed to better forecast variability in travel times over an analysis period (one year is often used).

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	Measured travel time data and distributions are for all vehicles, including those transporting both people and goods. Depending on the available data, separate truck measures may also be analyzed.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes – It can be calculated on individual facilities with existing data. Proven forecasting processes and tools are currently focused on freeways and highways.
Can it consider land use context?	No – Travel time reliability is not sensitive to land use context.
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes – Existing conditions support needs analyses in system planning. As the industry moves forward and establishes proven methods to forecast travel time reliability on facilities in addition to freeways and highways, these measures will be able to support system planning, including future conditions needs assessments, alternatives analysis, and scenario comparisons.
Can it be used at different scales to compare scenarios or alternatives?	Yes – It can be calculated to compare scenarios and alternatives. For example, FREEVAL is a tool that allows quick comparisons of freeway alternatives once the base condition and data inputs are provided.

Legal Defensibility	
Are the measures able to be applied as a standard and legally defensible?	No – Travel time reliability measures are impacted by non-recurring events, such as weather incidents and crashes.
Can they document incremental changes or impacts and be compared to a standard?	No - Not recommended as a standard.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Yes – Used across the country at the state and MPO levels to comply with the final rule implementing federal MAP-21 and FAST Act transportation funding legislations.
Is the measure already in use by ODOT?	Yes – ODOT reports travel time reliability measures for the Portland Region Traffic Performance Report. If travel time reliability measures are forecasted, the processes currently used are only applicable to limited-access highways.
Is the measure already in use by Metro?	Yes – Metro reports travel time reliability measures to comply with the final rule implementing federal MAP-21 and FAST Act transportation funding legislations.

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – Travel time reliability relates to providing a reliable transportation system.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – ODOT, Metro and local agencies are able to plan and fund projects and programs individually and as a region that maintain or increase travel time reliability for different modes, including operations management. As the industry moves forward and establishes proven methods to forecast travel time reliability on facilities in addition to freeways and highways, additional testing will be needed to determine if the methodologies are sensitive enough to show changes for these projects and/or programs.

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Unknown - Need to test.
Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	No – Not currently forecastable except on limited-access highways.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	Yes – Travel time reliability can support evaluation of the OTP goals related to reliability of the vehicle system.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	No - The solutions and mitigation measures are not always affordable for this measure. Capacity enhancements could be explored, which are typically achieved through additional roadways, additional travel lanes, and wider intersections. These are expensive improvements that frequently require right-of-way and property acquisition. This is why there is emphasis in transportation planning on less expensive solutions such as reducing peak hour vehicle volumes, reducing trip lengths through better land use

planning, and increasing opportunities for trips to be completed by walking, biking, taking transit. As the industry moves forward and establishes proven methods to forecast travel time reliability on facilities in addition to freeways and highways, additional testing will be needed to determine if the methodologies are sensitive enough to show changes for these projects and/or programs.

Advantages/Limitations (best suitability/difficult applications)

ODOT APM Chapter 9 includes this discussion of "Considerations for Performing a Reliability Analysis", focused on freeway reliability analysis. All tools discussed in ODOT APM Chapter 9 for forecasting reliability measures are focused on freeway segments.

"Evaluating reliability is most useful when a roadway facility operates, or is forecast to operate, over capacity on a regular basis, leading to highly variable travel times. In these cases, even if it is not financially or physically feasible to provide extra capacity through road widening, the effects of incremental improvements can still be evaluated in terms of reducing worst-case travel times, providing more consistent travel times, and/or reducing overall person delay.

For future-year forecasting, the additional effort required to conduct a reliability analysis using default values is minimal, once the facility has been coded and calibrated in an analysis tool that implements the HCM freeway facilities method. In other words, if a project would require a facility analysis using the core freeway facility methodology anyway, there is little reason not to go ahead and generate a set of reliability performance measures at the same time.

When forecasting the effects of project alternatives on a roadway's reliability, it is desirable to incorporate local reliability-related input values to the extent that the alternatives affect those inputs. For example, if an intersection improvement would be expected to affect the intersection's crash rate, using a local existing-conditions crash rate in lieu of a national default value is desirable. Similarly, when comparing and prioritizing potential projects on different roadways, it is desirable to account for differences in local traffic demand patterns. If the projects are located in different parts of the state with different climates, then using local weather data would also be desirable. Developing local input data for reliability methods is discussed in APM Chapter 11, Appendix 11F."

The HCM 6th Edition recommends against using the Buffer Index to track travel time trends "because it is linked to two factors that can change: average and 95th percentile travel times. If one factor changes more in relation to the other, counterintuitive results can appear".

This measure is not recommended for regulatory standard or performance target. May be used as an evaluation tool in system plans and plan amendments. Travel time reliability measures are valuable for agencies like DOTs and transit operators as it does a good job of succinctly summarizing "worst case conditions" for operations. It is most beneficial for evaluating existing conditions as it can be difficult to forecast as many of the issues that result in large degrees of unreliability are related to non-recurring events. The best forecasts are derived from statistical relationships of how planning and/or buffer time relate to congestion or redundant pathways. Simulation-based modeling of this is expensive and impractical for many types of studies. This measure has proven hard for the public to understand and relate to. This metric tends to favor widening roads or building dedicated-ROW transit. However, if used to look at short-trip travel time reliability, active modes tend to rate very well since they do not tend to have congestion or factors that make them unreliable very often. This could be a metric that is used as a tool to identify corridors that need investment or better system management for plans or plan amendments.

The following describes how Travel Time Reliability could be applied as a measure for the different applications in system planning.

Identifying system needs and system adequacy in system planning	Travel time reliability measures can be reported for roadway segments along corridors or within large or small subareas to support existing conditions needs and adequacy identification if a target is set for reliability.
Evaluating the transportation/mobility impacts of land use decisions in plan amendments	Current tools and methodologies for forecasting travel time reliability metrics are focused on limited-access highways and freeways. Metro is interested in exploring future applications of the DTA model to support forecasting travel time reliability metrics. It is not known how sensitive the forecasting would be to different land use scenarios.
Evaluating mitigations when a threshold of significance is exceeded	Current tools and methodologies for forecasting travel time reliability metrics are focused on limited-access highways and freeways. Metro is interested in exploring future applications of the DTA model to support forecasting travel time reliability metrics. It is not known how sensitive the forecasting would be to different transportation improvements.

Vehicle Miles Traveled (VMT) per Capita

Vehicle miles traveled (VMT) is the number of miles traveled by motorists within a specified time period and study area. VMT/capita compares this number to a defined population, such as total number of residents or employees within a specific study area. VMT/capita can be calculated to include or exclude different types of trips, such as trips that start or end within the study area, commute trips, freight and delivery trips, etc. VMT/capita can indicate how much people who live and work in a study area must drive to meet their obligations and daily needs. Since most vehicles are powered by internal combustion engines, GHG emissions tend to rise and fall with VMT; however, this relationship is likely to weaken as electric vehicles become more common.

Relationship to Elements

EQUITY	VMT per capita can be evaluated for Equity Focus Areas and for specific demographics and trip types.
ACCESS	Lower VMT/capita indicates better access to destinations, especially for people using non-auto modes.
EFFICIENCY	More efficient land use and transportation systems tend to generate lower VMT/capita as people drive fewer miles to reach their destination.
RELIABILITY	
SAFETY	Lower VMT/capita correlates with improved safety for people traveling in vehicles and for people using other modes, since fewer miles of travel means fewer opportunities to be involved in a crash.
OPTIONS	Does not directly measure access to travel options but tends to decline with improved transit and multimodal access.

Variations of the Measure and Methodology

VMT/capita can be measured in several ways depending on the application. At the RMP, TSP and area planning levels, VMT/capita can be used to evaluate how efficiently a transportation system serves its users. Appropriate metrics include (* indicates a measure used in the 2018 RTP):

- **Total VMT/capita***, which measures all vehicle trips on the network within the region or analysis area, divided by the service population (residents or employees). When calculated using a travel model or multi-zone big data analysis, pass-through trips can be included or excluded, depending on the plan's purview. This metric is most suitable for planning efforts where it is important to capture potential changes in visitor and commercial travel.
- **VMT/resident or VMT/household**, which measures the rate of vehicle travel per person living in the plan area. This can be calculated using a travel model by dividing VMT from all home-based trips by the number of residents or households in the planning area. This is appropriate for plans and development projects where strategies are being considered that would reduce household reliance on auto travel. However, it excludes commercial and non-home-based travel, and therefore may underestimate the VMT associated with home deliveries and trips made by residents while away from home.
- **VMT/worker**, which measures work-related VMT/worker. This is appropriate for plans and development projects where strategies are being considered that would reduce auto commuting.
- **VMT exposure/capita**, which measures Total VMT/capita or Total VMT by speed bin/capita within a defined area, including pass-through trips. This is suitable for analysis in areas where traffic safety and air quality are concerns, particularly for residents, students, or employees whose VMT makes up only a small portion of the total VMT in the area.

At the facility/corridor level, vehicle miles travelled can be compared to person miles travelled (**PMT/VMT**) to evaluate project alternatives that would expand transit service and/or roadway capacity.

Current Applications and Thresholds/Targets

State and Regional

The State of Oregon's Transportation Planning Rule (TPR) defines VMT as vehicle miles of travel by automobiles, light trucks, and similar vehicles used for the movement of people, and specifically excludes VMT by buses and VMT occurring in goods movement (LCDD 660-012-0005 (41)). The TPR requires that Metropolitan Planning Organizations (such as Oregon Metro) "adopt standards to demonstrate progress towards increasing transportation choices and reducing automobile reliance" and approve standards that (among other measures), are unlikely to increase VMT per capita by more than five percent (660-012-0035 (5)). MPOs can ensure that a plan alternative meets the TPR's requirement to develop a multimodal transportation system by demonstrating "that adopted plans and measures are likely to achieve a five percent reduction in VMT per capita over the 20-year planning period"(660-012-0035 (6)).

ODOT reports observed VMT on its facilities using Highway Performance Monitoring System data. ODOT's Analysis Procedures Manual (APM) identifies VMT as an RTP measure and a supplemental measure for TSPs and Project Development.

Metro has evaluated total, per capita, and per employee VMT at the regional level since 2010. Metro's RTP analysis relies on travel model VMT/capita, evaluated as a rate for all members of the service population. The 2018 RTP System Evaluation found that VMT/capita would decline by four percent, assuming the buildout of the 2040 Constrained Projects list along with projected housing, population, and employment growth. Metro also uses VMT/capita as a Climate Smart Monitoring Measure. VMT is currently not being reported by Transportation Analysis Zone[2] or Census Block. Additional work is needed to determine exposure and generation by these metrics.

National

State DOTs commonly use VMT on state facilities as a performance metric. **California** has shifted away from the use of automobile level of service (LOS) at intersections to VMT/capita to evaluate the environmental impacts of new development on the transportation system, and now uses changes in total VMT (including estimates of induced VMT) to evaluate the environmental impacts of new transportation infrastructure.

Evaluation Criteria

Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Yes – It can use Metro travel model to evaluate existing and forecasted VMT/capita
Is the measure easy for both the public and practitioners to understand?	Somewhat intuitive, although nuances of trip type and user population can be challenging to communicate.
Does it rely on readily available data and a proven analysis process?	Yes – It can be evaluated using Metro travel model and well-understood analysis methods.

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	As applied under Oregon's TPR, VMT/capita is focused on person travel. Freight VMT/capita could theoretically be evaluated.
Can it be distinguished for different facility types such as throughways vs arterials?	PMT/VMT can be evaluated at the facility level, but VMT/capita is typically evaluated for a larger geographic area as part of a sub-area plan, citywide TSP, or RTP.
Can it consider land use context?	No; however, VMT/capita typically reflects land use context as well as demographic factors
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes - Total VMT/capita is applicable for system planning and plan amendments only; VMT/resident and VMT/worker are applicable at all levels.
Can it be used at different scales to compare scenarios or alternatives?	Yes – It can be evaluated at regional, city, neighborhood/plan area, corridor/facility, and project levels.

[2] A Transportation Analysis Zone (TAZ) is a unit of geography used in transportation planning and transportation models for aggregating traffic related data.

Legal Defensibility	
Are the **measures able to be applied as a standard and legally defensible?**	Measure could be used to set a standard.
Can they document incremental changes or impacts and be compared to a standard?	Yes - It could be compared to TPR reduction target or to other targets (e.g., 15% reduction standard applied for environmental analysis in California)

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Yes - California evaluates environmental impacts of transportation using VMT/capita; many state DOTs evaluate VMT on state-owned facilities
Is the measure already in use by ODOT?	Yes - ODOT reports VMT on state facilities
Is the measure already in use by Metro?	Yes - VMT/capita is used in RTP analysis

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Unknown – Need to test.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes - VMT/capita typically falls when transit service and non-auto infrastructure are expanded and rises when auto capacity expands; however, VMT/capita also rises along with incomes

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Yes - VMT/capita typically falls when transit service and non-auto infrastructure are expanded and when land use patterns allow for reduced trip lengths.
Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	Yes - In compact, mixed-use neighborhoods VMT/capita tends to be lower than in sprawling neighborhoods dominated by single land uses. Land use plans that forecast a reduction in VMT/capita from current conditions would therefore align with Metro's 2040 Growth Concept.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	Yes - Low VMT/capita aligns with compact growth and transportation options.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	Primarily changed by land use and availability of non-auto modes which have a wide range of costs in a constrained environment.

Advantages/Limitations (best suitability/difficult applications)

For RTPs, TSPs, and transportation infrastructure programs, VMT per capita is the preferred way to evaluate VMT as a transportation planning metric/standard as it is not skewed by population or employment growth. At the individual project level, complexities arise when attempting to forecast and account for VMT; if VMT/capita is to be used as a measure of development impacts, model outputs of VMT/capita at the sub-area level can be used to evaluate likely VMT/capita of a new development project. Calculations are less complex for large area plans, but standards must be established in terms of specific VMT metrics (such as Total VMT/capita vs. VMT/resident). VMT/capita tends to rise along with incomes, so it is important differentiate between populations that are auto-dependent due to displacement/housing costs/limited transit options (e.g., East Portland) and populations that are auto-dependent by choice (e.g., West Hills). Forecasting VMT/capita requires the use of a travel model, which could increase the demand for access to Metro's travel model.

The following describes how VMT per Capita could be applied as a measure for the different applications in system planning.

Identifying system needs and system adequacy in system planning	TSPs/Large Subareas –Forecasted VMT/capita can be compared to the existing condition to determine if land use changes or improvements to multimodal access are needed or would help to reduce VMT/capita. This does not directly measure system adequacy Corridors/Smaller Subareas – Forecasted PMT/VMT along a corridor could indicate need for expanded travel options as travel demand models are sensitive to major/programmatic transportation infrastructure
Evaluating the transportation/mobility impacts of land use decisions in plan amendments	TSPs/Large Subareas –Forecasted VMT/capita could be compared to the existing condition to determine if the plan amendment would result in a reduction in VMT/capita or an increase which could be a negative impact that requires mitigation or changes to the plan. Smaller Subareas – Travel demand models are unlikely to reflect small changes in land use density and diversity; the Metro travel model's sensitivity should be evaluated to identify

Evaluating mitigations when a threshold of significance is exceeded	System Planning/Subarea Planning Level – Metro travel demand model can be used to evaluate the VMT/capita differences between plan alternatives with different levels of land use density and diversity Development – Travel models are not sensitive to project-level mitigations for VMT/capita, such as transportation options programs and incentives to reduce car ownership and driving

Access to Destinations/Opportunity

The number of essential destinations within a certain travel time or distance, by different modes. Metro's 2018 RTP defines accessibility as "the ability to reach desired goods, services, activities and destinations with relative ease, within a reasonable time, at a reasonable cost and with reasonable choices… Locations that can be accessed by many people using a variety of modes of transportation generally have a high degree of accessibility."

Relationship to Elements

EQUITY	Measuring and having standards for access to destinations and opportunity will result in a system that increases opportunity for all people, not just those that own or travel in vehicles. This will help reduce barriers and disparities in access to affordable travel options. This measure can also be evaluated for Equity Focus Areas and for destinations that are important to specific communities.
ACCESS	This measure evaluates potential increases in people's access to opportunities, social connections, and goods.
EFFICIENCY	This measure indicates how efficiently people can meet their needs by traveling using different modes.
RELIABILITY	
SAFETY	
OPTIONS	This measure can be evaluated for specific modes and compared across multiple modes (e.g., comparing the number of destinations accessible with 30 minutes of transit travel time versus 30 minutes of auto transit time).

Variations of the Measure and Methodology

Access to destinations is typically measured in terms of the number of destinations accessible from a single origin point within a defined travel time at a defined time of day. The measure can be calculated in several different ways, as described below. Items with an asterisk (*) were include in Metro's 2018 RTP.

- Access to jobs and community places by mode (included in Metro's 2018 RTP)
- Access to jobs/community places using low-stress networks, where BLTS and/or PLTS analysis is already complete or can be calculated using available data

Access to destinations is often used to compare how well the transportation system serves people using different modes (e.g., transit users vs. auto users) and people living in different locations (e.g., comparing what can be accessed from the center of a Census tract in an Equity Focus Area vs. what can be accessed from the center of a Census tract in a higher-income neighborhood).

Defining key destinations and opportunities is essential to evaluating access to destinations and opportunity in a meaningful way. Access to jobs is one component of access to opportunities, which can also include access to destinations that provide education and training. Community destinations are typically understood as places where people can access key services and meet their daily needs. Typically, they include public agency offices, healthcare providers, libraries, community centers, schools, places of worship, and grocery stores and other essential shopping destinations; they can also be defined more narrowly or broadly depending on the community of focus. For example, when evaluating how well members of an immigrant community can access destinations and opportunities, emphasis could be placed on destinations that are culturally relevant and on jobs in sectors where community members are most likely to work.

To evaluate existing conditions, access to destinations and opportunities by multiple modes can be evaluated using detailed GIS networks and transit performance data. Ideally, the networks include data on vehicle speeds at different times of day to reflect the effects of traffic congestion. However, travel demand models are needed to evaluate travel times for different modes under forecasted conditions. To provide consistent results for existing and forecasted conditions, Metro spatial analysts recommend combining GIS data on destinations with travel times calculated using Metro's travel model.

Metro's Economic Value Atlas provides data on access to low-wage and middle/high-wage jobs accessible within 30 minutes by all travel modes at the Census Tract level, calculated using the regional travel demand model.

Current Applications and Thresholds/Targets

State/Regional

In its *Analysis Procedures Manual* (APM), **ODOT** identifies accessibility to destinations for motor vehicles, pedestrians, and bicyclists as a recommended performance measure for Regional Transportation Plans and as supplemental measure for TSP and Designated MMA, and a screening measure for Facility Plan and Project Development.

Access to community places and jobs are used in **Metro**'s 2018 RTP as key performance measures for addressing Goal 1 (Vibrant Communities) and Goal 9 (Equitable Transportation). For Metro's 2018 RTP, staff used Metro's travel demand model to identify the how many low and middle-wage jobs (jobs with annual wages of $65,000 or less) could be reached in a typical commute time using different travel modes at the regional level and for both Equity Focus Areas and non-Equity Focus Areas. The 2018 RTP evaluated access to transit in terms of the percentage of households within walking distance of high-quality transit; it also identified housing and transportation costs as an accessibility measure but did not define a methodology for calculating those costs.

The City of Portland's 20-Minute Neighborhoods program, incorporated into the city's Climate Action Plan, sets a target of enabling 90 percent of its residents to meet their basic needs within a 20-minute walk or bicycle ride.

National

Access to destinations has been used for a variety of studies around the United States. The Department of Housing and Urban Development has used access to destinations to inform the allocation of Low-Income Housing Tax Credits to proposed affordable housing developments. The Federal Highway Administration (FHWA) worked with the Atlanta Regional Council create travel sheds showing the number of homes and jobs reachable by multimodal networks in Atlanta, Georgia.

Evaluation Criteria

Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Yes, so long as destinations are clearly defined.
Is the measure easy for both the public and practitioners to understand?	Yes, access to destinations is easy to explain and for the public to understand.
Does it rely on readily available data and a proven analysis process?	Yes, data analysis and processes are well understood; however, calculation of this performance measure requires the use of Metro's travel demand model.

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	Focused on people's access to destinations, including access to goods available at retail stores.
Can it be distinguished for different facility types such as throughways vs arterials?	Typically evaluated at the area level, although it could theoretically be evaluated for different facility types.
Can it consider land use context?	No
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes – It can be applied to system planning, plan amendment, and development review applications; however, individual developments would generally have limited effects on access to destinations.
Can it be used at different scales to compare scenarios or alternatives?	Yes – It can be used to compare scenarios and project or plan alternatives, particularly for land use plans that would allow for substantial housing and jobs growth and for transportation projects that would improve access by transit, bicycling, and/or walking.

Legal Defensibility	
Are the measures able to be applied as a standard and legally defensible?	Challenging to set a standard but a target could be set.
Can they document incremental changes or impacts and be compared to a standard?	Not recommended as a standard; however, performance targets could be set for long-range access improvements.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Somewhat – has been used to assess equity and outcomes for land use and transportation system plans and to prioritize sites for affordable housing funds, but generally access to destinations is used to develop targets for long-range plans rather than establishing a standard that must be achieved.
Is the measure already in use by ODOT?	Yes – Recommended for use in Regional Transportation Plans.
Is the measure already in use by Metro?	Yes – Used to evaluate equity in Metro's RTP

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – Access to destinations and opportunity directly measures access and relates to providing an equitable transportation system with multiple travel options.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – Implementing the regional vision for growth in jobs and housing and planned improvements to multimodal (especially transit) systems will improve access to destinations and opportunity.

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Yes – Compact, mixed-use areas served by multiple transportation modes tend to have better access to destinations and opportunity than less-dense areas with segregated land uses.
Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	Not directly, however, reducing barriers to adding housing and jobs would improve access to destinations and opportunity.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan (OTP) goals and policies?	Yes – Evaluating multimodal access to destinations and opportunity is consistent with the Statewide Transportation Planning Rule and the OTP, which require developing a balanced multi-modal system.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	In some cases, multimodal access to destinations could be substantially improved through closing gaps in walking and bicycling networks or reallocating existing right-of-way to transit vehicles, but access improvements most often result from large-scale changes to land use and transportation options.

Advantages/Limitations (best suitability/difficult applications)

Access-related performance metrics have become more common with technical advances in spatial analysis and data, which allow analysts to quickly evaluate many origins and destinations. Access performance metrics excel at linking transportation and land use; however, future land use changes cannot be forecasted with confidence, which makes assessments of future access somewhat uncertain. Access to destinations and opportunities can be improved by both transportation investments and changed land uses; it is therefore a particularly strong performance metric for plan amendments and system planning where different land use and/or transportation infrastructure scenarios are being evaluated.

This measure is suited to comparing alternative plan and/or project scenarios that would increase jobs and/or housing or that would expand multimodal transportation options.

Metro's travel demand model can be used to develop travel times from specific locations for both existing and future conditions; combined with data on key destinations from Metro's Data Center, access to destinations can be evaluated. Changes to travel time by mode for specific scenarios can either be modeled using the travel demand model or estimated based on project characteristics. Metro's regional Dynamic Traffic Assignment model could be applied to evaluate peak hour travel times, when traffic congestion reduces access; however, the DTA model has only been calibrated for specific areas within the region (e.g., the I-205 corridor) and may not provide meaningful results for all case study areas.

The following describes how Access to Destinations could be applied as a measure for the different applications in transportation planning.

identifying system needs and system adequacy in system planning	TSPs/Large Subareas – Metro's travel demand model could be used to evaluate destinations and opportunities accessible by multiple modes with and without the proposed system improvements Corridors/Smaller Subareas – Could be used to evaluate access to destinations and opportunities with and without a project that would change travel time and speed for one or more travel modes
evaluating the transportation/mobility impacts of land use decisions in plan amendments	TSPs/Large Subareas – Metro's travel demand model could be used to evaluate destinations and opportunities accessible by multiple modes with and without added housing and jobs

	Corridors/Smaller Subareas – Less relevant for this scale of analysis
Evaluating mitigations when a threshold of significance is exceeded	Not recommended for use as a standard; however, should be considered when evaluating different project and/or plan scenarios

Level of Traffic Stress

Level of traffic stress (LTS) classifies points and segments on routes into different categories of stress ranging from 1 (low stress) to 4 (high stress) based on factors that correlate to the comfort and safety of the bicyclist or pedestrian using that facility.

Relationship to Elements

EQUITY	Measuring and having standards for the level of traffic stress experienced by people walking and biking will result in a system that enhances mobility for all people, not just those that own or travel in vehicles. This will help reduce barriers and disparities in access to affordable travel options. This measure can also be evaluated for Equity Focus Areas and for specific facilities where equity across modes and times of day may be a focus.
ACCESS	Providing low stress bicycle and pedestrian networks increases accessibility for non-motorized users, especially when these networks are planned in accordance with essential destinations and transit stops.
EFFICIENCY	
RELIABILITY	
SAFETY	Variables related to lower stress bicycle and pedestrian facilities are linked to user comfort and often to safety as well. Providing dedicated space for cyclists and pedestrians, increasing buffer distance to the vehicle travel lanes, and lower vehicle travel speeds are LTS variables that are indicators for lower and less severe crash rates.
OPTIONS	Providing a low stress bicycle and pedestrian network increases the opportunities for residents and visitors to use non-vehicular travel options to serve their trip needs.

Variations of the Measure and Methodology

Throughout the country, many different BLTS methodologies are being applied to support bicycle facility planning. The original methodology, described in "Low-Stress Bicycling and Network Connectivity,"[3] was published by Mineta Transportation Institute (MTI) in 2012. This methodology has been refined in the years since, with ODOT adopting a version of it in its Analysis Procedures Manual. In 2019, MTI published a study that applied multiple LTS methodologies and compared the results to crowdsourced feedback on bicycling comfort ("Evaluating Alternative Measures of Bicycle Level of Traffic Stress Using Crowdsourced Route Satisfaction Data"[4]). In the 2019 report, Harvey et al. reviewed seven BLTS methodologies that were currently in use to compare data needs and outputs, which included ODOT's APM methodology prior to its changes in 2020.

Adapted Tabled Based on MTI 2019 Report

Note: **Bolded variables** are also used in ODOT's APM BLTS methodology.

Method	Description	Variables
ODOT	The Oregon Department of Transportation (ODOT) developed their own LTS method to support bicycle planning within Oregon.	**Bike Lane Width (Continuous)** **Parking Lane Width (Continuous)** **Speed Limit (Continuous)** **Lanes per Direction (Count)** **Bike Lane Frequently Blocked (Binary)** **Center line (Binary)** **Functional Class (Categorical)** **Average Daily Traffic (ADT) (Count)** **Right Turn Lanes (Count)** **Right Turn Lane Length (Continuous)** **Right Turn Lane Speed (Continuous)** **Bike Lane Aligned Through Intersection (Binary)** **Left Turn Lanes (Count)** **Traffic Signal at Intersections (Binary)** **Pedestrian Refuge at Intersections (Binary)** **Cross Street Speed Limit (Continuous)** **Cross Street Lanes (Count)**
Conveyal	This method was developed by the transportation consultancy and software development firm Conveyal and was designed explicitly to require minimal data inputs, almost all of which were available through OSM. The Conveyal method was developed in partnership with the World Bank in an effort to provide high-level analyses in nearly any location worldwide.	**Functional Class (Categorical)** **Lanes (Count)** **Speed Limit (Ratio)** **Bike Lane (Binary)**

[3] Mekuria, Maaza C., Peter G. Furth, and Hilary Nixon. 2012. Low-Stress Bicycling and Network Connectivity." Mineta Transportation Institute. Retrieved from: https://transweb.sjsu.edu/research/Low-Stress-Bicycling-and-Network-Connectivity
[4] https://transweb.sjsu.edu/sites/default/files/1711-Fang-Bicycle-Level-of-Stress-Crowdsourced-Route-Satisfaction.pdf

Furth	Furth published this method, which he called "LTS 2.0," in order to streamline data requirements and improve geographic generalizability.	**Bike Lane Width (Continuous)** **Parking Lane Width (Continuous)** **Center line (Binary)** **ADT (Count)** **Speed Limit (Continuous)** One Way (Binary)
Lowry	This method with streamlined data inputs was published within a broader study on bicycle facility stress.	Residential Land Use (Binary) **Lanes (Continuous)** **Speed Limit (Continuous)** Bike Facility (Categorical)
Mekuria	This was the "original" LTS method, developed by a Mineta Transportation Institute research project.	**Bike Lane Width (Continuous)** **Right Turn Lanes (Count)** **Right Turn Lane Length (Continuous)** Bike Lane Continuous at Intersection (Binary) **Bike Lane Aligned Through Intersection (Binary)** **Right turn lane speed (Continuous)** **Parking Lane Width (Continuous)** **Lanes Per Direction (Count)** Residential Land Use (Binary) High Parking Turnover (Binary) **Speed Limit (Continuous)** **Bike Lane Frequently Blocked (Binary)** Raised Median (Binary) **Center line (Binary)** **Pedestrian Refuge at Intersections (Binary)** **Traffic Signal at Intersections (Binary)** **Cross Street Speed Limit (Continuous)** **Cross Street Lanes (Count)**
Montgomery	Montgomery County, MD developed their own LTS method to support their 2018 Bike Master Plan.	**Bike Facility Width (Continuous)** Bike Facility Type (Categorical) **Speed Limit (Continuous)** **Parking Lane Width (Continuous)** Parking (Binary) High Parking Turnover (Binary) **Center line (Binary)** **ADT (Count)** Residential Land Use (Binary) Bike Facility Buffer Type (Categorical) Many Driveways (Binary) Raised Median (Binary)
PFB	This method was developed by People for Bikes (PFB) in order to conduct LTS analyses throughout the United States using OSM data.	Bike Facility (Categorical) Residential Land Use (Binary) **Speed Limit (Continuous)** **Lanes per Direction (Count)** Parking (Binary) Curb-to-Curb Width (Continuous)

Harvey et al included these recommendations when comparing the methodologies:

- *System planning: More high-level/low-data methods using GIS (e.g. Conveyal); apply more data-intensive methods for project development*
- *Corridor planning: More detailed/variable-intensive methods using GIS and/or spreadsheet tools (e.g. ODOT APM)*
- *Modal plans: For large areas and/or diagnostics, use a lower-data method; apply more data-intensive methods when deciding between preferred facility types and/or developing projects*

Unlike BLTS, PLTS is less commonly used outside of Oregon. The following variables are used to conduct ODOT's PLTS methodology, established in the APM:

- Segment data
  - Sidewalk conditions and width
  - Buffer type and width
  - Bike lane width
  - Parking width
  - Number of lanes and posted speed
  - Illumination presence
  - General land use
- Crossing data
  - Functional class
  - Number of lanes and posted speeds
  - Roadway ADT (optional)
  - Sidewalk ramps
  - Median refuge & illumination presence
  - Signalized general intersection features

Current Applications and Thresholds/Targets

PSU's research paper discussed these current applications of the measure:

- *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.*
- *Metro: None identified.*
- *Oregon: Level of traffic stress is included in the Scappoose TSP as a performance measure (and has since been used in many others, in particular for bike and pedestrian specific updates).*
- *Nationally: The Federal Highway Administration (FHWA) calculated bicycle level of traffic stress for a case study in Fort Collins, Colorado to assess low-stress networks and route directness. Florida Department of Transportation (FDOT) sanctioned the use of bicycle level of traffic stress for when designing multimodal streets. Ada County Highway District in Idaho announced a new policy in summer 2021 to set updated LOS and LTS thresholds for arterials. The adopted thresholds increase the acceptable vehicle LOS to E while updating the BLTS and PLTS thresholds to 2.*

BLTS

ODOT's TSP guidelines for determining bicycle solutions states *"Chapter 14 of the Analysis and Procedures Manual, or APM, identifies four methodologies for evaluating bicycle facilities. Per the APM, Bicycle Level of Traffic Stress, or BLTS, is the most appropriate methodology for a TSP. BLTS applies a rating system that reflects the stress a cyclist experiences on a roadway, ranging from BLTS 1 (little traffic stress) to BLTS 4 (high traffic stress). The analysis results can help identify a range of potential solutions for improving the stress of a roadway, which may involve modifications to other elements of the transportation system."*

APM Chapter 14.4.2 discusses BLTS targets, stating *"A BLTS 2 is often used as the target as it will typically appeal to the majority of the potential bike-riding population and maximize the available bicycle mode share. Other BLTS levels may also be used as targets depending on a jurisdiction's needs and maturity of the available bike network.*

When evaluating networks near schools (within ¼ mile), the desirable level of traffic stress is BLTS 1 since BLTS 1 is targeted at 10-yr olds (5th grade) or parents of younger children. Elementary school-age children should be able to travel between homes and schools without having to cross arterial streets (LTS 3 and 4). Ideally, elementary schools and their related attendance boundaries should be placed to allow at least a few BLTS 1 routes. Middle and high school placement may not allow only BLTS 1 routes but routes should be no more than BLTS 2 since older students can use these without difficulty. When applying BLTS and PLTS, a common target is LTS 2 to support a wider range of users."

PLTS

ODOT's TSP guidelines for determining pedestrian solutions states "*Chapter 14 of the Analysis and Procedures Manual, or APM, identifies four methodologies for evaluating pedestrian facilities. Per the APM, Pedestrian Level of Traffic Stress, or PLTS is the most appropriate methodology for a TSP. PLTS applies a rating system that reflects the stress a pedestrian experiences on a roadway, ranging from PLTS 1 (little traffic stress) to PLTS 4 (high traffic stress). The analysis results can help identify a range of potential solutions for improving the stress of a roadway, which may involve modifications to other elements of the transportation system."*

APM Chapter 14.5.3 discusses PLTS targets, stating *"PLTS 2 is generally a reasonable minimum target for pedestrian routes. This level of accommodation will generally be acceptable to the majority of users. Higher stress levels may be acceptable in limited areas depending on the land use, population types, and roadway classifications, but they will generally not be comfortable for most users. Each land use has specific needs for the pedestrian network and study areas should have multiple targets for the different areas.*

Facilities within a quarter mile of schools, and routes heavily used by children should use a target of PLTS 1. This is because of the large number of children that may use the system with little or no adult supervision. The area around elementary schools should contain no PLTS 3 or 4 because of the associated safety concerns and the discouraging effect that such facilities have on walking rates. Pedestrian facilities near middle and high schools may include PLTS 2, since the students are in the older age group, but PLTS 1 routes are preferred.

Other land uses should also have a target of PLTS 1; these include downtown cores, medical facilities, areas near assisted living/retirement centers, and transit stops. Downtown cores, for example, should *have wide sidewalks with street furniture. Roadways near medical facilities and residential retirement complexes should have sidewalks in good condition with adequate width.*

Transit stops should have facilities that connect the passengers from the origin of their trip to the destination of their trip. The PLTS should be overlaid with the typical ¼ mile walking distance to transit for transit routes (or a roadway for a proposed route) to fully show where PLTS 1 is desired.

When setting targets, looking at the end user is vital. The land use that surrounds a corridor, pedestrian walking behavior, and local demographics will all influence the target PLTS for a corridor."

Evaluation Criteria Findings

Technical Feasibility

Is the performance measure reasonably simple to analyze?	LTS measures are more complex due to the number of variables, requiring significant data or a set of assumptions to apply at the system level if data is unavailable.
Is the measure easy for both the public and practitioners to understand?	Yes – This measure relatively easy to understand and commonly used in system planning in Oregon.
Does it rely on readily available data and a proven analysis process?	Yes – ODOT provides a proven analysis process, which can be applied in common applications like ArcGIS or Microsoft Excel. This measure relies on detailed GIS data at a facility level, which a local agency may or may not have. If data is not available, the process requires significant time collecting field data, reviewing aerial imagery, or setting variable assumptions.

Flexibility for Intended Planning Applications and Different Contexts

Can it be focused on people, goods, or both?	Related to person travel only.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes – It can be calculated on individual facilities.
Can it consider land use context?	Yes – One of the variables for PLTS is land use context. In addition, the targets for LTS measures can be set in consideration of land use, such as targeting an LTS of 1 within the walkshed of a school or major transit stop.
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes – It can be applied to all planning applications.
Can it be used at different scales to compare scenarios or alternatives?	Yes – LTS measures are relevant at a system scale for planning low stress networks and also applicable at the intersection or link level. Scenarios and alternatives that impact the LTS variables can be compared, such as

	added/removed vehicle lanes, new bicycle or pedestrian facilities, or impacted ADT.

Legal Defensibility	
Are the measures able to be applied as a standard and legally defensible?	Measure could be used to set a standard.
Can they document incremental changes or impacts and be compared to a standard?	It is sensitive to incremental improvements such as adding illumination, widening the sidewalk, or providing a buffer but degree of change or impact within an LTS level cannot be measured (similar to the challenge with LOS). Volume changes can impact BLTS on mixed traffic segments and at unsignalized intersections.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Yes – Used across the country at the state, county, and local levels.
Is the measure already in use by ODOT?	Yes – ODOT's TSP guidance suggestions using LTS measures and the APM establishes the methodologies and it's used in local planning.
Is the measure already in use by Metro?	No – LTS measures are not specifically used by Metro.

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – LTS assessments link to accessibility and travel options.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – ODOT, Metro and local agencies are able to plan and fund projects and programs individually and as a region that lower the stress of facilities and intersections.

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Yes – Low stress networks support compact, urban form by allowing for more comfortable local trips on bike or by foot. PLTS evaluations review land use context and LTS targets can be set based on land use context and corridor characteristics.
Can it be used to assess supportiveness to planned land uses and reduction of	Yes – LTS measures can help assess if the transportation system can support planned land uses.

barriers to implementation of planned land uses?	
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	Yes – Statewide Planning Goals require transportation plans to support land use plans. In addition, LTS measures support OTP goals for developing a balanced multi-modal system.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	Bicycle and pedestrian facility mitigations can be relatively low-cost. Although meeting a target LTS of 2 could be financially restrictive on some facilities that are already built, are near wetlands or other barriers, or that have minimal ROW.

Advantages/Limitations (best suitability/difficult applications)

Not recommended for regulatory standard. Good candidate for performance target in some contexts. May be used as an evaluation tool in system plans and plan amendments. Could be embedded into a customized MMLOS.

One limitation is that automating LTS evaluations can be difficult, as described by Harvey et al:

"Authors of LTS methods tend to describe them as being straightforward, but in fact operationalizing them can be fairly complex. The Mekuria method was defined by a series of seven lookup tables related to different combinations of bike lane presence, parking presence and intersection treatments. Within each table, LTS values were identified by cross-referencing potential combinations of roadway attributes (See Appendix C). Many of the tables also included footnotes that added additional levels of decision making complexity, sometimes including additional variables. Multiple tables might have been applicable to a given street segment. Following the "weakest link" principle, each segment was assigned the maximum LTS value derived from any relevant table. While the table system was fairly intuitive for manual classification, it did not translate efficiently into a coding algorithm. Other LTS systems were also documented by similar series of lookup tables."

The following describes how LTS could be applied as a measure for the different applications in system planning.

Identifying system needs and system adequacy in system planning	TSPs/Large SubAreas – LTS evaluations via ArcGIS can identify needs for providing a low-stress bicycle and pedestrian network. Corridors/Smaller SubAreas – Utilize to identify needs for transportation facilities adjacent to bicycle and pedestrian trip generators or land uses and along bicycle and pedestrian priority corridors.

Evaluating the transportation/mobility impacts of land use decisions in plan amendments	PLTS evaluations may change depending on the land use but may not be sensitive to a site-specific change. BLTS is impacted by land use changes (i.e. volume changes) on mixed traffic segments and at unsignalized intersections.
Evaluating mitigations when a threshold of significance is exceeded	ODOT APM LTS methodologies are specific in showing potential mitigations to meet an LTS target.

Multimodal Level of Service (MMLOS)

MMLOS describes a group of performance measures that evaluate the quality and level of comfort of facilities for different travel modes based on factors that impact mobility from the perspectives of pedestrians, cyclists, and transit riders, respectively. It is intended to provide a parallel to automobile LOS at intersections; however, there is no nationally accepted best practice for evaluating MMLOS that is equivalent to that for auto LOS.

Relationship to Elements

EQUITY	Measuring and having standards for the quality of service of all modes will result in a system that enhances mobility for all people, not just those that own or travel in vehicles. This will help reduce barriers and disparities in access to affordable travel options. This measure can also be evaluated for Equity Focus Areas and for specific facilities where equity across modes and times of day may be a focus.
ACCESS	Providing high quality bicycle and pedestrian facilities increases accessibility for non-motorized users, especially when these networks are planned in accordance with essential destinations and transit stops.
EFFICIENCY	
RELIABILITY	
SAFETY	Variables related to better MMLOS for bicycle and pedestrian facilities are linked to user comfort and often to safety as well.
OPTIONS	Evaluates how well transit, bicycle, and pedestrian modes are served by the facility.

Variations of the Measure and Methodology

Multiple approaches to evaluating MMLOS have been tested and applied around the US. Typically, MMLOS measures are used to evaluate transportation project alternatives that would affect conditions for people walking, bicycling, or taking transit.

The best-known MMLOS methodology was developed for the Transportation Research Board's *Highway Capacity Manual* (HCM 2010) and includes performance measures at the street segment and intersection level for all four major modes. ODOT has adapted both qualitative and quantitative versions of the HCM 2010 MMLOS methodology:

- Quantitative MMLOS methodologies: Adaptation of HCM 2010 methodologies. These are best applied at the corridor or facility level where alternatives are defined in detail.
- Qualitative Multimodal Assessment (QMA) methodology: Adaptation of ODOT's quantitative MMLOS methodologies. This is best applied at the TSP level where alternatives are not defined in detail and/or data are limited.

ODOT has developed Excel-based calculator tools to streamline analysis for its quantitative methodology – see **Exhibit 14-30** from the ODOT APM (below).

Many other methods for calculating MMLOS have been developed, generally by and for individual agencies and jurisdictions. By comparison, Level of Traffic Stress metrics have been applied widely across the US, since the data inputs required to evaluate them tend to be more readily available than the data needed to evaluate MMLOS performance measures.

Exhibit 14-30 ODOT Multimodal Level of Service Methods in the APM

APM Section	Method/Facility Type	Description	Calculator
14.9	Segment Pedestrian LOS	PLOS based on a simplified re-estimation of the original video clip data used to create the HCM Pedestrian LOS using fewer variables	Simplified MMLOS Calculator
14.10	Segment Bicycle LOS	BLOS based on a simplified re-estimation of the original video clip data used to create the HCM Bicycle LOS using fewer variables	Simplified MMLOS Calculator
14.11	Segment Separated Bicycle Lanes	BLOS of separated bicycle lanes. Augments the re-estimated HCM bicycle methodology	Separated/Buffered Bikeways Calculator
14.12	Segment Buffered Bike Lanes	BLOS of buffered bicycle lanes. Augments the re-estimated HCM bicycle methodology	Separated/Buffered Bikeways Calculator
14.13	Shared-use Paths	BLOS and PLOS for paved shared-use (multi-use) paths. Full application of the HCM method with addition of computational engine.	Shared Path Calculator
14.14	Unsignalized Intersections (TBD)	TBD	TBD
14.16.1	Pedestrian Signalized Intersection LOS	PLOS for pedestrian crossings at a signalized intersection.	Pedestrian and Bicycle Signalized Intersection MMLOS Calculator
14.16.2	Bicycle Signalized Intersection LOS	BLOS for bicyclist crossing at a signalized intersection.	Pedestrian and Bicycle Signalized Intersection MMLOS Calculator
14.17	Transit LOS	Segment Transit LOS for fixed-route transit vehicles operating in exclusive or mixed-use lane. May include buses, BRT, streetcars, or LRT operating in mixed mode street-running conditions. Based on the HCM Transit LOS method using default assumptions.	Simplified MMLOS Calculator

Current Applications and Thresholds/Targets

State/Regional

MMLOS measures are included in the **ODOT** Analysis Procedures Manual (APM) as recommended performance measures for Facility Plans, Development Review, and Project Development, and as a supplemental measure for Designated Multimodal Mixed-Use Areas (MMA). ODOT evaluates MMLOS both qualitatively and quantitatively, depending on the scale of analysis and how well-defined project alternatives are.

National

Many MMLOS methods have been developed across the United States. The 2010 edition of the *Highway Capacity Manual* includes MMLOS performance measures and is used by most jurisdictions in the U.S., although relatively few jurisdictions have adopted multimodal performance standards for their transportation facilities. Several individual jurisdictions, including the San Francisco Department of Public Health and the Cities of Fort Collins and Aspen in Colorado, Charlotte, North Carolina, and Carlsbad, California have developed customized MMLOS evaluation methods and evaluation tools.

These typically address many of the same factors as the HCM 2010 ODOT MMLOS methodologies and are not used as a performance standard. Several jurisdictions, including Charlotte and Fort Collins, refer to these methodologies when developing their standards for street and transportation facility design. Bellevue, Washington used MMLOS to assess the transportation system in their 2014 Comprehensive Plan update and uses multimodal system capacity (which includes an evaluation of pedestrian, bicycle, and transit LOS) in its development review process. In development review it can be used to quantify impacts to each mode that can then be mitigated with improvements to any mode.

Evaluation Criteria Findings

Technical Feasibility

Is the performance measure reasonably simple to analyze?	Methodologies are well-established; ODOT provides spreadsheet tools to analyze MMLOS measures for pedestrian, bicycle, and transit modes.
Is the measure easy for both the public and practitioners to understand?	Relatively easy to understand when compared with auto LOS at a high level (e.g., "pedestrian segment LOS describes how comfortable it is to walk along a street"). Some applications can create counterintuitive results, such as road diets worsening pedestrian LOS, which is substantially affected by changes to the volume of adjacent auto traffic.
Does it rely on readily available data and a proven analysis process?	MMLOS requires large amounts of data that are not routinely collected by local and regional governments.

Flexibility for Intended Planning Applications and Different Contexts

Can it be focused on people, goods, or both?	Focused on people.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes – different design standards can be established for different facility types.
Can it consider land use context?	Yes – different design standards can be established for different land use contexts (e.g., downtown vs. residential neighborhood streets).
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Best applied to system planning and plan amendments; rarely applied for development review due to the difficulty of establishing achievable performance standards for multiple travel modes.
Can it be used at different scales to compare scenarios or alternatives?	Best applied at the corridor or subarea level; can be used to identify infrastructure deficiencies and evaluate project alternatives.

Legal Defensibility

Are the measures able to be applied as a standard and legally defensible?	Difficult to set as a standard for each mode because it could rarely be met at the same time given limited right-of-way.
Can they document incremental changes or impacts and be compared to a standard?	Not recommended for use as a performance standard, since many of the factors affecting MMLOS results are

	outside the control of individual developments and local jurisdictions.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Somewhat – it has rarely been adopted as a performance standard.
Is the measure already in use by ODOT?	Yes – adopted in APM.
Is the measure already in use by Metro?	No.

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – it measures the quality of service for different transportation options at the corridor level.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	To some extent, however, many of the factors affecting MMLOS results are outside the control of individual developments and local jurisdictions.

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Unknown; need to test.
Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	Somewhat – can be used to evaluate whether a transportation facility provides high-quality multimodal transportation options.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	Yes – it evaluates how well a specific facility provides different travel options and accommodates multimodal transportation.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	To some extent, however, many of the factors affecting MMLOS results are outside the control of individual developments and local jurisdictions or require substantial changes to pedestrian and/or bicycle infrastructure.

Advantages/Limitations (best suitability/difficult applications)

Regardless of which methodology is applied, quantitative MMLOS performance measures require substantial amounts of data on pedestrian and bicycle facilities; since these data are not consistently available at a regional level, MMLOS is most suited to subarea plans and corridor studies where field data can be collected and where differences between alternatives may not be captured by similar Level of Traffic Stress methodologies.

While ODOT's qualitative MMLOS performance measure requires less data than quantitative measures and therefore can be applied at a larger scale of analysis, it overlaps substantially with system completeness performance measures. At the segment level, pedestrian and bicycle MMLOS scores evaluate many of the same variables as PLTS and BLTS, which can be easier and more intuitive to evaluate using widely collected data.

One major challenge to applying MMLOS is that pedestrian and bicycle segment LOS are influenced by the volume of adjacent vehicle traffic, which falls outside the control of public agencies. As a result, even substantial changes to pedestrian and bicycle infrastructure may not produce meaningful changes to MMLOS scores, and standards established for MMLOS may not be feasible to achieve without excessive costs or impacts to other modes.

MMLOS evaluates many of the same variables that are evaluated using the system completeness and bicycle/pedestrian level of traffic stress performance measures. Given the amount of data required to evaluate MMLOS, it should be tested alongside those performance measures to identify whether it provides additional information about future conditions or project alternatives.

The following describes how MMLOS could be applied as a measure for the different applications in system planning.

identifying system needs and system adequacy in system planning	TSPs/Large Subareas – Not recommended for use at this scale. Corridors/Smaller Subareas – Could be used to compare project alternatives.
evaluating the transportation/mobility impacts of land use decisions in plan amendments	TSPs/Large Subareas – Not recommended for use at this scale. Corridors/Smaller Subareas – Could be used to compare project alternatives.
Evaluating mitigations when a threshold of significance is exceeded	Not recommended for use as a standard; however, could be used to evaluate negotiable improvements to multimodal transportation facilities if a proposed subarea plan or transportation project could increase pedestrian and bicyclist exposure to adjacent auto traffic.

Pedestrian Crossing Index

The percent of a corridor or roadway segment meeting the pedestrian crossing target spacing.

Relationship to Elements

EQUITY	Measuring and having standards for the distance between pedestrian crossings will result in a system that enhances mobility for people walking and taking transit, not just those that own or travel in vehicles. This will help reduce barriers and disparities in access to affordable travel options. This measure can also be evaluated for Equity Focus Areas and for specific facilities where equity across modes and times of day may be a focus.
ACCESS	Providing better connected pedestrian facilities increases accessibility for non-motorized users, especially when these networks are planned in accordance with essential destinations and transit stops.
EFFICIENCY	Providing reasonably spaced pedestrian crossings increases the efficiency of walking, biking, and transit modes by reducing out of direction travel needed to access a safe crossing.
RELIABILITY	
SAFETY	Providing higher visibility, marked pedestrian crossings reduces safety concerns for vulnerable road users.
OPTIONS	Providing better connected pedestrian facilities increases the opportunities for residents and visitors to use non-vehicular travel options to serve their trip needs.

Variations of the Measure and Methodology

ODOT recently conducted a project to begin to include this measure in their updated annual key performance measures. This is the only application and methodology the project team is aware of.

Methodology:

1. *Gather all necessary data in GIS including facility data (type and condition) and the priority corridors. Priority corridors may need to be revisited and updated approximately every 15 years as land use conditions change. An update to the priority corridors may utilize non-infrastructure focused criteria from the most recent Statewide Active Transportation Needs Inventory update. If the priority corridors are updated, the Continuous Improvement Advisory Committee should be notified, as it will affect the performance tracking.*
2. *In the short-term, the ODOT Bicycle and Pedestrian Program and ODOT GIS Program will retain the priority corridors, marked crossings data, and GIS toolbox script. The steps for establishing and using the GIS toolbox script for this measure are discussed in detail in Appendix A. The high-level methodology processed by the GIS toolbox script includes the following steps:*
    a. *Determine the marked crossings, including crossings with and without ADA ramps, along each high priority corridor and locate marked crossings on the ODOT LRM system.*
    b. *Create 750-foot buffer area around marked crossings (the buffer distance is a variable that is determined by user through the GIS toolbox).*
    c. *Establish spatial correlation between priority corridors and the marked crossings buffer area that has the same roadway identifier on ODOT LRM system.*
    d. *Clip out the priority corridor segments that are covered by the marked crossing buffer area.*
    e. *Calculate the length of each priority corridor that is covered by the marked crossing buffer area.*

Summarize the length and calculate the percentage of each priority corridor that is covered by the marked crossing buffer area.

$$\text{Percent of priority bicycle and pedestrian corridors meeting target crossing spacing} = \frac{\text{Center Lane Miles Covered by Marked Crossing Buffer Area on BPPC}}{\text{Center Lane BPPC Miles}}$$

Current Applications and Thresholds/Targets

The ODOT Pedestrian and Bicycle Program recently included this measure when updating the program's key performance measures. A spacing target of 750 feet was used, with the measure being applied to state priority walking and biking corridors. As stated in the work leading to inclusion of this measure, "*The Blueprint for Urban Design provides target crossing spacing for different urban contexts. Those targets range from 250 ft – 1,500 ft, and 750 ft falls within the target spacing for most contexts. Several contexts (traditional downtown/CBD and urban mix) have crossing spacing targets that are more stringent (lower than) 750 ft. The measure does not preclude or discourage closer crossing spacing than 750 ft but does attempt to set a target reasonable for all contexts*."

For the potential wider application of this measure on roadways outside of ODOT's Priority Bicycle and Pedestrian Corridors, a range of target crossing distance targets could be assigned to roadways based on functional classification and land use context to better represent regional goals. Metro's regional policies include ideal spacing considerations for bicycle/pedestrian crossings (330 feet) and street connectivity spacing (530 feet) with more frequent bike/ped crossings to support access to transit and walking and biking.

Evaluation Criteria Findings

Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Yes – Can be calculated very simply for a corridor with measurements and identifying buffered distances from crossings in AutoCAD or ArcGIS. For an entire network, the calculations requires running a script in ArcGIS that may need to be customized and the crossing locations need to be available in GIS. Need to test how complex this process would be applied at the TSP level.
Is the measure easy for both the public and practitioners to understand?	Unknown - need to test.
Does it rely on readily available data and a proven analysis process?	No - ODOT's application uses ArcMap to run the analysis and requires pedestrian crossing location information along the analyzed roadway facilities.

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	Related to person travel only.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes – It can be calculated on individual facilities.
Can it consider land use context?	Yes – The pedestrian crossing spacing targets can be set in consideration of land use, such as decreased spacing in downtowns and commercial areas.
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes – It can be applied to all planning applications but is not sensitive to changes in vehicle volumes or bike/ped volumes; however bike and ped volumes can be used to look at warrants for a protected crossing.
Can it be used at different scales to compare scenarios or alternatives?	Less useful for comparing scenarios and alternatives.

Legal Defensibility	
Are the measures able to be applied as a standard and legally defensible?	Measure could be used to set a standard.
Can they document incremental changes or impacts and be compared to a standard?	Yes – Sensitive to additional pedestrian crossings.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Not aware of widespread use by other jurisdictions.
Is the measure already in use by ODOT?	Yes – It is a new key performance measure that ODOT will incorporate moving forward with their annual reporting.
Is the measure already in use by Metro?	Not currently used as a measure. Metro does have ideal bicycle and pedestrian spacing considerations identified in the regional policies.

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – Links to accessibility and travel options.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – ODOT, Metro and local agencies are able to plan and fund projects individually and as a region that decrease pedestrian crossing spacings.

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Yes – Decreased spacing between pedestrian crossings supports compact, urban form by allowing for better connected pedestrian facilitates to support local trips by foot. Spacing targets can be set based on land use context and corridor characteristics.
Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	Yes – Can help assess if the transportation system can support planned land uses.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	Yes – Statewide Planning Goals require transportation plans to support land use plans. In addition, the measure can support OTP goals for developing a balanced multi-modal system.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	Yes – Pedestrian crossings are relatively low-cost solutions. Maintenance needs depend on the type of crossing installed.

Advantages/Limitations (best suitability/difficult applications)

This measure assumes a target spacing for each facility. ODOT recently developed a methodology for this measure, but a process for determining specific target crossing spacings by facility was not included. A matrix of targets may be needed that relates to facility type and land use, potentially utilizing Metro's Designing Livable Streets and Trails Guide or ODOT's Blueprint for Urban Design classifications.

May be used as a target to identify needs for additional crossings and as an evaluation tool in system plans and plan amendments if the land use changes warrant closer target spacing. This is a good metric to identify gaps and is increasingly used in system or corridor plans. For transportation planning, the existing conditions and future no-build conditions will be the same although the land use could change the need for crossings.

The following describes how Pedestrian Crossing Index could be applied as a measure for the different applications in system planning.

identifying system needs and system adequacy in system planning	TSPs/Large Subareas – On the identified key pedestrian network or entire network, utilize ArcGIS to identify corridors and roadway segments that lack pedestrian crossings to meeting the target spacings based on land use context. Corridors/Smaller Subareas – Utilized ArcGIS to identify needs adjacent to pedestrian trip generators or land uses and along bicycle and pedestrian priority corridors.
evaluating the transportation/mobility impacts of land use decisions in plan amendments	Land use decisions may impact the context of a corridor or roadway segment and influence the target pedestrian crossing distance.
Evaluating mitigations when a threshold of significance is exceeded	When pedestrian crossing distance targets are not met, the mitigations will include additional marked pedestrian crossings.

System Completion

The percent of planned facilities that are built within a specified network or on a specified corridor/roadway segment.

Relationship to Elements

EQUITY	Measuring and having system completion standards for all modes will result in a system that enhances mobility for all people, not just those that own or travel in vehicles. This will help reduce barriers and disparities in access to affordable travel options. This measure can also be evaluated for Equity Focus Areas and for specific facilities where equity across modes and times of day may be a focus.
ACCESS	Providing more complete systems for each mode increases accessibility to travel options.
EFFICIENCY	Providing a complete transportation system for each mode allows people to have travel options for completing their trip efficiently and providing options is the most efficient way to move people in a compact urban environment.
RELIABILITY	
SAFETY	Providing more complete systems and facilities for pedestrians and bicycles reduces safety concerns for vulnerable road users.
OPTIONS	Providing more complete systems for each mode increases the opportunities for residents and visitors to use non-vehicular travel options to serve their trip needs.

Variations of the Measure and Methodology

For Metro, system completeness is a system evaluation measure in Chapter 7 of the 2018 RTP, analyzed using ArcGIS and GIS data (from jurisdictions and agencies, RLIS, ODOT, and the RTP) and regional travel demand model data.

- For the pedestrian network, the 2018 RTP used a geospatial analysis of GIS data of constructed sidewalks as of 2012 compared to the Regional Pedestrian Network from 2018 RTP Chapter 3 to determine percent complete.
- For the bicycle network, the 2018 RTP used a geospatial analysis of GIS data of constructed on-street bikeways (as of 2016) and constructed regional trails (as of 2017) compared to the Regional Bicycle Network from 2018 RTP Chapter 3 to determine percent complete.
- For the transit network, the 2018 RTP used a geospatial analysis to determine how much of the planned regional pedestrian, bike, and trail networks are completed within a walking distance to transit. Walking distance to transit was defined as:
    - Within 1/2-mile from light rail stops
    - Within 1/3-mile from streetcar stops, and
    - Within 1/4-mile from bus stops for existing and planned stops.

ODOT's APM Chapter 9 also discusses potential infrastructure system completeness measures including:

- Network connectivity – extent that the network is inter-connected
- System completeness – percent of planned facility elements such as sidewalks, bike lanes, or improved pedestrian crossings that currently exist
- Percent completeness of bike and walk facilities within ¼ mile of transit stops or ½ mile of schools
- Percent of planned network with sidewalks and/or bicycle facilities
- Percent of network restricted to heavy vehicles
- Capacity available on parallel local facilities
- Ratio of shortest network path distance (driving, walking, or biking) to shortest straight line distance (as shown in Exhibit 9-16). This is a theoretical minimum distance. Ratios closer to 1 are preferred.
- Number of roadway links divided by the number of roadway nodes or intersections (as shown in Exhibit 9-17).
- Intersection density
- Number of intersections per square mile within a region or area
- Density of pedestrian-oriented/local streets and/or multi-modal streets miles per square mile within a region or area
- The RTP policies define local street connectivity standards for new residential and mixed use development (530 feet), with bike/ped crossings every 330 feet, arterial spacing every mile, etc unless limited due to topography, natural resources and existing development. This can be a basis for addressing vehicle system completion using an intersection density measure.

Metro is also interested to include TSMO and TDM elements, e.g., for example, the TSMO strategy is considering a measure for how complete the ITS/communications system is for key regional routes like frequent transit corridors, freight intermodal connectors, etc.

Potential additional system completeness measures could include percent of the bicycle network meeting its target for low-stress facilities or separated bikeways as well as definitions for complete intersections with regard to turn lanes.

Current Applications and Thresholds/Targets

A threshold or target is not established for the region, but the goal is for an increasing percent complete trend over time. Percent complete can be a difficult measure because the planned system does change as agencies and jurisdictions refine their TSPs and other plans to reflect growth, development/redevelopment, or other changes.

PSU's research paper discussed these current applications of the measure:

- *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. System completeness was also identified as a recommended infrastructure measure in the ODOT Region 1 Accessibility Performance Measures report. 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.*
- *Metro: Regional Bike and Pedestrian Network Completion is used by Metro to support Congestion Management Process (CMP) and Climate Smart Strategy implementation monitoring and reporting. 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).*
- *Oregon: Pedestrian system completeness was used in the Sherwood TSP to assess existing and planned pedestrian facilities. Bicycle system completeness was used in the Oregon City TSP to assess existing and planned bicycle facilities. Use of system completeness was also suggested as an alternate mobility measure in a 2014 consultant report for Washington County.*
- *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.*

For ODOT, the relevant question under many measures is adequacy/completeness of the state highway, not systemwide completeness. There may be times when we would look at adequacy within a mobility corridor. Specific to system completeness: this measure is applied differently when a complete system or modal network has already been defined, as in the RTP, versus when first developing the modal networks in a TSP. ODOT's primary interest in this type of measure is to know where their highways are incomplete, not just to know systemwide percentages or averages.

Evaluation Criteria Findings

Technical Feasibility	
Is the performance measure reasonably simple to analyze?	Yes – Reasonably simple to analyze if the planned system is determined.
Is the measure easy for both the public and practitioners to understand?	Yes – This measure relatively easy to understand, although the potential change in the planned system could cause confusion if using the measure to track progress over time.
Does it rely on readily available data and a proven analysis process?	This measure relies on detailed GIS data at a facility level, which a local agency may or may not have. The evaluation is conducted using software packages that are readily available within the industry.

Flexibility for Intended Planning Applications and Different Contexts	
Can it be focused on people, goods, or both?	Yes – Measure system completion for each modes and could be used to look at designated freight routes.
Can it be distinguished for different facility types such as throughways vs arterials?	Yes – It can be calculated on individual facilities.
Can it consider land use context?	Yes – The identified planned system used as a basis for the measure should consider land use.
Can it be used for one or all intended applications (system planning, plan amendments, and development review)?	Yes – It can be applied to all planning applications.
Can it be used at different scales to compare scenarios or alternatives?	Able to compare scenarios and alternatives although the scale of evaluation can play a role in whether an incremental change is impactful. If looking at a corridor-level, filling a sidewalk gap may be more impactful than if the analysis is rolled up for a city-wide measure.

Legal Defensibility	
Are the measures able to be applied as a standard and legally defensible?	Measure could be used to set a standard.
Can they document incremental changes or impacts and be compared to a standard?	The scale of evaluation can play a role in whether an incremental change is impactful. If looking at a corridor-level, filling a sidewalk gap may be more impactful than if the analysis is rolled up for a city-wide measure and is not sensitive to changes in volumes for any mode. Documenting the proportionate share from additional trips added to a system gap would be challenging.

Current Uses of the Measures by ODOT, Metro, Local Governments and Other States and MPOs	
Is the measure(s) in use by other states, MPOs and/or jurisdictions?	Yes – Used across the country at the state, county, and local levels.
Is the measure already in use by ODOT?	Yes – One example is the ODOT Bicycle and Pedestrian Program reports percent of target roadside facilities for the annual sidewalk and bike lane performance measure summary.
Is the measure already in use by Metro?	Yes – Metro evaluated system completeness for the 2018 RTP.

Ability to Show Impact or Progress Toward Desired Mobility Elements	
Does the measure provide a link between the mobility policy and the outcomes demonstrated by the performance measures?	Yes – System completion links to accessibility and travel options.
Are ODOT, Metro and local agencies (alone or working collectively toward the regional goals) able to impact these outcomes?	Yes – ODOT, Metro and local agencies are able to plan and fund projects and programs individually and as a region that further complete modal networks and planned facilities.

Supportive of Planned Land Uses and Compact Urban Form	
Does the measure help evaluate support for compact, urban form and planned land uses (including mixed use centers and industrial areas) as envisioned in the 2040 Growth Concept and implemented in local comprehensive plans?	Yes – The identified planned system used as a basis for the measure should consider land use.
Can it be used to assess supportiveness to planned land uses and reduction of barriers to implementation of planned land uses?	Yes – The identified planned system used as a basis for the measure should consider land use.
Does it evaluate consistency with Statewide Planning Goals and Oregon Transportation Plan goals and policies?	Yes – Statewide Planning Goals require transportation plans to support land use plans. In addition, system completeness evaluated for all modes supports OTP goals for developing a balanced multi-modal system.

Leads to Financially Achievable Solutions	
Does the measure allow solutions or mitigation measures, i.e. projects, services and programs that ODOT, Metro, cities, counties and transit providers can afford to build, operate and maintain?	No - The solutions and mitigation measures are not always affordable for this measure, such as new roadway connections or providing bike lanes in constrained areas.

Advantages/Limitations (best suitability/difficult applications)

From an implementation tracking standpoint, system completeness is a very strong metric. If the transportation system planning process has already considered the best way to accommodate future travel demand, the maximum capacity that will be provided for vehicles, and the comfort or performance for other modes, then the plan should articulate the future cross-section for each roadway. This can then be used over time, coupled with other performance measures to determine timing, to determine if additional vehicle capacity should be provided or if the vehicle system is already complete and to determine if there are gaps for the bicycle and pedestrian modes. For cities that are densifying or transitioning to a more urban form, system completeness is becoming more widely implemented.

System Completeness could be applied as a performance target and a regulatory standard. It could be used as performance monitoring measure in system plan implementation, such as for a dashboard. It is not as directly useful for plan amendments as the measure is not likely to be impacted by changes in travel demand from a potential land use change. However, the plan amendment would trigger a review as to whether the planned system is adequate.

The following describes how System Completion could be applied as a measure for the different applications in system planning.

identifying system needs and system adequacy in system planning	System completion evaluations via ArcGIS can identify needs to complete the planned facilities and roll up completion percentages by study area as needed.
evaluating the transportation/mobility impacts of land use decisions in plan amendments	Land use decisions may impact the context of a corridor or roadway segment and influence the planned facilities used for the system completeness evaluations.
Evaluating mitigations when a threshold of significance is exceeded	When system completion targets are not met, mitigations include filling gaps.