City of Bellevue

Transportation Commission Study Session

DATE: March 3, 2016

TO: Chair Lampe and Members of the Transportation Commission

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SUBJECT: Level-of-Service in Bellevue – Toward a Multimodal Approach to Mobility

DIRECTION REQUESTED

	Action
X	Discussion
X	Information

At the March 10, 2016 Transportation Commission meeting, Transportation Department staff and the consultant team from Fehr & Peers will provide background and introduce a suite of metrics and standards that may be considered as Bellevue advances the Transportation Element policy direction to move toward a multimodal approach to mobility. This study session topic is the first of several meetings in 2016 during which the Transportation Commission will craft a recommendation for metrics and standards to amend the Transportation Element of the Comprehensive Plan and the Traffic Standards Code, BCC 14.10.030.

BACKGROUND

Existing Conditions

Transportation Level-of-Service (LOS) in Bellevue is defined on a policy level in the Transportation Element of the Comprehensive Plan and is codified in the Traffic Standards Code (BCC 14.10.030). Existing LOS standards for concurrency management are based on a metric that quantifies vehicle mobility through specified intersections (called “system” intersections) in terms volume-to-capacity (v/c) ratio in the PM peak period (a two-hour period between 4-6 PM). System intersections are aggregated in Mobility Management Areas (MMAs) for which an

area mobility standard (level-of-service) is established. Standards for long-range transportation planning are not formally established in policy or by code, but the common practice in Bellevue is to use a forecast average vehicle delay (in seconds) at the same system intersections in the PM peak hour.

Level-of-Service Overview

The state Growth Management Act (GMA) requires local governments to identify level-of-service (LOS) standards for city-owned arterials and transit routes for the purposes of ensuring concurrent investment in transportation as land uses change. This is often known as "transportation concurrency." The Puget Sound Regional Council (PSRC) implements GMA requirements by reviewing and certifying local government comprehensive plans for compliance. Certification is required to receive regional-and state-allocated transportation funds.

The city of Bellevue Comprehensive Plan, originally adopted under the Growth Management Act in 1993, updated in 2004 and in 2015, and the Traffic Standards Code (BCC Chapter 14.10.030) address GMA transportation concurrency requirements with a volume-to-capacity (v/c) measure in the PM peak period at selected "system" intersections within Mobility Management Areas (MMAs). While the v/c metric does not explicitly include a specific LOS standard for transit, bicycle or pedestrian modes, the LOS standards are established in consideration of land use and available mobility options. For instance, the LOS standard varies among MMAs from a v/c of .80 to .95 depending on land use and transportation factors.

For long-range transportation planning, the City uses travel demand and traffic operational modeling to forecast intersection and area-wide LOS based on the average delay of vehicles at intersections in the PM Peak period. This method is generally consistent with guidance from the Transportation Research Board (TRB) on estimating the quality of vehicular traffic through intersections.

Both the concurrency and long-range planning methods explicitly consider capacity and delay only for vehicles and provide quantitative metrics and analysis for this single mode of travel. Throughout the city, and significantly in existing mixed-use urban neighborhoods such as Downtown, Crossroads and Factoria; and in evolving neighborhoods such as BelRed and Wilburton, mobility is characterized by high numbers of people who are walking, and riding transit and bicycles. However, the quantitative metrics and analysis upon which many transportation planning, design, and investment decisions are made are related to vehicle capacity and delay at intersections, which can lead to unfavorable outcomes for non-vehicle modes.

Evolving Multimodal Level-of-Service Approaches for Concurrency and Long-Range Planning

In the 2015 update of the Comprehensive Plan, the Transportation Commission studied several approaches to define and manage LOS and to establish standards that consider and incorporate

all modes of travel. In developing policy recommendations to the City Council, the Transportation Commission engaged in a detailed review of the various methodologies used around the state and country to measure and monitor LOS for each mode. As documented in the MMLOS Final Report, April 2014, the Commission supported a corridor approach combined with some elements from a revised MMA structure to provide context for use in long-range transportation planning. The Commission recommended a "mobility unit" approach for transportation concurrency management purposes and suggested that targets be established as a way to track progress. Adopted policy directs the Transportation Commission to refine and detail the preferred approaches to develop multimodal LOS metrics and standards that will inform concurrency and long-range transportation planning.

Comprehensive Plan Transportation Element Policies

The 2015 Bellevue Comprehensive Plan update includes a new policy recommended by the Transportation Commission, and adopted by the City Council on August 3, 2015 that directs the establishment of a more robust and explicit multimodal approach to mobility with new metrics and standards that would apply to all modes and that may vary depending on the context. The adopted Transportation Element goal statement sets the stage, and the policies follow:

Goal: To maintain and enhance a comprehensive multimodal transportation system to serve all members of the community.

TR-30. Establish multimodal level of service and concurrency standards and other mobility measures and targets for roadway corridors and in each area of the city in consideration of planned development patterns and mobility options.

Other policies supportive of a multimodal mobility approach include:

TR-20. Manage the multimodal transportation system in a corridor approach within and across Mobility Management Areas.

TR-22. Implement and prioritize transportation system improvements to meet the level of service standards for all transportation modes, recognizing the range of mobility needs of each corridor and Mobility Management Area.

TR-29. Observe the following policy guidance in revising level-of-service standards by Mobility Management Area:

1. Reflect the availability of mobility options;
2. Consider community goals that may be as important as managing vehicular congestion, such as goals for land use, neighborhood protection from wider streets and cut-through traffic, livability, or economic vitality. For example, a higher level of vehicular congestion is allowed in some areas of the city under the following conditions:
    a. In return for stronger emphasis on transit, walking, bicycling and other mobility options, and

b. Where the impacts of wider streets or intersections are judged to be worse than the congestion they are designed to solve.

3. Establish multimodal level–of-service standards adequate to ensure a functional transportation system.

TR-31. Define Mobility Management Areas that reflect street patterns and connectivity, available mobility options, topography, development patterns, and land use objectives.

TR-32. Utilize level-of-service standards for transportation corridors that reflect the range of available and intended mobility options.

TR-33. Utilize concurrency standards that consider the available and intended mobility options for transportation corridors, Mobility Management Areas and implementation and management priorities.

TR-34. Monitor the level-of-service for all modes and adjust programs and resources as necessary to achieve mobility objectives.

MMLOS Objective

The objective of this multimodal LOS update project is to prepare new LOS metrics and standards that implement Transportation Element policy. The City Council has asked the Transportation Commission to prepare a recommendation to accomplish the following:

- Revise the existing LOS metrics for each applicable mode;
- Amend LOS standards by mode for roadway corridors/segments and/or for Mobility Management Areas, the boundaries of which may be revised;
- Update the methodology used to track concurrency and to forecast LOS for long-range planning;
- Create a tool to inform investment decisions for transportation projects that are implemented by the public sector through the Capital Investment Program Plan and by the private sector through development review;
- Initiate a monitoring protocol to gathering data and tracking performance.

Recommended multimodal LOS metrics and standards would inform transportation project design and investment decisions in the interest of developing a comprehensive citywide multimodal transportation system.

Council may, upon receiving the Commission's recommendation, direct the staff and the Transportation Commission to draft amendments to the Transportation Element of the Comprehensive Plan and to the Traffic Standards Code, BCC 14.10.030.

Geographic Scope

Updated multimodal level-of-service standards would be established citywide. Particular focus will be paid to the distinct mobility and livability challenges for Downtown Bellevue, mixed-use urban places such as BelRed, Crossroads, Eastgate and Factoria, and smaller commercial nodes through which arterial corridors pass such as Bellevue Way through Northtowne, 119th Avenue

SE through Newport Hills, and 156th Avenue SE through Lake Hills. In other areas of the city, LOS along arterial corridors and at intersections will be addressed in context with adjacent land uses.

INFORMATION

With the above background as context, this section presents a short-list of potential multimodal LOS analysis methods that could be used to analyze transportation conditions across Bellevue's diverse neighborhoods. This list was distilled from a much larger list that is attached to this memorandum. The measures that were identified meet the basic goals outlined by the Transportation Commission, namely that they are focused on analyzing corridors and have flexible standards that can vary by MMA or some other measure of urban form/availability of transportation alternatives.

The focus of the discussion with the Transportation Commission is on how the metrics are evaluated, how well they describe the quality of the transportation system for the modal user, and ultimately identify/prioritize transportation improvements. Also included is a method for setting LOS standards for long-range planning.

Pedestrian Mode LOS Metric

The Pedestrian LOS metric is primarily based on the design of the pedestrian facility along with the characteristics of the adjacent roadway traffic. This measure is based on similar measures developed in San Francisco, CA and Charlotte, NC. Elements of the proposed measure are also included in the current Pedestrian LOS measure used in the *Highway Capacity Manual*, which is the most commonly cited source for traffic LOS measures.

The components that define Pedestrian LOS are listed below:

Component	**Description**
Sidewalk presence	Binary variable – whether a sidewalk is present. This is measured for each side of the street. Generally used to identify if a minimum facility is present.
Sidewalk width	Width of sidewalk in feet. Narrower sidewalks (4-5 feet) can represent a good facility in low-traffic/low pedestrian activity areas. Wide sidewalks (8-12+ feet) may be needed for a good quality facility in high pedestrian activity areas.
Buffer width	Width of a landscape buffer between the curb and the sidewalk. Wider buffers generally improve sidewalk quality as traffic volumes increase. No buffer may be acceptable on low-volume streets.
Crossing frequency	The frequency of appropriately marked/signalized crossings of the corridor. 300 foot crossings are ideal for pedestrian-oriented corridors

	in dense areas. In less dense areas, crossing frequency can increase to ¼ or ½ mile spacing, or where there are crossings for schools or high-utilization transit stops. The type of crossing is defined by the speed and volume of traffic on the corridor.
Crossing delay	The average wait time to cross the corridor. Based solely on the traffic signal cycle length. The HCM identifies acceptable pedestrian wait times. This measure can be used as a baseline to ensure that cycle lengths do not get too long in pedestrian-oriented areas.
Other factors that are included in Pedestrian LOS evaluation and would impact the facility design, but are not explicitly calculated in the Pedestrian LOS	
Traffic volume	Total daily traffic volume on the corridor. Higher traffic volumes require greater separation (buffer) and/or wider sidewalks and signalized pedestrian crossings.
Traffic speed	Speed limit or 85th percentile speed. Similar to traffic volumes, higher speeds (even on low-volume roads) require additional buffer and crossing protection.

Pedestrian LOS is calculated by evaluating the each characteristic or component of the pedestrian facility and determining if it meets "acceptable" or "optimal" standards. What constitutes an acceptable or optimal condition varies in consideration of the urban form (potentially defined using MMA boundaries) and traffic characteristics of the roadway. An illustrative example of how the analysis methodology can be applied is provided below.

	Downtown Arterial Street (e.g., Main Street)		**Lake Hills School Walking Route**	
Component	**Acceptable**	**Optimal**	**Acceptable**	**Optimal**
Sidewalk presence	Both sides of street	Both sides of street	One side of street	Both sides of street
Sidewalk width	5' - 8'	8' or wider	4' – 5'	5' or wider
Buffer width	0' – 5'	5' or wider	0' – 5'	5' or wider
Crossing frequency	600'	300'	Adjacent to schools	Adjacent to schools and every ¼ mile
Crossing delay	100 seconds	90 seconds	100 seconds	90 seconds

To be rated as Acceptable or Optimal, all conditions must be met. For example, using the above components, the segment of Main Street between 106th and 107th Avenue would be evaluated and rated as below:

	Main Street Segment Between 106th and 107th Avenue Analysis	
Component	**Condition**	**Rating**
Sidewalk presence	Missing from South side of Street	🔴 Not Acceptable
Sidewalk width	3’	🔴 Not Acceptable
Buffer width	0’	🟡 Acceptable
Crossing frequency	600’	🟡 Acceptable
Crossing delay	90 seconds	🟢 Optimal
Final Rating		🔴 Not Acceptable

As shown in the table above, since at least one criterion does not meet the Acceptable standard (yellow dot 🟡), the facility is rated as Not Acceptable (red dot 🔴).

Some pros and cons of this proposed measure are identified below:

Pros

- Transparent metric, simple to understand
- Focuses on high-quality pedestrian design
- In-sync with Pedestrian and Bicycle Transportation Plan
- Easy to evaluate in GIS
- Sensitive to urban form and transportation choices
- Sensitive to street crossing frequency

Cons

- Moderate/significant effort required to identify acceptable and optimal standards for a range of facilities
- Requires data that City may not have
- Limited information about whether the LOS measure is correlated with additional walking mode share

Bicycle Mode LOS Metric

The Bicycle LOS metric is similar to what was described for pedestrians and is focused on the design of the bicycle facility along with the characteristics of the adjacent roadway traffic. The components of the Bicycle LOS measure are well established through national research from

the Mineta Transportation Institute and can be related to the ability to meet the needs of bicycle rider groups that have been identified by planners in Portland (e.g., interested but concerned, enthused and confident, strong and fearless).

The components that define Bicycle LOS are listed below:

Component	**Description**
Facility type	Presence of a sharrow, bicycle lane, or a path (including cycle track). Paths generally provide better quality of service for cyclists, but often can't be accommodated within the existing right-of-way. Sharrows do not tend to offer much benefit to interested but concerned cyclists.
Bicycle lane/path width	Width of bicycle lane (or path). Higher traffic volumes/speeds tend to warrant wider bicycle lanes (which can be buffered).
Arterial crossing treatment	Appropriateness of arterial crossings along analysis segment. For example; a traffic signal, HAWK beacon, or other appropriate treatment.
Other factors that are included in Bicycle LOS evaluation and would impact the facility design, but are not explicitly calculated in the Bicycle LOS	
Traffic volume	Total daily traffic volume on the corridor. Higher traffic volumes require greater separation (buffer) and/or wider sidewalks and signalized pedestrian crossings.
Traffic speed	Speed limit or 85th percentile speed. Similar to traffic volumes, higher speeds (even on low-volume roads) require additional buffer and crossing protection.
Grade	Steep streets may warrant a bicycle climbing lane when a lane would not otherwise be necessary

Determining Acceptable and Optimal Bicycle LOS is based on the characteristics of the adjacent traffic. While Pedestrian LOS could theoretically be evaluated for every street in the city, Bicycle LOS is generally evaluated only on the priority bicycle corridors routes such as those identified in the Pedestrian and Bicycle Transportation Plan. An example matrix of how Bicycle LOS could be evaluated is presented below. For the purpose of this report, the Bicycle LOS matrix defines the type of facility needed to achieve an Acceptable or Optimal standard based on traffic volume for arterials/collectors and local streets. Future matrices will take into account a higher level of complexity for facility need based on additional factors such as traffic speed.

<table>
<tr><th></th><th colspan="3">Arterial/Collector</th><th colspan="2">Local Street</th></tr>
<tr><th>Traffic Volume</th><th>Optimal</th><th>Acceptable</th><th>Not Acceptable</th><th>Acceptable</th><th>Optimal</th></tr>
<tr><td>>15,000</td><td>Trail, cycle track, 7+’ bike lanes</td><td><7’ bike lanes, wide lanes</td><td>No bike lanes, sharrows</td><td rowspan="4">Signalized crossing at arterials with volume > 25,000 or at all locations not within ¼ mile of existing signal</td><td rowspan="4">Route signage, signalized crossing at all arterial intersections</td></tr>
<tr><td>10,000-15,000</td><td>Trail, cycle track, bike lanes</td><td>Sharrows</td><td>No bike markings</td></tr>
<tr><td>5,000-10,000</td><td>Trail, cycle track, bike lanes, sharrows in urban area</td><td colspan="2">Sharrows</td></tr>
<tr><td><5,000</td><td>Sharrows</td><td colspan="2">No bike markings</td></tr>
</table>

Some pros and cons of this proposed measure are identified below:

Pros

- Established evaluation methodology
- Focuses on high-quality bicycle design
- In-sync with pedestrian bike plan
- Easy to evaluate in GIS

Cons

- Moderate/significant effort required to identify acceptable and optimal standards for a range of facilities
- Requires data that City may not have
- Limited information about whether the LOS measure is correlated with additional bicycling mode share/route choice

Transit Mode LOS Metric

Defining and achieving a LOS standard for transit can be difficult since Bellevue does not operate the transit system and cannot therefore guarantee any transit level of service. With this limitation in mind, the primary Transit LOS metric focuses on the amenities that are provided at transit stops/station. In addition, an aspirational Transit LOS measure is identified that relates to transit system performance. This aspirational measure could be tracked to help

guide some City investments and to work with transit agency partners to improve service. The appendix lists many other potential aspirational Transit LOS measures as well.

The components that define Transit LOS:

Component	**Description**
Shelter	Is a transit shelter provided? Metro's rule of 20-50 daily boardings can be used as a threshold.
Seating	Is seating provided? Most shelters have seating, for those that don't, consider proximity to areas with elderly/disabled persons (e.g., hospitals, community centers, senior housing).
Access	Are sidewalks provided on each side of the street, and are there adequate crossings of the street to reach the stops?
Bicycle parking	Is adequate bicycle parking available? This could include a "staple" rack for busy on-street stops or a bicycle cage for transit centers/rail stations.

As with the other measures, the definition of Acceptable and Optimal Transit LOS will vary based on urban form/MMA. An example matrix of how Transit LOS could be evaluated is presented below. For the purpose of this report, the example focuses on two ridership extremes high ridership (light rail station) and low-ridership (flag stop). Future matrices can account for varying levels of ridership within Bellevue if preferred.

	Light Rail Station (e.g., East Main Station)		**Low-ridership bus stop (under 20 boardings per day)**	
Component	**Acceptable**	**Optimal**	**Acceptable**	**Optimal**
Shelter	Required – may be built into adjacent building	Required – may be built into adjacent building	None	None
Seating	Two benches per platform	Three benches per platform	None	If within 600 feet of: hospital, senior housing, community center
Access	Complete sidewalks on both sides of	Complete sidewalks on both sides of	Sidewalk on one side of street	Sidewalk on one side of street within 600 feet

	street within ¼ mile	street within ¼ mile	within 300 feet of stop	of stop; appropriately marked crossing within 600 feet of stop
Bicycle parking	Bicycle racks for 15 bikes	Bicycle cage	None	None

An aspirational Transit LOS measure that the City can use to inform long-term planning and capital investments is based on the ratio that compares PM peak period transit travel time to vehicle travel time between major points along a corridor. For example, if it takes a bus 20 minutes to travel between Crossroads and Factoria during the PM peak period and 15 minutes to drive between the two locations, then the travel time factor is 20/15 = 1.33. In general, very high ridership corridors should have travel time factors that are closer to or less than 1.0. Travel time factor can be improved by implementing components such as Transit Signal Priority, bus queue jump lanes, high occupancy vehicle (HOV) lanes, and several other options. However, the actual performance of the bus route is outside of the control of the City, therefore it is considered an aspirational performance measure.

Some key pros and cons of the proposed Transit LOS measure that focuses on stop amenities and access are identified below:

Pros

- Simple to calculate
- Focuses on high-quality station/stop design
- Identifies access deficiencies
- Under city control

Cons

- Does not speak to the performance of the transit service
- May require additional data

Vehicle Mode LOS Metric

In general, no major changes would be needed to Vehicle LOS in a MMLOS scenario, as the system that the City uses has been effective over the last 25 years. However, it is worth considering consolidation of the near-term and long-term Vehicle LOS methodologies to focus on the volume/capacity ratio metric. Currently, for long-term planning purposes, the Vehicle LOS is calculated using average vehicle delay in the PM peak period. While delay is a well-accepted measure of vehicle LOS, it was originally envisioned as primarily a tool to describe existing and near-term conditions for detailed traffic studies. The ability for a transportation morel to forecast delay at an intersection to the nearest second 20 years in the future is difficult when considering that the calculation requires information on each of the 12-16 vehicle movements at an intersection in addition to pedestrian activity. Volume/capacity is a simpler

and more transparent measure that is more in-line with the other measures suggested in this memo.

One other option to consider is a corridor-oriented Vehicle LOS measure. The Vehicle LOS metric focuses on intersection performance. While it is true that intersections generally control traffic flow along a corridor, the focus on intersections can make it difficult to describe the overall performance of a roadway corridor. There are well-established methods and thresholds for calculating Vehicle LOS along corridors that could be used instead of intersection LOS methods, however, this will require some additional data collection and refinements to the City's travel demand forecasting model.

While no major changes are suggested for the Vehicle LOS metric, one concept that is complementary to a capacity-based Vehicle LOS metric is the concept of an "ultimate facility." An ultimate facility is a roadway that has reached a certain prescribed "footprint" (e.g., number of lanes at an intersection or along a corridor), additional lanes/right-of-way improvements cannot be considered to improve operations and that a lower level of operational performance is deemed to be acceptable. The premise is that at a certain point, the downsides to widening a road or intersection are too great from the perspective of right-of-way impacts, costs, and impacts to other modes. Locally the ultimate facility concept is used in Snohomish County along major arterial corridors like 128th Avenue and 164th Avenue where additional widening would impact adjacent homes and businesses.

The letter grade system of communicating Vehicle LOS may also warrant revision. It is difficult to explain that the City is "accepting" LOS E+ conditions in certain areas of the City. The correlation to school grades may cause people to ask why not strive for LOS A! Therefore, it may be appropriate to link the Vehicle LOS to the simple red, yellow, green measures identified throughout this memo. One potential option is outlined in the adjacent table.

MMA Name	LOS Threshold Based on V/C Ratio	Adopted LOS
North Bellevue	🟢 0.0-0.85 🟡 0.85-1.00 🔴 > 1.00	🟢
Bridle Trails	🟢 0.0-0.80 🟡 0.80-1.00 🔴 > 1.00	🟢
Downtown	🟢 0.0-0.95 🟡 0.95-1.00 🔴 > 1.00	🟡
Wilburton	🟢 0.0-0.90 🟡 0.90-1.00 🔴 > 1.00	🟡

Some key pros and cons of the retaining the City's intersection-based Vehicle LOS measure are identified below:

Pros

- Retains current method
- Allows for different thresholds to be set based on urban form (which is also the current practice)
- Ultimate facility would constrain the dimensions of roadways in dense/other sensitive parts of the city

Cons

- Narrow/localized view of intersection performance – not necessarily corridor based
- Improving v/c can have negative impacts on other modes (which is partially offset by the ultimate facility designation)

Other Multimodal Metrics

In addition to the mode-specific metrics identified above, the attachment at the end of this memo contains a list of global/multimodal metrics that various communities have used to track outcomes or evaluate system performance. Measures include mode share, vehicle miles traveled, greenhouse gas emissions, system completeness, person/employment accessibility, and collisions. Many of these global measures are aligned with City goals and policies and these measures could be valuable to track. However, they are not as well suited to a corridor based LOS evaluation method as those mentioned earlier in this memo.

A measure that deserves some additional mention is system completeness. System completeness is a way to track the proportion of the planned transportation system that is implemented over time. System completeness could be a very strong framework to ensure that a multimodal transportation system is built in conjunction with development and public investments. System completeness differs significantly from the current system for concurrency evaluation that evaluates intersection volume/capacity ratio and does not consider how other types of improvements could improve the transportation system. To improve the V/C ratio for vehicles by widening an intersection for instance, may deteriorate the LOS for other modes that may be improved with bicycle lanes, transit lanes, or curb bulbs. But the whole point of this work with the Transportation Commission is to develop a methodology to evaluate the transportation system through a multimodal lens and to develop tools (metrics and standards) to help identify and prioritize projects for all modes along transportation corridors and within mobility management areas.

RECOMMENDATION

Staff has no specific recommendation at this time, although the materials in this memo represent our narrowing of the universe of options. The Information section above provides a range of opportunities to develop metrics and standards for multimodal LOS that staff and the consultant team believe are appropriate for the Transportation Commission to consider.

NEXT STEPS

Following the March 10 meeting, staff will take the feedback received from the Transportation Commission and refine, as necessary, the modal LOS metrics described above. These refined metrics will be presented and discussed at a subsequent Transportation Commission meeting – probably May 12, 2016. In addition to the refined LOS metrics, we plan to present and discuss the following topics:

- Update on LOS best practices across Washington State and other communities – How are other communities evaluating LOS and what can we learn from them?
- Balancing LOS standards on multimodal corridors – Multimodal LOS standards can sometimes be incompatible since improving the quality of travel for one mode cannot always be done while maintaining the quality for other modes. Our expectation is to review the results of applying the revised LOS metrics on a handful of multimodal corridors in Bellevue to discuss the results and how to prioritize.

ATTACHMENTS

Tables 1-5 are the full list of Modal LOS Performance Measures Considered. Shaded rows are determined to be appropriate for Bellevue and are the measures discussed in the memo.

Table 1. Pedestrian LOS Performance Measures Considered

Mode	Metric	Description	Pros	Cons
Pedestrian	Facility Design Standards	Establishes standards for pedestrian facilities at a site, project, or segment/intersection level. Standards can vary based on urban form and a rating system (red, yellow, green) can be assigned to assess performance citywide.	- Transparent metric, simple to understand - Promotes construction of high-quality pedestrian facilities - Variable standards based on urban form and neighborhood preferences - Simple to analyze in GIS	- Moderate/significant effort to establish minimum standards for various urban forms - Typically does not consider future traffic volumes or pedestrian demands - May require some data the City does not currently have
	Crossing Delay	# of seconds of delay for the average pedestrian at a signalized crossing	- Intuitive; directly relatable to familiar auto Level of Service (LOS) measure - Can be included in conventional LOS analysis with modest additional effort	- Addresses only one aspect of the pedestrian experience (signalized crossing delay), without considering other aspects, like comfort, safety, and route directness
	Crossing Frequency	Average or maximum distance between pedestrian crossings along a particular corridor. Can include minimum crossing quality standards.	- Intuitive - Low data collection and analysis effort	- Addresses only one aspect of the pedestrian experience (crossing frequency), without considering other aspects, like comfort, safety, and route directness
	Pedestrian Environment Quality	Composite measure incorporating above metrics and/or additional aspects of the pedestrian environment (e.g., sidewalk width, vehicle volumes, presence of buffer between sidewalk and roadway, etc.) at the street segment and intersection level. Generally we recommend design standards and crossing frequency.	- Potentially most comprehensive approach to measuring pedestrian level of service - Flexible to include aspects of pedestrian environment that are most important to community - Segment and intersection framework allows network-based measures that leverage other metrics, such as connectivity/accessibility to employment, transit stops, trip ends, etc. at a given level of pedestrian comfort.	- Requires additional development or selection of desired aspects and weighting within the composite score - Limited literature exists on which aspects of the pedestrian environment most influence safety or propensity to walk - Data collection could be a significant effort, depending on how many aspects are included in the composite score and what info the City has available

Table 2. Bicycle LOS Performance Measures Considered

Mode	Metric	Description	Pros	Cons
Bicycle	Bicyclist Environment Quality/ Level of Traffic Stress (LTS)	Composite measure incorporating specified aspects of the bicycling environment (e.g., # of travel lanes, speed of traffic, presence of bike infrastructure, etc.) at the street segment and intersection level. We recommend a moderate number of built environment variables be chosen to keep data collection/calculation costs from being too high.	- Established calculation methodology (Mekuria, Furth, Nixon 2012) - Transparent metric - Promotes high-quality facilities - Easy to analyze in GIS	- Limited, but growing literature exists on which aspects of LTS most influence safety, propensity to bike, or route choice. - Significant effort to collect baseline existing conditions database over a large area (though Furth et al. and Montgomery County, MD have proven the concept)
	Facility Design Standards	Established minimum standards for bicycle facilities at a site, project, or segment level. Intersection crossing design can also be considered.	[Similar to Pedestrian Facility Design Standards, above] - Transparent metric - Variable standards to adapt to different urban forms - Promotes construction of high-quality bicycle facilities - Simple to analyze in GIS	- There is strong evidence that traffic conditions other than design influence the quality of the bicycle environment. A simple design-based approach does not take these factors directly into account.
	Highway Capacity Manual Bicycle Level of Service (HCM LOS)	Composite measure incorporating specified aspects of the bicycling environment (e.g., curb-to-curb width, automobile turning movement flows, bike lane width, on-street parking occupancy, etc.) at the street segment and intersection level.	- Established calculation methodology (Highway Capacity Manual 2010)	- Some changes have counterintuitive effects on Bike LOS score (e.g., a road diet could degrade bicycle LOS, while lane widening could improve bicycle LOS) - Significant effort to collect baseline existing conditions database over a large area
	Bicyclist Environment Quality/ Level of Traffic Stress (LTS)	Composite measure incorporating specified aspects of the bicycling environment (e.g., # of travel lanes, speed of traffic, presence of bike infrastructure, etc.) at the street segment and intersection level. We recommend a moderate number of built environment variables be chosen to keep data collection/calculation costs from being too high.	- Established calculation methodology (Mekuria, Furth, Nixon 2012) - Transparent metric - Promotes high-quality facilities - Easy to analyze in GIS	- Limited, but growing literature exists on which aspects of LTS most influence safety, propensity to bike, or route choice. - Significant effort to collect baseline existing conditions database over a large area (though Furth et al. and Montgomery County, MD have proven the concept)

Table 3. Transit LOS Performance Measures Considered

Mode	Metric	Description	Pros	Cons
Transit	Stop/Station Accessibility	Count of origins/destinations (e.g., residents, employees, enrolled students, etc.) within a given distance of the transit stop/station. Can be combined with Pedestrian and Bicyclist Comfort measures (above) to determine accessibility along a given level-of-comfort network. Can also be calculated as distance from a particular site to the nearest transit stop/station. Can be combined with Frequency of Service (below) to determine how many transit vehicle runs are accessible within a given distance from the site.	- Can be readily computed using GIS analysis - A measure of the land uses around a transit stop	- Does not account for quality or performance of transit service
	Stop/Station Amenities	Established standards for amenities (e.g., benches, shelters, vending, etc.) at transit stops/stations.	- Simple to calculate - Focuses on high-quality stop/station design - Under City control	- Does not describe the performance of the transit service - May require additional data
	Traffic Signal Priority (TSP) Deployment	Percent of transit vehicles, signals, and/or routes equipped and enabled for Traffic Signal Priority. Can be weighted by route or run ridership.	- Transparent metric - Simple to calculate	- Process metric that does not reflect how well the signal priority system is performing - Corridor Travel Time / Travel Time Reliability (below) may better reflect the net result of TSP deployment
	Travel Time Factor	Ratio of travel time by transit to travel time for a comparable trip made by auto.	- Provides understanding of one key element of mode choice - Public can relate to the variable - Can be controlled by the City to a degree	- Requires AVL data for existing conditions - Difficult to predict and forecast
	Travel Time Reliability	Measure of the variability of transit travel times relative to the average transit travel time, reported at the segment level. Can be	- Useful for identifying unreliable segments for targeted improvements	- Requires Automatic Vehicle Location (AVL) data - Difficult to forecast

Mode	Metric	Description	Pros	Cons
		weighted by ridership to reflect the typical passenger experience.		
	Load Factor	Ratio of passengers to seats.	- Reflects transit vehicle crowding, an important element of the transit passenger experience	- Comfortable standing capacity varies by vehicle type/need to know or forecast bus capacity - Difficult to account for how long a passenger needs to stand - Does not reflect the number of potential passengers who choose not to board due to overcrowding - Not under the control of the City
	Frequency of Service	Number of transit vehicles per hour in the peak period.	- Reflects one element of transit quality that is very understandable by patrons - City could choose to purchase additional service to increase frequency - Can set different frequency targets for different routes depending on urban form	- Does not account for quality of transit service in non-peak hours (although this could also be evaluated) - Does not account for stop/station access conditions - Does not account for speed/performance of transit service
	Transit Service Accessibility	Combines Stop/Station Accessibility and Frequency of Service. Can be calculated for a given area as the average of combined frequency of all accessible transit services, weighted by residents + employees within a given distance of transit (e.g. 1/2 mile from rail and 1/4 mile from bus). Can also be calculated at the site level using a similar approach.	- Sensitive to land use changes - Sensitive to transit service changes - Simple to forecast	- Does not account for quality of transit service in non-peak hours - Does not account for speed/performance of transit service
	Span of Service	Number of hours of transit operation. Similar to Transit Service Accessibility, can be a weighted average by residents and employees within a given distance of transit.	- Provides an indication of off-peak service	- Does not account for speed/performance of transit service - Not under the control of the City

Table 4. Auto LOS Performance Measures Considered

Mode	Metric	Description	Pros	Cons
Auto	Intersection Delay "Critical Lane Volume" (CLV)	Measure of the maximum volume per lane in one direction (e.g., north-south or east-west) is compared against a standard that can be varied by context.	- Simple to calculate and review	- Does not consider individual approach volumes, signal timing, geometries, or operational performance - Narrow, local-scale view of auto operations - Geared toward geometric intersection improvements/mitigations - Changes to infrastructure based solely on V/C or LOS can lead to unintended consequences, such as degraded conditions for pedestrians and bicyclists
	Intersection Delay Highway Capacity Manual (HCM) Volume-to-Capacity (v/c) Ratio and Level of Service (LOS)	Ratio of volume to capacity for each lane group, aggregated to determine a weighted average for the entire intersection.	- Current City system - More sensitive to detailed geometries and operational performance than CLV - Allows for different thresholds based on urban form/transportation options - Can be used for basic operations analysis	- Narrow, local-scale view of auto operations - Changes to infrastructure based solely on V/C or LOS can lead to unintended consequences, such as degraded conditions for pedestrians and bicyclists - Tends to support additional lanes to address congestion problems
	Corridor Travel Time	Measure of time needed to travel between two points on a corridor during a particular time period (e.g., peak period). Can be reported for each mode.	- Intuitive - Allows direct comparisons - Allows for different thresholds for different urban forms	- Need to define corridor segments or OD pairs

Mode	Metric	Description	Pros	Cons
	Travel Time Reliability Travel Time Index (TTI)	Ratio of travel time in the peak period to travel time at free-flow conditions.	- Simple to calculate	- Reflects relative amount of congestion and favors long, uncongested commutes over short commutes in moderate congestion. For example, a 60-minute commute including 15 minutes of travel in congestion has a lower TTI (1.33) than a 20-minute commute including 10 minutes of travel in congestion (TTI = 2.00).
	"Ultimate Design"	Establishes a typology for a final roadway buildout. Progress toward the ultimate design can be tracked and additional "improvements" beyond the ultimate design will not be allowed.	- Allows comprehensive consideration of the desired state of roadway infrastructure at the planning stage - Sets a clear outcome goal for each roadway segment and intersection	- Not a measure of performance per se - Significant effort to prepare ultimate design for each roadway - Difficult to establish process for modifying or making exceptions to ultimate design

Table 5. Additional Multimodal Performance Measures Considered

Mode	Metric	Description	Pros	Cons
Multimodal / Other	Mode Share	% of total person trips made by each mode (e.g., auto, transit, bicycle, pedestrian).	- Provides an understanding of how people are choosing to travel - Allows tracking of how people are shifting modes	- Does not account for trip length - Separate information on pedestrian and bicycle mode share is difficult to derive from travel demand models
	Vehicle Miles Traveled per Person Trip	Total miles traveled in automobiles divided by total person trips by all modes.	- Reflects mode choice - Reflects trip lengths - Sensitive to land use changes - Allows attribution of traffic to generators and attractors	- New metric that may be unfamiliar or unintuitive
	Greenhouse Gas Emissions	Tons of carbon dioxide equivalent. Can also be reported on a per capita or per person trip basis.	- Includes effect of motor vehicle fleet mix	
	Vehicle Hours Traveled per Person Trip	Total person hours traveled in automobiles divided by total person trips by all modes.	- Reflects mode choice - Reflects trip lengths and speeds - Accounts for roadway facility conditions - Sensitive to land use changes - Allows attribution of traffic to generators and attractors	- New metric that may be unfamiliar or unintuitive
	System Complete-ness	% of planned transportation system that is operational. Can be measured in lane/service miles (including transit, bicycle, and pedestrian infrastructure) or dollar cost, and broken out by mode.	- Allows comprehensive consideration of the desired state of roadway infrastructure at the planning stage - Supports concurrency of land development and transportation infrastructure implementation	- Process metric that does not ensure any particular operational outcome
	Employment Accessibility	# of jobs accessible from a given location (e.g. parcel) within a fixed amount of time (e.g. 45 minutes). Results can be presented separately by each mode of travel. Can also be expressed at multiple travel time intervals (e.g., 15, 30, 45, and 60 minutes).	- Reflects land use and transportation system - Reflects trip lengths as well as speeds - Reflects quality of transit service	- Theoretical measure, since one resident cannot hold all accessible jobs; does not account for matching appropriate employment opportunities to residents

Mode	Metric	Description	Pros	Cons
		Can be aggregated to specific plan or citywide levels, weighting by residential population.		- Commute trips make up a relatively small percentage of total trip making
	Person Trip Accessibility	Number of desired destinations (per travel demand model) that can be reached from a given location within a fixed amount of time (e.g., 45 minutes). Results can be presented separately by each mode of travel. Can also be expressed at multiple travel time intervals (e.g., 15, 30, 45, and 60 minutes). Can be aggregated to specific plan or citywide levels, weighting by residential population.	- Accounts for all types of trips, not just commute	- Although travel demand models are calibrated to aggregate measures of traffic volume, individual origin-destination demand pairs may not be accurate
	Person Trip Duration	Duration of average person trip, in minutes. Can be reported by mode.	- Intuitive - Reflects benefit of mixed land uses and shorter trips, even in congestion - Simple to calculate using travel demand model outputs for auto and transit modes	- Difficult to calculate for pedestrian and bicycle modes
	Intersection Person Delay	Average delay in seconds for all users at an intersection. Can be reported for each mode and as a weighted average of all modes.	- Intuitive; directly relatable to familiar auto Level of Service (LOS) measure - Addresses all users in a directly comparable way - Can be included in conventional LOS analysis with modest additional effort	- Addresses only conditions at signalized intersections
	Collisions per Person Trip	Ratio of total number of collisions to total number of completed person trips in a given area. Collisions can be divided by severity (e.g., fatal, severe injury, property damage only) and/or reported by mode involved.	- Normalizes a cost of transportation (collisions) by the productive benefit of transportation (completed person trips) - Responds favorably both to reductions in the number of collisions for a given amount of travel and to	- Difficult to obtain accurate collision data; many collisions are not reported - Collisions cannot be readily forecasted using existing data and methods.

Mode	Metric	Description	Pros	Cons
			increased trip making for a given number of collisions - Potentially illustrates an additional benefit of shorter trip lengths: if collisions per mile traveled remain constant and total miles traveled decreases for the same number of person trips, then collisions per person trip will decrease even though collisions per mile does not.	