

14 MULTIMODAL ANALYSIS

14.1 Purpose

In order to truly quantify the operation of a roadway segment, all of the modes that use it need to be analyzed. This includes pedestrians, bicycles, transit in addition to automobiles and trucks. This chapter will eventually cover a reasonable range of different multimodal analysis types and modal considerations that will apply to plans and projects of all detail levels.

14.2 Multimodal Analysis Methodologies

The current generation of multimodal analysis methodologies are generally a perception-based rating system of the safety, comfort, and convenience of transportation facilities from the perspective of the user, whether a motorist, bicyclist, pedestrian or transit rider. The range of methodologies presented in this chapter is meant to be complimentary, not competitive, and have been tested for compatibility. There are many types of multimodal analysis methodologies available; however, not all are suitable for all applications. The overall context of the plan or project and the resulting scope of work will control the ultimate methodological choice. Some methods require very specific data which may not typically be collected in a high level study such as a transportation system plan. Some methods are too simple and will not be able to answer the questions posed in the design of a modernization project.

Applicability of multimodal analysis methods by project type is illustrated in Exhibit 14-1. Methods increase in detail from left to right, while plan/project types increase in complexity from top to bottom. As the application increases in level of detail, more specific questions can be addressed, but the analysis will require more data and resources. Regardless of method applied, it is important to include some sort of multimodal analysis on all analysis efforts.

Exhibit 14-1 Multimodal Analysis Tool Applications¹

	Qualitative Multimodal Assessment	Level of Traffic Stress ²	Multimodal Level of Service
Regional Transportation Plan (RTP)	○	●	
Transportation System Plan (TSP)	●	●	
Facility Plan/Interchange Area Management Plan (IAMP)	○	○	●
Project Development		○	●
Development Review		○	●

¹Solid circles represent the preferred methodology. Outlined circles represent where methodology can also be used.

²Use of LTS for project development and development review should be limited to a screening-based analysis to quickly identify existing and future needs

Any project or plan could use any single level or multiple levels of multimodal analysis, but many levels of analysis are more suited to a particular application. For example, Level of Traffic Stress (LTS) could be used at a system level to identify key locations, which then can be analyzed further using Multimodal Level of Service (MMLOS).

The primary tool for Regional Transportation Plans (RTP) is LTS as this methodology can be easily adapted to use travel demand model inputs or can be generalized enough to apply to a whole region without too much data and effort. The Qualitative Multimodal Assessment (QMA) can be used to fill in other modes that are not covered by LTS. These methods require limited data, most of which can be obtained from existing inventories, aerial photography, or from “windshield” field surveys. These methods will be able to identify areas of concern whether in system connectivity (LTS) or in operations (Qualitative Multimodal Assessment).

Transportation System Plans (TSP) have enough detail in the inventory and analysis to provide for adequate QMA and/or LTS analyses. Do not duplicate modes between the two methodologies if both are used in a single effort.

More detailed planning efforts such as facility plans and Interchange Area Management Plans (IAMP) typically will use MMLOS-based methods as there is a need for more objective results especially in comparisons of alternatives. This level usually will have a higher amount of detailed data available which is consistent with the smaller analysis

segments and more specific detail required. Most elements could be obtained without doing a detailed field inventory, provided that unobstructed, high-quality aerials that can be used for the basis of measurements are available. This data level will make comparison easier across concepts and time periods with less subjectivity than with QMA.LTS and/or QMA can still be used if a plan will be relatively standalone. Plans that need to be consistent with future potential project development efforts especially with environmental assessments or environmental impact statements should use MMLOS-based methods for alternatives and limit LTS/QMA to screening analysis.

Project development requires the highest amount of data as objective design-level decisions need to be supported. The MMLOS methods are the most rigorous and commensurate with the typical available data. LTS can also be used as an initial screening measure to identify areas with existing or future needs. Analysis with the MMLOS segment and intersection methodologies even with appropriate ODOT defaults will take more effort and have a greater chance of needing additional specific field inventory data.

Assessing multimodal impacts in development review will typically involve use of LTS to quickly identify existing/future needs or development impacts and then using MMLOS techniques to identify mitigation scenarios. The urban context will need to be taken into account as the more urban an area is, even a standard zone change (i.e. residential to commercial) may require more detail. Transportation Planning Rule (TPR) -0060 analysis for a plan amendment can likely rely on more use of LTS (however, transit is only available at the MMLOS level) Transportation Impact Analyses (TIA) would likely need to primarily use MMLOS techniques in order to capture the specific scenario details.

While the designation of Multimodal Mixed Use (MMA) areas are based solely on safety concerns, once the designation is in place, non-automobile multimodal impacts can still be analyzed. Depending on the level of effort desired for a plan/project/TIA that involves a MMA, the multimodal analysis could use any of the methodologies.

14.3 Qualitative Multimodal Assessment

The Qualitative Multimodal Assessment (QMA) methodology is based on work done by David Evans and Associates and generally uses the principles of the full version 2010 Highway Capacity Manual (HCM) MMLOS but was modified to stay consistent as much as possible with the more objective methods presented later in this chapter. This methodology uses the roadway characteristics and applies a context-based subjective “Excellent/Good/Fair/Poor” rating. This method is best applied when comparing different alternatives side-by-side to each other but can also be used with a single scenario to compare the proposed improvement to existing conditions and to applicable standards. For example, a six foot sidewalk is standard in a residential area and would be rated Good (or Excellent if it had a buffer). Ratings can be “averaged” to obtain one for every mode, or they can be shown for every element if more detail is desired like in a technical appendix. This method is most appropriate when one or more of the following conditions

apply:

- The subject roadway does not easily divide into segments with uniform characteristics between intersections.
- The subject roadway has rural/suburban characteristics with infrequent or no signal control, where the MMLOS methodology is not applicable.
- Insufficient data is available to complete a MMLOS analysis
- Future alternatives may not have enough detail to properly quantify roadway characteristics required by other methodologies.



If a roadway has limited facilities because they are provided on parallel roadways (i.e. bike boulevards), consideration should be given to also applying the methodology to that parallel facility. This way the complete picture of the multimodal facilities offered along a corridor can be shown.

The full HCM MMLOS is most applicable to urban roadways with uniform segments broken up by signalized intersections. The MMLOS only evaluates segments bracketed by signalized intersections but the qualitative assessment can be done at all types of traffic control (e.g. roundabouts). Many communities do not have any signals or have too few signals to make the full HCM MMLOS method usable. In addition, this methodology allows for a multimodal look at a reasonable cost without requiring intensive data gathering. For most planning efforts, design details are not generally available until later, within phases such as refinement plans or project development, so it can be difficult to properly create the MMLOS inputs. All of the elements below should be considered for each mode. However, not all of the elements below will be contextually applicable in every community (i.e. volumes not sufficient for traffic signals or all-way stop control) so deviations can occur but should be documented.

14.3.1 Pedestrian

On segments, the following factors are considered:

- **Outside travel lane width:** Wider travel lanes are rated better than narrower travel lanes because of the larger buffer space between vehicles and pedestrians.
- **Bicycle lane/shoulder width:** The addition of bicycle lanes or shoulders creates greater separation between vehicles and pedestrian traffic and acts as a buffer. Wider facilities are rated better than narrow or non-existent facilities.
- **Presence of buffers (landscaped or other):** Buffer presence that separates pedestrians from traffic results in an improved rating. Wider buffers are rated better than narrower or non-existent ones.
- **Sidewalk/path presence:** The presence of sidewalks or paths will rate higher versus shoulders or no facilities at all. Wider sidewalks/paths rate better than narrower or non-existent ones.

- **Lighting:** The presence of lighting, whether roadway or pedestrian-scale, is rated better than roadways without lighting.
- **Travel lanes and speed of motorized traffic:** Less travel lanes and lower vehicle speeds will rate higher than more lanes and higher speeds.

At intersections, the following factors are considered:

- **Traffic control:** Intersections with a traffic signal or all-way stop control with crosswalks are rated better than locations with only two-way stop control or locations without crosswalks.
- **Crossing width:** Fewer turn or through travel lanes to be crossed is rated better than more turn/through lanes because the exposure to traffic and potential conflicts are less.
- **Median islands:** The presence of a median island is rated better than no islands as two-stage crossings are possible at unsignalized crossings.

14.3.2 Bicycle

On segments, the following factors are considered:

- **Preferred Bicycle facility type:** Bicycle facilities with greater separation from vehicles rate higher than shared or lesser separated facilities. Wider bicycle facilities will rate better than narrower or non-existent ones. Ideally, arterials (7000+ AADT) have separated facilities (i.e. buffered bike lanes, cycle tracks, bike paths); collectors (1500-7000 AADT) have bike lanes; and local streets have shared facilities. This will vary by location, context, and size of the community. For more information, please refer to the Separation Matrix of the ODOT [Bicycle and Pedestrian Design Guide](#) (Chapter 1, Page 3).
- **Shoulder presence/width:** Shoulders serve bicyclists in the absence of bike lanes, and wider shoulders rate higher than narrower or non-existent ones.
- **Outside travel lane width:** Wider travel lanes are rated better than narrower travel lanes on higher volume/speed roadways (i.e. arterials) because of the larger buffer space between vehicles and bicyclists. On lower volume and speed urban roadways, narrower lanes are better than wider lanes for better shared lane utilization (i.e. sharrow marked roadways).
- **Grade:** Level roadways/shallow grades are rated better than roadways with steep grades.
- **Pavement condition:** Poor pavement condition or obstacles (such as sewer grates, skewed railroad crossings, or in-street trackage) affect bicycling so better pavement condition and lack of obstacles will rate better than poor condition and many obstacles.
- **Obstructions:** Shoulders/bike lanes free of debris and other temporary obstacles such as construction barricades are rated higher than ones that are usually littered with gravel, glass, or frequently blocked.
- **On-street parking:** No parking or low parking utilization is rated better than high utilization and turnover rates because of potential conflicts with bicycles. Back-in

parking is rated better than front-in parking. Parallel parking is rated better if it includes a buffer from the bike lane.

- **Travel lanes and speed of motorized traffic:** Less travel lanes and lower vehicle speeds will rate higher than more lanes and higher speeds.

At intersections, the following factors are considered:

- **Traffic control:** Intersections with a traffic signal or all-way stop control with crosswalks are rated better than locations with only two-way stop control or locations without crosswalks. Intersections with bike signals are rated the highest.
- **Crossing width:** Fewer turn or through travel lanes to be crossed is rated better than more turn/through lanes because the exposure to traffic and potential conflicts are less.

14.3.3 Transit

The following factors are considered for transit:

- **Frequency and on-time reliability:** More frequent service and higher on-time schedule reliability are better than less frequent service and less reliable schedules.
- **Schedule speed/travel times:** Faster average peak hour schedule speeds and travel times are rated better than slower speeds and longer travel times.
- **Transit stop amenities:** The presence of shelters, benches, and lighting is rated better than stops with limited or no amenities. High-rated stops should have adequate boarding/maneuvering areas.
- **Connecting pedestrian/bike network:** Stops connected to a network of paths or sidewalk-equipped streets with improved crossings are better than those with no pedestrian facilities.

14.3.4 Auto

The following factors are considered for the auto mode:

- **Volumes/queues:** Lower observed volumes and queues are rated higher than higher volumes/queues on mainline and side-street intersection approaches. The number of lanes and functional class can be used as a surrogate to actual volumes if they are not readily available at this stage.
- **Safety:** Roadway conditions that provide for a decreased chance of crashes such as having illumination, longer intersection/driveway spacing, lower speeds, turn lanes and greater separation between fixed objects are better than conditions that may promote more crashes. The values of the seven criteria below can be “averaged” to obtain a single value for safety if desired.
 - Lighting: Roadways with lighting are rated better than ones without.
 - Driveway density: Lower driveway density is rated better than higher driveway density

- Intersection spacing: Longer intersection spacing distances are rated higher than shorter intersection spacing.
- Speed: Lower speeds are rated higher than higher speeds
- Fixed objects: Roadways with fewer fixed objects (trees, signs, barriers, etc.) close to the roadway (less than 25 feet) are rated higher than ones with more.
- Median/traffic separators: Presence of a median and/or traffic separators are rated higher than segments without.
- Turn Lanes: Intersection/driveway approaches with turn lanes are rated higher than approaches without turn lanes.

Example 14-1 Qualitative Multimodal Application

This example is based on work by David Evans and Associates on the OR99 Corridor Plan, but has been simplified and modified from the original analysis to illustrate the methodology.

The study area on OR99 in Talent, Oregon south of Medford is approximately one mile in length with a single traffic signal at Rapp Road. South of Rapp Road the area becomes increasingly less dense and suburban/rural to the southern city limits. There are limited bicycle, pedestrian, and transit facilities. OR99 is currently a four-lane undivided section, so a five-lane and a three-lane scenario was developed for analyzing potential future project alternatives. Conditions along the OR 99 corridor (limited signalization, limited data, and difficult to subdivide into homogenous segments) support the use of a qualitative MMLOS analysis to assess the multimodal aspects of existing and future scenarios. The table at the end of the example summarizes the analysis results.

Pedestrian & Bicycle Facilities - Existing Conditions

No existing separate pedestrian or bicycle facilities are in the corridor except the Bear Creek Greenway Trail located to the east of OR99 but not adjacent to the highway in this location. Pedestrians must walk on the shoulder and bicycles must share the right lane with vehicles, so the pedestrian and bicycle facilities are rated poor throughout.

Pedestrian & Bicycle Facilities - Future Scenarios

Both future scenarios would add a sidewalk or path to each side of the highway and would include a buffer on at least one side of the highway and bike lanes on both sides. The segments were rated as good for these conditions. The less travel lanes in the three-lane scenario rated higher than the five lane scenario as it creates a better environment for bicycles and pedestrians. At intersections, the three-lane scenario was rated better than the five-lane scenario because there would be fewer travel lanes for a pedestrian or a bicyclist to cross.

Transit Facilities – Existing and Future

Conditions are not expected to change in any substantial way from existing conditions. While connectivity to stops would increase, frequency, reliability, speed and travel time will be unchanged, therefore positive change will not be enough to change the grade

overall.

Auto Facilities – Existing and Future

The assessment reflects the volumes and the safety evaluation. Analysis of existing conditions and both future scenarios resulted in relatively lower volumes with shorter queues on side street approaches. The low volumes minimize conflicts between through and turning vehicles so the safety conditions are relatively close for all scenarios.

Segment/ Intersection	Mode			
	Pedestrian	Bicycle	Transit	Auto
Existing Conditions – (Four Lanes)				
Rapp Rd to Arnos Rd	Poor	Poor	Fair	Good
<i>OR99 at Arnos Rd</i>	Poor	Poor	Fair	Good
Arnos Rd to Creel Rd	Poor	Poor	Fair	Good
<i>OR 99 at Creel Rd</i>	Poor	Poor	Fair	Good
Scenario 1 - Five lanes				
Rapp Rd to Arnos Rd	Good	Fair	Fair	Good
<i>OR99 at Arnos Rd</i>	Fair	Fair	Fair	Good
Arnos Rd to Creel Rd	Good	Fair	Fair	Good
<i>OR 99 at Creel Rd</i>	Fair	Fair	Fair	Good
Scenario 2 – Three lanes				
Rapp Rd to Arnos Rd	Good	Good	Fair	Good
<i>OR99 at Arnos Rd</i>	Good	Good	Fair	Good
Arnos Rd to Creel Rd	Good	Good	Fair	Good
<i>OR 99 at Creel Rd</i>	Good	Good	Fair	Good

14.4 Bicycle Level of Traffic Stress

The Bicycle Level of Traffic Stress methodology breaks road segments into four classifications for measuring the effects of traffic-based stress on bicycle riders. The original methodology can be obtained from the paper, "[Low Stress Bicycling and Network Connectivity](#)", Mineta Transportation Institute, Report 11-19, May 2012. The version of the methodology described in this section has been modified from the original to correct inconsistencies in the tables, allow for additional intersection and bicycle features, and allow for more flexibility and engineering judgment in practice. Support for left turn lanes, one-way streets, roundabouts, buffered bike lanes, and shared lane markings have been added. A methodology for high-speed rural applications has been added since the original was for primarily urban areas. More detailed information on

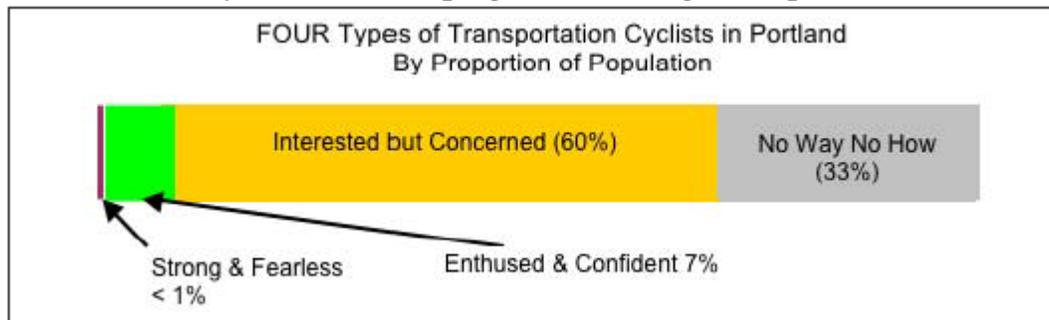
changes is provided in the specific topic areas.

This measure of traffic stress quantifies the perceived safety issue of being in close proximity to vehicles whether on a spacing distance or speed basis. The methodology does not include explicit consideration of traffic volumes as the proximity stress is present regardless of how much traffic happens to be occurring at that time. For example, a bicyclist travelling on a higher-speed arterial in the early morning hours without any bike lanes will still be having traffic (even though volumes are low) passing by closely and at high speeds. This bicyclist will experience higher stress than one riding in a buffered bike lane under the same conditions because the proximity to traffic is greater. An analogy to this would be as a pedestrian, having sidewalks with landscaped buffers is much more pleasant to walk on than curb-tight sidewalks right next to moving traffic. There are places in the methodology where there is implicit consideration of volumes, such as in the ability to cross intersections and interactions with turn lanes. Full consideration of traffic volumes require the use of more detailed methodologies, however the level of detail required is not necessarily consistent with the typical planning application but more project-like.

This methodology allows a quick assessment of system connectivity without going into the data requirements (i.e. traffic volumes) and calculations of the HCM Bicycle Multimodal Level-of-Service (MMLOS) method and is well suited for high-level plans such as corridor and transportation system plans (TSP). This method can also be used in detailed refinement-level plans and projects as a screening or flagging tool. Most of the data should be available as part of TSP inventories and/or supplemented with aerial photos. Depending on the community, TSP inventories may be limited to collector and arterial streets. Field inventory may still be needed to verify elements or supplement when vegetation or other obstructions make it difficult to see. Traffic counts/daily volumes are not required except for higher-speed rural applications. The methodology is designed for urban application, but can also be used for rural locations. The methodology is visual-based so the results can be easily communicated from the engineer to other agency and local government staff and the general public.

The tendencies of the general population to choose the bicycle as a mode and make route choices can be broken into four overall groupings based on City of Portland, [Oregon] surveys (Exhibit 14-2). While the percentages may change in different cities and rural/suburban areas, the groupings are still applicable.

Exhibit 14-2 Bicycle Rider Groupings as Percentage of Population



Source: “*Four Types of Transportation Cyclists in Portland*” by Roger Geller (2006)

The smallest group, “Strong and Fearless” represents people who will travel by bike under any condition and on any roadway. A second group, the “Enthusied and Confident” represents advanced cyclists who travel on most roadways but avoid high volume and speed conditions. Over half of the population falls into the largest group, “Interested but Concerned” who would ride if roadway conditions were perceived to be safe enough. The last group, representing around a third of potential riders, is “No Way No How”, who will not ride under any circumstances. More information on this methodology can be obtained from “*Four Types of Transportation Cyclists in Portland*” by Roger Geller (2006) and “*Four Types of Cyclists? Examining a Typology to Better Understand Bicycling Behavior and Potential*” (2012) Jennifer Dill and Nathan Winslow McNeil.

The Bicycle Level of Traffic Stress methodology adopted the above groupings, as the perception of user comfort being impacted by the proximity of vehicular traffic is one of the major decisions on whether one chooses this mode of travel. Further separation generally means less stress for users. The smallest group “Strong and Fearless” (avid cyclists and/or commuters) will travel most routes under any conditions, weather, light level, etc. and will tolerate the highest stress levels. On the other end, the “Interested but Concerned” group (casual or inexperienced riders) has little stress tolerance and will only accept the routes with the greatest perceived safety (separation). The research further breaks the largest “Interested but Concerned” group into adult and children riders where children require more safety awareness than adults along roadways and at intersections. Lastly, the “No Way No How” group was not included since the methodology concentrates on the current or potential bicycle-riding population.

Different trip purposes could have multiple ranges of acceptable stress levels for the same person. Someone making a work-based trip will likely have a greater stress tolerance than if they were riding merely for recreation. Going for a bike ride might mean a low stress tolerance for some riders, but they might accept a much higher stress level if they are on their way to work. Familiarity with the route, costs associated with driving and parking a car daily near a worksite, available bicycle infrastructure, vehicle availability/ownership, and other factors can influence someone’s maximum acceptable level of traffic stress.

The overall rider groupings are translated into four levels of traffic stress (LTS) classifications.

- LTS 1 – Represents little traffic stress and requires less attention, so is suitable for all cyclists. This includes children that are trained to safely cross intersections (around 10 yrs. old/5th grade) alone and supervising riding parents of younger children. Generally, the age of 10 is the earliest age that children can adequately understand traffic and make safe decisions which is also the reason that many youth bike safety programs target this age level. Traffic speeds are low and there is no more than one lane in each direction. Intersections are easy to cross by children and adults. Typical locations include residential local streets and separated bike paths/cycle tracks.
- LTS 2 – Represents little traffic stress but requires more attention than young children can handle, so is suitable for teen and adult cyclists with adequate bike handling skills. Traffic speeds are slightly higher but speed differentials are still low and roadways can be up to three lanes wide in total for both directions. Intersections are not difficult to cross for most teenagers and adults. Typical locations include collector-level streets with bike lanes or a central business district.
- LTS 3 – Represents moderate stress and suitable for most observant adult cyclists. Traffic speeds are moderate but can be on roadways up to five lanes wide in both directions. Intersections are still perceived to be safe by most adults. Typical locations include low-speed arterials with bike lanes or moderate speed non-multilane roadways.
- LTS 4 – Represents high stress and suitable for experienced and skilled cyclists. Traffic speeds are moderate to high and can be on roadways from two to over five lanes wide in both directions. Intersections can be complex, wide, and or high volume/speed that can be perceived as unsafe by adults and are difficult to cross. Typical locations include high-speed or multilane roadways with narrow or no bike lanes.

14.4.1 Additional Rider Factors

The Bicycle Level of Stress does not include other factors that may be important to bicycle riders that should be taken into consideration when applying this methodology. These can include presence of steep or long climbs, poor pavement condition, heavy vehicle use, narrow travel lanes, neighborhood crime, noise, absence of lighting, high driveway density, skewed railroad crossings, in-pavement streetcar/railroad tracks, and curbside conditions (snow removal or litter/gravel in the roadway). Congested conditions can also be considered if they add difficulty to getting gaps in traffic to get into a right or left turn lane for instance. Roadway locations with either a documented (reported total bike crashes including any injury or fatal ones) or a perceived (near misses, known unreported crashes) crash history should be flagged for reference.

Some of these can be significant determinants to the comfort of potential cyclists and

may, at times, degrade a segment by one or even two levels rendering a route unacceptable. If a number of these considerations exist, the stress levels can be optionally adjusted to account for them or they can be placed on a stress map or in a separate graphic to flag them as concerns. These can also come into play when determining alternate paths to high-stress routes. As some of these can be subjective, adequate documentation should be provided outlining the reasons for the deviations. Roadways where biking is prohibited, such as certain urban freeways, should also be noted.

14.4.2 LTS Targets

A target level of traffic stress for the bikeway system may be identified in an attempt to maximize the bicycle mode share with the available resources. A LTS 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 LTS 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 LTS 1 since LTS 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 LTS 1 routes. Middle and high school placement may not allow only LTS 1 routes but routes should be no more than LTS 2 since older children can use these without difficulty.

14.4.3 LTS Criteria

The traffic stress criteria in the LTS methodology is broken into three categories. Table-based criteria are applied separately for segments, intersection approaches, and intersection crossings. Depending on the community context and the detail level desired, segments can be block-by block or be between higher functionally-classified roadways (arterials or collectors). The overall methodology can usually be simplified based on the general consistency of facility types, as certain elements (i.e. no turn lanes, no bike lanes, limited speeds, etc.) may not exist in a particular community. Segments are typically considered to be two-way but there are areas where conditions are not the same on each side of the street (i.e. parking only on one side). Both directions can be reported separately, or the worst direction reported. The methodology uses the worst overall LTS value for each overall segment. For example, if a segment has a LTS 2 but there is an intersection approach at the end of the segment at LTS 4, then the whole segment is coded LTS 4. The same applies for entire routes which are typically reported in a single direction between two points of interest and can contain many segments and intersections. It is likely that the LTS will be different (i.e. right turn lane vs. left turn lane) in the two directions, so both directions should be reported. One poor crossing at LTS 4 will render a route unacceptable to most people even though the rest of the route is at LTS 2.

14.4.4 LTS Segment Criteria

The LTS segment criteria are broken into three classes: physically separated paths and lanes, standard bike lanes, and without bike lanes (mixed traffic). The physically separated paths include bike paths and cycle tracks which may be separated from motor vehicles by landscaped buffers, curbs, or on-street parking (for cycle tracks). Physically-separated bike paths and lanes (assuming full bike standards) are generally classified as LTS 1.

Marked bike lanes have different criteria depending on whether they are adjacent to a parking lane or not, as shown in Exhibit 14-3 and Exhibit 14-4. These exhibits are formatted differently from the original methodology to fix inconsistencies with roadways with bike lanes having higher stress levels than roadways without bike lanes. In addition, slight changes were made so bike lane width makes a difference in the lower stress levels. Buffered bike lanes have been added to Exhibit 14-4 to account for their increased positive separation effects.

The criteria are based on through lanes per direction, the sum of the width of the bike and parking lanes, speed limit or prevailing speed, and any bike lane blockage (in commercial areas from driveways, loading zones, stopped buses, or parking maneuvers). For these and following tables, the criteria aggregate following the weakest link principle: the dimension with the worst level of stress governs. For example, a roadway with one lane per direction, 25 mph, but has frequent bike lane blockages will be at LTS 3 which overrides the LTS 1 values of the other components.

Exhibit 14-3 Bike Lane with Adjacent Parking Lane Criteria

1 Lane per direction				≥2 lanes per direction	
Prevailing or Posted Speed	≥ 15' bike lane + parking	14' – 14.5' bike lane + parking	≤ 13' bike lane + parking or Frequent blockage ¹	≥ 15' bike lane + parking	≤ 14.5' bike lane + parking or Frequent blockage ¹
≤25 mph	LTS 1	LTS 2	LTS 3	LTS 2	LTS 3
30 mph	LTS 1	LTS 2	LTS 3	LTS 2	LTS 3
35 mph	LTS 2	LTS 3	LTS 3	LTS 3	LTS 3
≥40 mph	LTS 2	LTS 4	LTS 4	LTS 3	LTS 4

¹Typically occurs in urban areas (i.e. delivery trucks, parking maneuvers, stopped buses).

Exhibit 14-4 Bike Lane without Adjacent Parking Lane Criteria

1 Lane per direction					≥2 lanes per direction	
Prevailing or Posted Speed	≥ 7' (Buffered bike lane)	5.5' – 7' Bike lane	≤ 5.5' Bike lane	Frequent bike lane blockage ¹	≥ 7' (Buffered bike lane)	<7' bike lane or frequent blockage ¹
≤30 mph	LTS 1	LTS 1	LTS 2	LTS 3	LTS 1	LTS 3
35 mph	LTS 2	LTS 3	LTS 3	LTS 3	LTS 2	LTS 3
≥40 mph	LTS 3	LTS 4	LTS 4	LTS 4	LTS 3	LTS 4

¹Typically occurs in urban areas (i.e. delivery trucks, parking maneuvers, stopped buses).

Mixed traffic conditions are roadways without any bike markings (including widened shoulders not marked as bike lanes). Mixed traffic segment criteria for urban/suburban sections are based on the speed limit or the prevailing speed if different, and the number of lanes by direction, as shown in Exhibit 14-5. This exhibit was reformatted into “lanes per direction” from the original methodology, for consistency with the other segment criteria exhibits and to fix the with/without bike lane issue previously mentioned.

Designated bike boulevards or marked shared low-speed “sharrow” routes also are considered as mixed traffic conditions, but depending on judgment and area context, may have LTS levels reduced by one. Markings and signs give bicyclists more perceived safety and warn drivers about potential bicycles being in the roadway which tends to lower overall speeds.

Exhibit 14-5 Urban/Suburban Mixed Traffic Criteria

Prevailing Speed or Speed Limit (mph)	Unmarked Centerline	1 lane per direction	2 lanes per direction	3+ lanes per direction
≤ 25 ¹	LTS 1	LTS 2	LTS 3	LTS 4
30	LTS 2	LTS 3	LTS 4	LTS 4
≥ 35	LTS 3	LTS 4	LTS 4	LTS 4

¹Presence of “sharrow” markings may reduce the LTS by a level for 25 mph or less sections depending on overall area context.

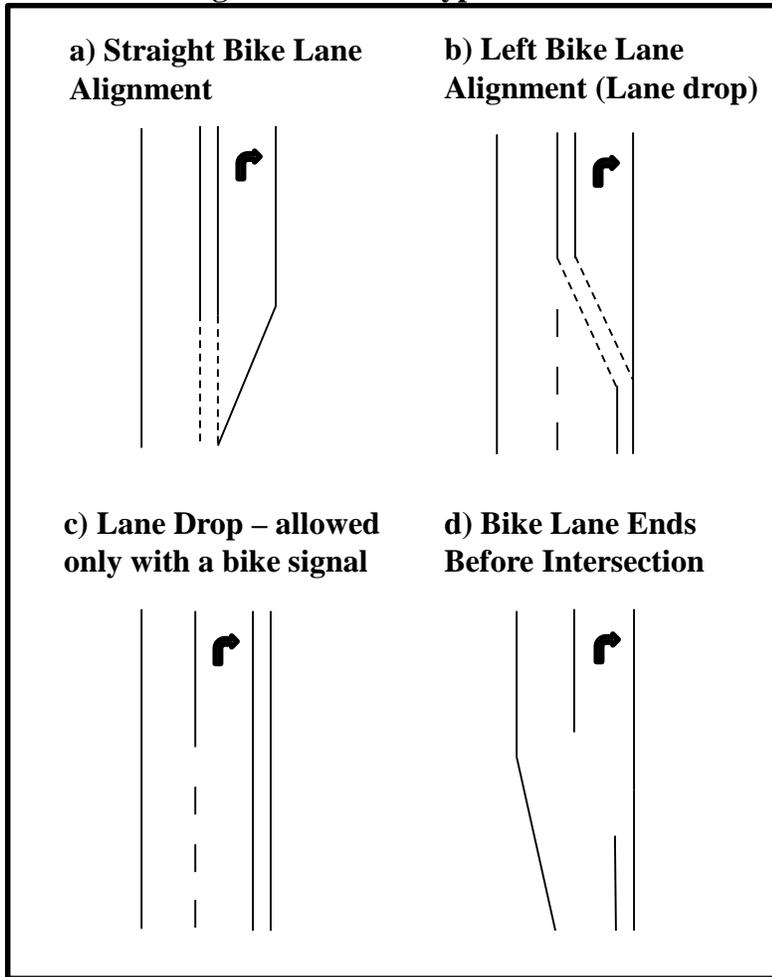
14.4.5 LTS Intersection Approach Criteria

Intersection approach criteria are based on the presence and type of right or left turn (vehicular) lanes. If there are no turn lanes on an approach, then this portion of the methodology is skipped.

ODOT Bicycle Design Guide standards have the right turn lane to the right of the bike lane so the bike lane continues straight and requires vehicles to turn and yield to bicyclists across a marked dashed bike lane (see Exhibit 14-6a). Locations where the through travel lane becomes a right turn lane (lane drop) may have a more stressful design where the bike lane shifts to the left while the travel lane continues straight (Exhibit 14-6b). In this case, the bike lane cannot be to the right of a right-turn lane unless controlled by a separate bicycle signal (see Exhibit 14-6c), as the through bicycle lane would directly conflict with the right turn lane with the potential for

many “right-hook” type crashes. Other intersection designs may have the bike lane end where the right turn lane begins (i.e. T-intersections, roundabouts) and re-appear on the other side of the intersection (Exhibit 14-6d).

Exhibit 14-6 Right Turn Lane Types



The right turn criteria are based on whether the bike lane stays straight or shifts to the left, turn lane length and turning speed. The longer the turn lane, the longer a bicyclist will have traffic on both sides in close proximity if continuing straight, or mixing with traffic if turning right. When the bike lane stays straight, turn lanes of 150’ or less (100’ is typical for most urban applications) and low turning speed (15 mph is a common for most residential and commercial areas) will have a LTS 2 as seen in Exhibit 14-7. Longer turn lanes, higher turning speeds or at skewed intersections will result in a LTS 3 rating. Dual shared or exclusive right turn lanes are typically in very high volume locations which add additional stress and are LTS 4.

A roadway with no marked bike lanes and a right turn lane will be a high stress location unless the right turn lane is short and rarely used. This condition will also occur if a bike lane is dropped ahead of an intersection. If the turn lane is short (less than 75’) then there is no impact on the LTS.

Exhibit 14-7 Right Turn Lane Criteria

Right-turn lane configuration	Right-turn lane length (ft)	Bike Lane Approach Alignment	Vehicle Turning Speed (mph) ²	LTS
Single	≤ 150	Straight	≤ 15	2
Single	>150	Straight	≤ 20	3
Single	Any	Left	≤ 15	3
Single ¹ or Dual Exclusive/ Shared	Any	Any	Any	4

¹Any other single right turn lane configuration not shown above.

²This is vehicle speed at the corner, not the speed crossing the bike lane. Corner radius can also be used as a proxy for turning speeds.

The original methodology did not consider the impact of left turn lanes. The left turn lane criteria were based on logical breaks in stress levels with the following considerations. Left turn lanes are more stressful than right turn lanes. Left turns require the cyclist to yield and merge into traffic like a vehicle and occupy the through and/or the left turn lane. The more through lanes a cyclist must cross to reach the left turn lane increases the stress level especially in higher speed locations, as both longitudinal and lateral mixing with traffic is increased, as shown in Exhibit 14-8.

Shared through-left lanes where a bike lane is present can act similar to mixed traffic conditions as the rider only has to move into the adjacent lane from the bike lane. Similarly, roadways with no bicycle lanes also act like mixed traffic conditions as the rider may already be in the shared left-through lane or just needs to move laterally into a left turn lane. Low-speed intersections that are set up for bicyclists to make two-stage left turns like with a bike box can be LTS 1. Please note that the only currently allowable bike box application is a two-stage left turn box at a “T”-intersection. All other intersection types and other bike box applications are considered experimental and require FHWA approval. See [FHWA’s Bicycle Facilities Design Guidance](#) web page for up to date information. Separate left turn lanes require the rider to occupy a through lane for some distance (to allow for signaling intentions to following vehicles). Dual left turn lanes (either shared or exclusive) indicate high-volume locations which add additional stress above and beyond the speed and necessary lateral movements and are typically LTS 4.



For rating routes, only include the effect of the left turn lane if the route requires a left turn. For through and right turn movements, include the effect of the right turn criteria.

Exhibit 14-8 Left Turn Lane Criteria

Prevailing Speed or Speed Limit (mph)	No lane crossed ¹	1 lane crossed	2+ lanes crossed	Dual shared or exclusive left turn lane ²
≤25	LTS 2	LTS 2	LTS 3	LTS 4
30	LTS 2	LTS 3	LTS 4	LTS 4
≥ 35	LTS 3	LTS 4	LTS 4	LTS 4

¹For shared through left lanes or where mixed traffic conditions occur (no bike lanes)

²Any other single left turn lane configuration not shown above.

14.4.6 LTS Unsignalized Intersection Crossing Criteria

Unsignalized intersection crossings can act as a barrier to bicyclists especially with a high number of lanes or higher speeds. The crossing can be an impediment to travel if the bicyclist has to cross six or more lanes at any speed or has to cross a 35 mph (or greater) four-lane street. The criteria for unsignalized intersection crossings depend on the presence of a median of sufficient width to provide for a two-stage crossing. Pedestrian/bicycle over/underpasses would be considered as separate facilities and are LTS 1.

Signalized crossings usually do not create a barrier as the signal provides a protected way across and are not considered in the methodology. Signalized intersections do pose risks for right-turn “hook” crashes, however, especially where right turn lanes are not present. Bicyclists may have also difficulty triggering the signal detection (vs. walking the bike across the street as a pedestrian). There may be areas where engineering judgment is required in assigning stress levels higher than LTS 1 at signalized intersections for these reasons. The presence of bike signals may be a mitigating factor in higher-risk areas thus keeping the LTS at 1.

Roundabouts were not included in the original research, but a single-lane roundabout assuming mixed traffic conditions (Exhibit 14-5) where the bicyclist takes the lane with the typical sub-25 mph speeds should be LTS 2. Dual-lane roundabouts should also use the mixed traffic conditions for two lanes (LTS 3). Dual-lane roundabouts may require bicyclists to cross a through lane to turn left which would have a similar application to Exhibit 14-8, however the mixed traffic conditions will likely still control. Right-turn bypass lanes within the roundabout would be considered as right turn lanes as shown in Exhibit 14-7.

Where there is no median refuge, with two-way crossings of up to three lanes, the LTS ranges from 1 to 3 depending on speed, as seen in Exhibit 14-9. For crossings of four to five lanes, the LTS ranges from 2 to 4.

Exhibit 14-9 Unsignalized Intersection Crossing Without a Median Refuge Criteria¹

Prevailing Speed or Speed Limit (mph)	Total Lanes Crossed (Both Directions) ²		
	≤ 3 Lanes	4 -5 Lanes	≥ 6 Lanes
≤ 25	LTS 1	LTS 2	LTS 4
30	LTS 1	LTS 2	LTS 4
35	LTS 2	LTS 3	LTS 4
≥ 40	LTS 3	LTS 4	LTS 4

¹For street being crossed.

²For one-way streets use Exhibit 14-10.

In a change from the original methodology, to better accommodate one-way streets, the intersection crossing with a median refuge criteria was changed to lanes per direction versus total lanes crossed. One-way streets carry higher volumes than two-way streets of the same number of lanes and thus can have greater stress levels applied to them. Use Exhibit 14-10 for one-way street applications.

Exhibit 14-10 has the maximum number of lanes a bicyclist encounters on each side of a median refuge. Adding a median refuge of at least six feet in width (10 feet for LTS 1 eligibility) will decrease the LTS versus when a refuge is not present. The presence of turn lanes are also accounted for as they add conflict points and vehicle paths to the awareness needs.

Exhibit 14-10 Unsignalized Intersection Crossing With a Median Refuge Criteria¹

Prevailing Speed or Speed Limit (mph)	Maximum Through/Turn Lanes Crossed per Direction		
	1-2 Lanes	2-3 Lanes	4+ Lanes
≤ 25	LTS 1 ²	LTS 1 ²	LTS 2
30	LTS 1 ²	LTS 2	LTS 3
35	LTS 2	LTS 3	LTS 4
≥ 40	LTS 3	LTS 4	LTS 4

¹For street being crossed.

²Refuge should be at least 10 feet to accommodate a wide range of bicyclists (i.e. bicycle with a trailer) for LTS 1, otherwise LTS=2 for refuges 6 to <10 feet.

Since crossings are not part of a link, the LTS to cross the major street is applied to the minor street. If the crossing LTS is greater than the minor street link LTS, the crossing LTS applies (controls) to that link.

14.4.7 Rural Applications

While the original methodology was designed only for urban applications, it can be used for rural roadways that have posted or operating speeds less than 45 mph. Rural roadways with speeds less than 45 mph tend to be one or two-lane local, undeveloped roadways that 1) connect rural communities, 2) exist in parks or other recreational areas or 3) provide a connection to a tourist destination. These are typically low volume and have no or little paved shoulder width. Sight

distances are likely to be lower (sharper vertical and horizontal curves) because of the lower road design standards used. LTS will be primarily based on speed in these cases. Use the regular LTS mixed traffic criteria shown in Exhibit 14-5 for these roadways and Exhibit 14-9 or Exhibit 14-10 for intersections. Approach criteria will probably not be applicable because low volume roadways generally do not have turning lanes.

Application of the LTS methodology to the typical higher-speed rural environment requires considering shoulder widths and volumes. Traffic counts/volumes are necessary for this method. The normal LTS methodology tops out at 40 mph, while most typical state and county rural roadways are posted at 45 - 55 mph.

A large portion of the bicycle-vehicle crashes occur when a vehicle attempts to overtake a bicyclist on a roadway with no or little available paved shoulder width. The wider the shoulder the less likely a bicyclist will be in the same path as vehicles. The occurrence of bike crashes is highest on higher volume rural facilities with little or no paved shoulders, poorly placed rumble strips, or deteriorated shoulder pavement conditions.

Narrow or no shoulders and higher volumes (increased overtaking conflicts) will increase the stress level. Unless an adjacent separated multi-use path/bike lane is provided (LTS 1), most rural roadways do not have bike lanes and bicyclists will depend on paved shoulders. Exhibit 14-11 shows the LTS for typical rural conditions for higher speed rural roadways.

Rural intersection crossing stress levels will be typically based on approach volumes and number of lanes (Exhibit 14-12). Since the rural environment is more unpredictable (higher speeds and motorists are less likely to be aware of or anticipate bicyclists) than the urban environment, the minimum LTS is 2.

Exhibit 14-11 Rural Segment Criteria with posted speeds 45 mph or greater^{1,2,3}

Daily Volume (vpd)	Paved Shoulder Width			
	0 - <2 ft	2 - <4 ft	4 - <6 ft	≥ 6 ft
<400	LTS 2	LTS 2	LTS 2	LTS 2
400 - 1500	LTS 3	LTS 2	LTS 2	LTS 2
1500 - 7000 ⁴	LTS 4	LTS 3	LTS 2	LTS 2
> 7000	LTS 4	LTS 4	LTS 3	LTS 3

¹ Based on p1-3 & Table 1-2 from the [Oregon Bicycle and Pedestrian Design Guide](#), 2011.

² Adequate stopping sight distances on curves and grades assumed. A high frequency of sharper curves and short vertical transitions can increase the stress level especially on roadways with less than 6' shoulders. Engineering judgment will be needed to determine what impact this will have on the LTS level on a particular segment.

³ Segments with flashing warning beacons announcing presence of bicyclists (typically done on narrower long bridges or tunnels) may, depending on judgment, reduce the LTS by one, but no less than LTS 2.

⁴ Over 1500 AADT, the Oregon Bicycle and Pedestrian Design Guide indicates the need for shoulders.

Exhibit 14-12 Unsignalized Rural Intersection Crossing with posted speeds 45 mph or greater¹

Daily Volume (vpd)	≤ 3 Lanes	4 -5 Lanes	≥ 6 Lanes
<400	LTS 2	n/a	n/a
400 - 1500	LTS 2	n/a	n/a
1500 - 7000	LTS 2	LTS 3	n/a
> 7000	LTS 3	LTS 4	LTS 4

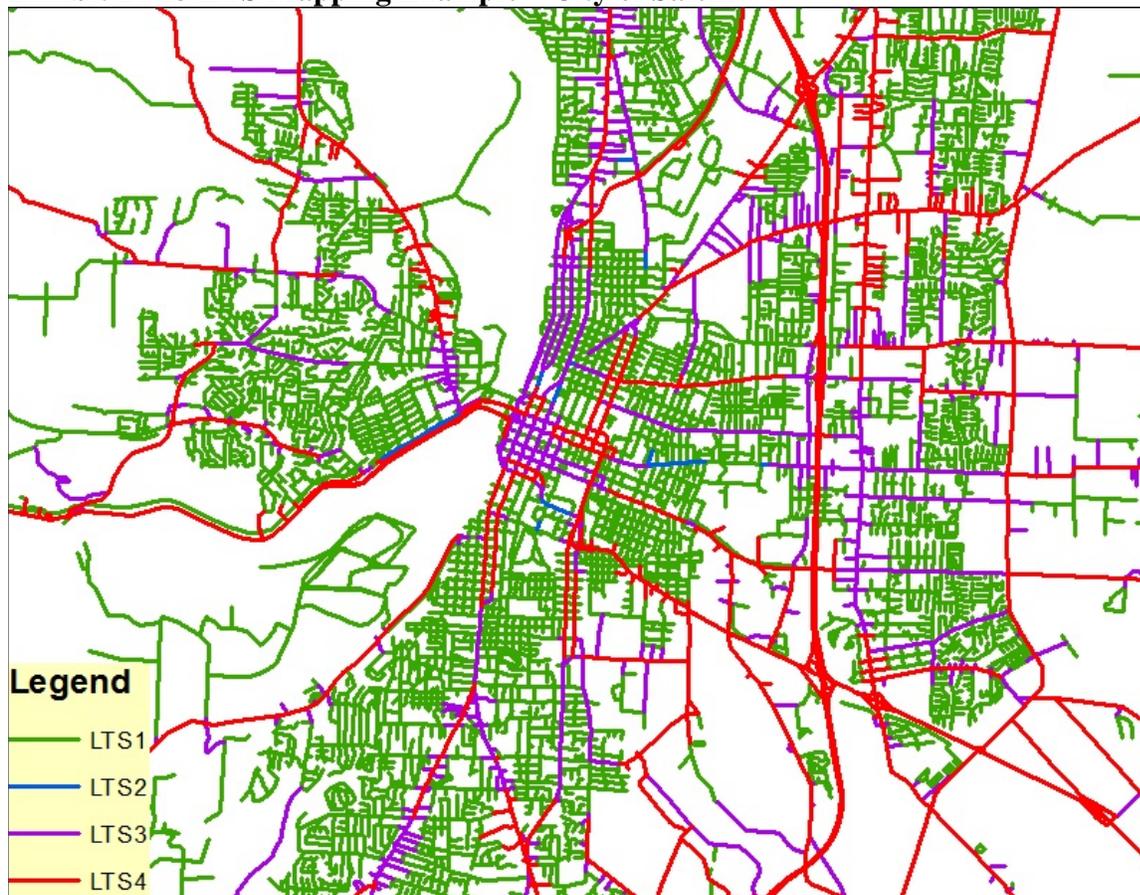
¹For roadway being crossed.

For intersection approaches, the presence of left or right lanes will increase the LTS at least by one level as they greatly increase the chance that vehicles will cut across the bicyclist's path or that the bicyclists will need to utilize these lanes to turn. Low volume roadways (less than 1500 ADT) are not likely to have turn lanes.

14.4.8 Route Connectivity using LTS

The LTS designations should be mapped on the system network. This can be facilitated with GIS or with a travel demand model if available. The objective of mapping is to identify locations with LTS values exceeding a desired level that may then be targeted for improvements. Exhibit 14-13 shows an example of using LTS showing the different stress levels. The high stress routes can easily be contrasted against the lower stress ones.

Exhibit 14-13 LTS Mapping Example – City of Salem¹

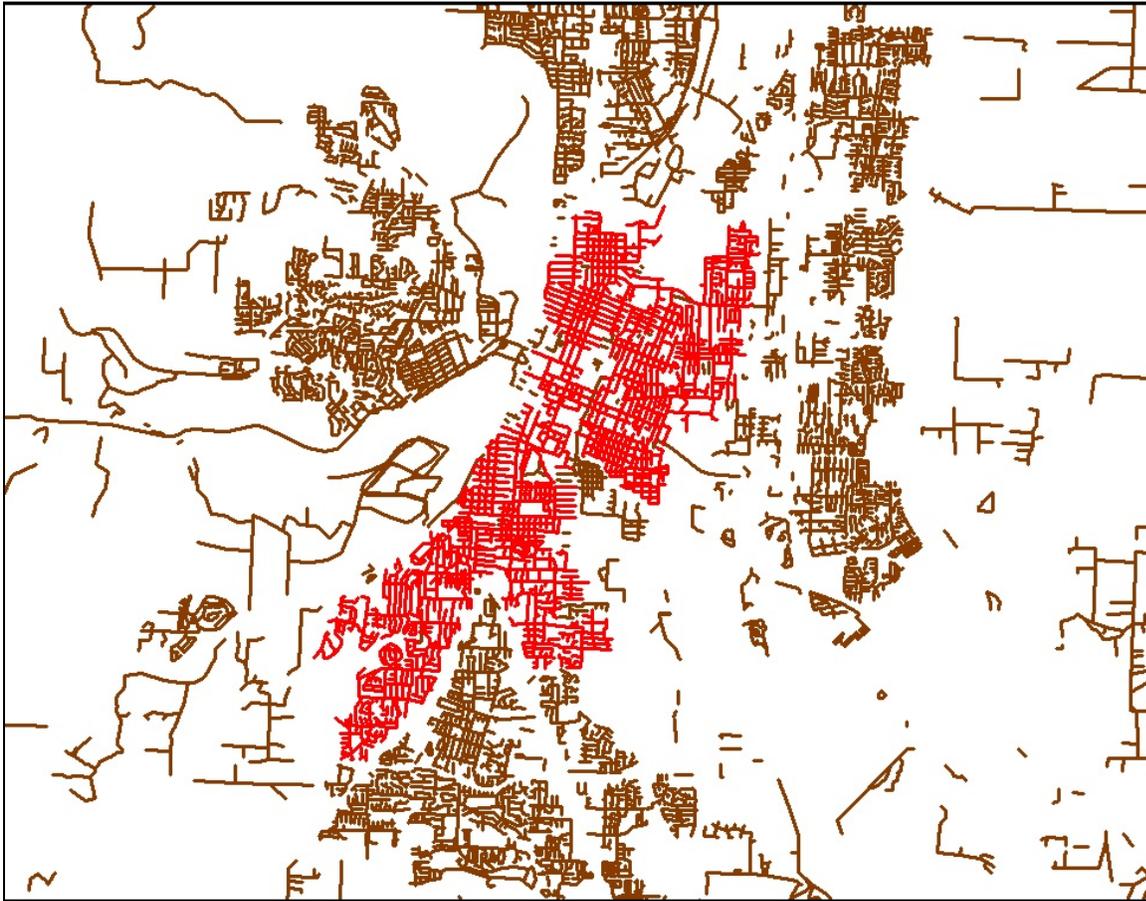


¹Source: Haizhong Wong, Matthew Palm, Jonathan Mueller, Salem BLOS Application, OSU, 2012.

Another significant advantage of the LTS methodology is that it allows the identification of connectivity “islands”, surrounded by higher LTS streets/intersections and other natural and physical barriers (i.e. rivers and railroads). This allows for a true connectivity look versus just considering system gaps, as one high stress location may prevent many routes or connections between adjacent neighborhoods. Improvements can be prioritized by the amount of additional low stress routes or points connected, thereby enhancing the system in addition to just gap filling.

Exhibit 14-14 shows an example of mapping just the LTS 1 and 2 routes. Barriers and high stress routes break the network into “islands” shown in brown and red. For emphasis in the original application, the downtown and surrounding system that can be reached via low stress routes is shown in red.

Exhibit 14-14 LTS Connectivity “Islands” – City of Salem¹



¹Source: Haizhong Wong, Matthew Palm, Jonathan Mueller, Salem BLOS Application OSU, 2012.

14.4.9 Specific Routes and Out-of-Direction Travel

Instead of tracking an entire jurisdiction/area of individual segments and crossings, the LTS mapping effort can also be applied based on routes between significant origins and destinations (i.e. neighborhoods to schools). Alternatively, this method may be used to help identify alternate (parallel) lower stress routes to help address a particular high stress location. It may be possible to attract potential cyclists by reducing the LTS of key links. For example, if an LTS 4 crossing is located along a route where all segments are at LTS 2 or less, it may be a good candidate for adding a median crossing refuge because it would complete the route and make it more attractive to more riders.

For each identified alternative route (for example to bypass a steep hill or a high stress intersection) a check for the out-of-direction travel should be made. For connectivity purposes, a route between two points should be low stress and without too much out-of-direction or extra travel distance. Too much extra travel time results in some riders choosing to travel the shorter, higher stress route, while other less stress-tolerant riders choose to not travel by bicycle at all, especially if they have a choice of modes.

According to the original research report¹, riders can typically tolerate up to 25% extra distance since the vast majority of trips are within 25% of the shortest-path available. However, most bicyclists choose trip paths that are only 10% longer than the shorter higher-stress routes, so 10% is a good target value. A 10% target represents a half-mile of extra travel on a five mile trip. Short trips should not have detours of longer than 1/3 mile which represents two minutes of travel time at 10 mph. In addition, the 25% maximum threshold for connectivity can also be used to predict route selection, to plan way-finding routes, or even analyze detour routes around a construction zone.

Routes can be assessed for acceptable out-of-direction travel if the either of the following relationships is true:

$$L_k/L_4 \leq 1.25; \text{ OR}$$
$$L_k - L_4 \leq 1,760 \text{ feet (0.33 mile)}$$

Where L_k = route distance at any given stress level, k.

L_4 = route distance using any links with stress levels up to and including LTS 4 (but not including links where riding is prohibited).

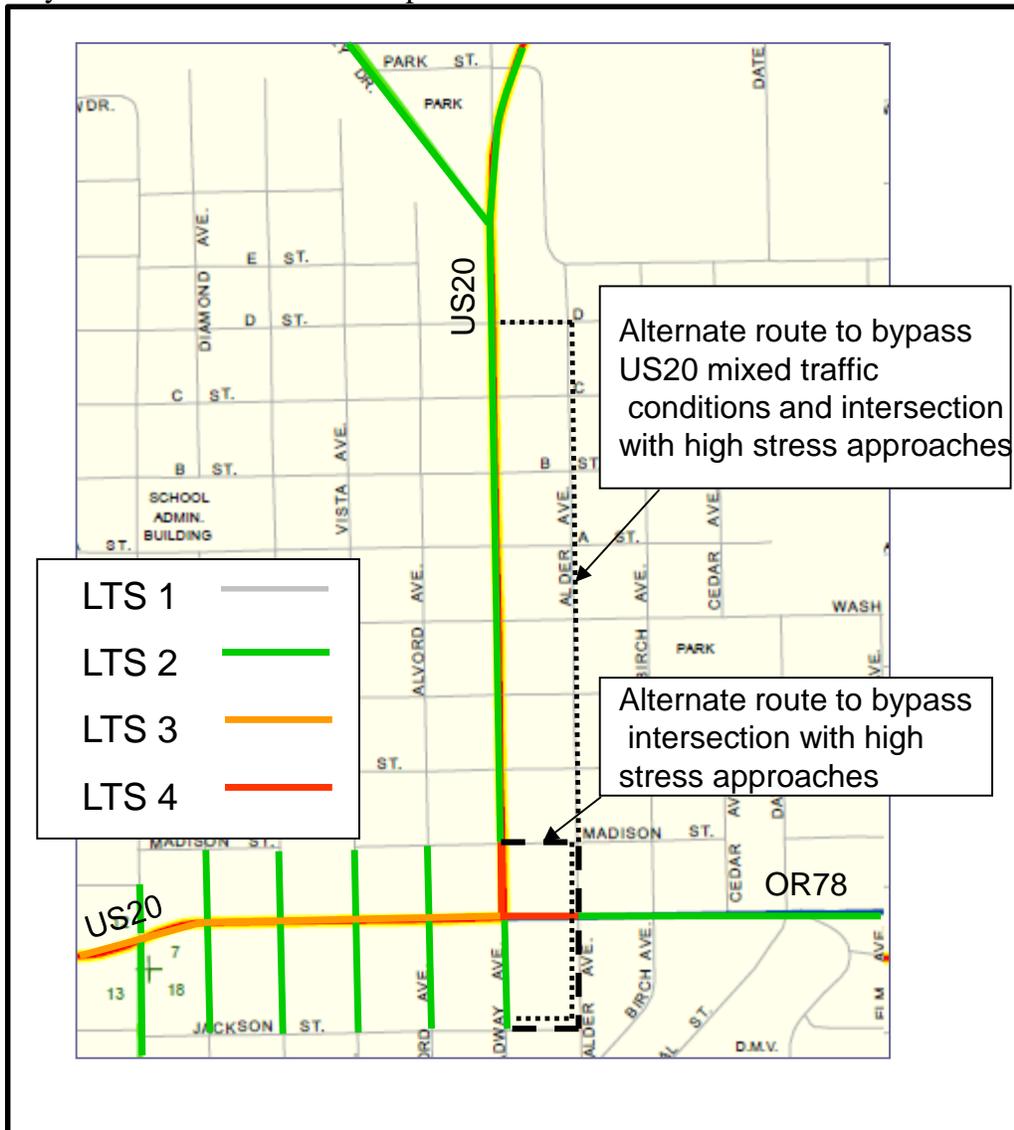
Note: Some routes with hills or many stops (or any of the previously mentioned additional considerations) may decrease desirability even though the criteria above are met.

¹Low-Stress Bicycling and Network Connectivity, Mekuria, Furth, & Nixon, Mineta Transportation Institute, May 2012, pp14-15.

Example 14-2 Alternate Route Out-of-Direction Travel

This example illustrates the impact of out-of-direction travel on alternate routing. Two routes, one short and one long, are shown bypassing a signalized intersection with high-stress approaches in the figure below. These are only two routes of the many that are available to use.

City of Burns US20 LTS Example



For the (exaggerated) short route, the normal high-stress route through the intersection is 700 feet. Adding in the two extra blocks of travel (600' total) to cross on a lower-stress path creates a 1300 foot route. While the total length of extra travel distance is acceptable as 600 feet is less than 1,760 feet, the overall extra trip distance as a proportion of the total is not, as $1300 \text{ feet} / 700 \text{ feet} = 1.86$ or 86% extra distance. For this route, bicyclists are unlikely to take the alternate path. Higher stress-tolerant users will just deal with the LTS 4 section while less tolerant users will likely take another mode such as walking or driving.

For the longer route, the normal higher-stress route is 2,650 feet through the downtown section and across the intersection. Like with the short route, the extra distance is 600 feet for a total route distance of 3,250 feet. In this case, the extra distance has less of a proportional impact on the trip as $3,250 \text{ feet} / 2,650 \text{ feet} = 1.23$ or 23%. This is less than the 25% threshold so bicyclists may choose this route instead, especially if they are less-stress tolerant. This distance is still greater than the desirable 10% level so not all (especially higher-stress tolerant riders) will use this particular route. This path would need to be over twice as long to meet the 10% level with even just a couple extra blocks out of direction.

14.4.10 Solutions to Decrease LTS Level

There are a number of ways to lower stress levels and to achieve a desired LTS level on a segment, approach, or crossing. For more detail on these solutions, please refer to the [Oregon Bicycle and Pedestrian Design Guide](#), the [ODOT Traffic Manual](#), and the [ODOT Highway Design Manual](#). A few examples (not exhaustive):

- Creating conventional bike lanes, buffered bike lanes, raised bike lanes, and bike boulevards.
- Creating segregated bike facilities such as cycle tracks or bike paths.
- Safety measures in design, such as couplets, medians, or pedestrian refuges. If four lanes of vehicular capacity is still needed then investigating a couplet may also achieve stress reductions.
- Increase width of outside lanes on roadways too narrow for striped bike lanes to create more buffer space and room for bicyclists.
- Paving/widening shoulders or removing parking.
- Reducing the number of lanes through a road diet.
- Install road markings (such as sharrows) and way-finding signs.
- Addition of flashing pedestrian beacons (i.e. RRFB's) or mid-block pedestrian hybrid beacons (i.e. HAWK) can improve higher-volume crossing locations.
- Removing or improving barriers, such as providing a safe grade-separated crossing over highways or railroads.
- Improving the pavement conditions on the shoulders of roadways.
- Adding left-turn bike boxes (see Section **Error! Reference source not found.** for limitations).
- Adding bike signals to clarify bike movements.
- Reducing speeds, enforcement of speeds limit or education about speed.

14.4.11 LTS Application Example

Example 14-3 Level of Traffic Stress

This example illustrates the use of LTS for the central section of the City of Burns in eastern Oregon in Harney County. This covers the signalized junction of US20 and OR78 in downtown

Burns as well as including surrounding residential areas. Data was quickly obtained by using available state highway inventory data and views from commercial aerial photos.

Segment LTS:

Most roadway sections are two lanes and 25 mph except for US20 west of the OR78 junction which has four lanes. No bike lanes are in the example area so all roadways are considered mixed traffic, which will be LTS 2 for the two-lane major roadways (US20 and OR78), LTS 3 for the four-lane section of US20, and LTS 1 for the local streets (no marked centerlines).

Approach LTS:

On the southbound and westbound approaches to the US20/OR78 junction, the right turn lanes are both a full block long with an adjacent shared-through left lane. These right turn lanes will create a high stress level for a bicyclist as it forces them to mix directly with right turning traffic if they wish to turn right or mix with through traffic in the southbound shared through-left lane if they wish to continue southbound. Because these are greater than 150 feet and do not have an adjacent bike lane, these are both coded LTS 4. The adjacent shared left-through lanes on both approaches would have an LTS 2, but the LTS 4 right turn lane arrangement supersedes it.

On the northbound approach, there is a short 50' right turn lane with an adjacent shared –left lane. The right turn lane is short, so there is no additional impact on the LTS. The adjacent shared though-left lane would be an LTS 2, as no lane would need to be crossed since an approaching bicyclist will end up in this lane if they are not turning right. Here, the approach LTS 2 will override the segment LTS 1 value.

The eastbound approach has a left-lane drop lane where the left turn lane is a full block long with an adjacent through-right lane. Since mixed traffic conditions exist, the bicyclist would just move into the left turn lane. This would be at a LTS 2 level, but the segment LTS 3 level would still control.

Crossing LTS:

The signalized intersection of US20 & OR78 is LTS 1. However, this is overridden on the southbound and westbound approaches by the LTS 4 for the approaches; on the eastbound side by the LTS 3 four lane sections; and on the northbound side for the LTS 2 approach. On the four-lane portion of US20, the local street crossings are increased to LTS 2 which affects the coding of local street segments that are adjacent to US20.

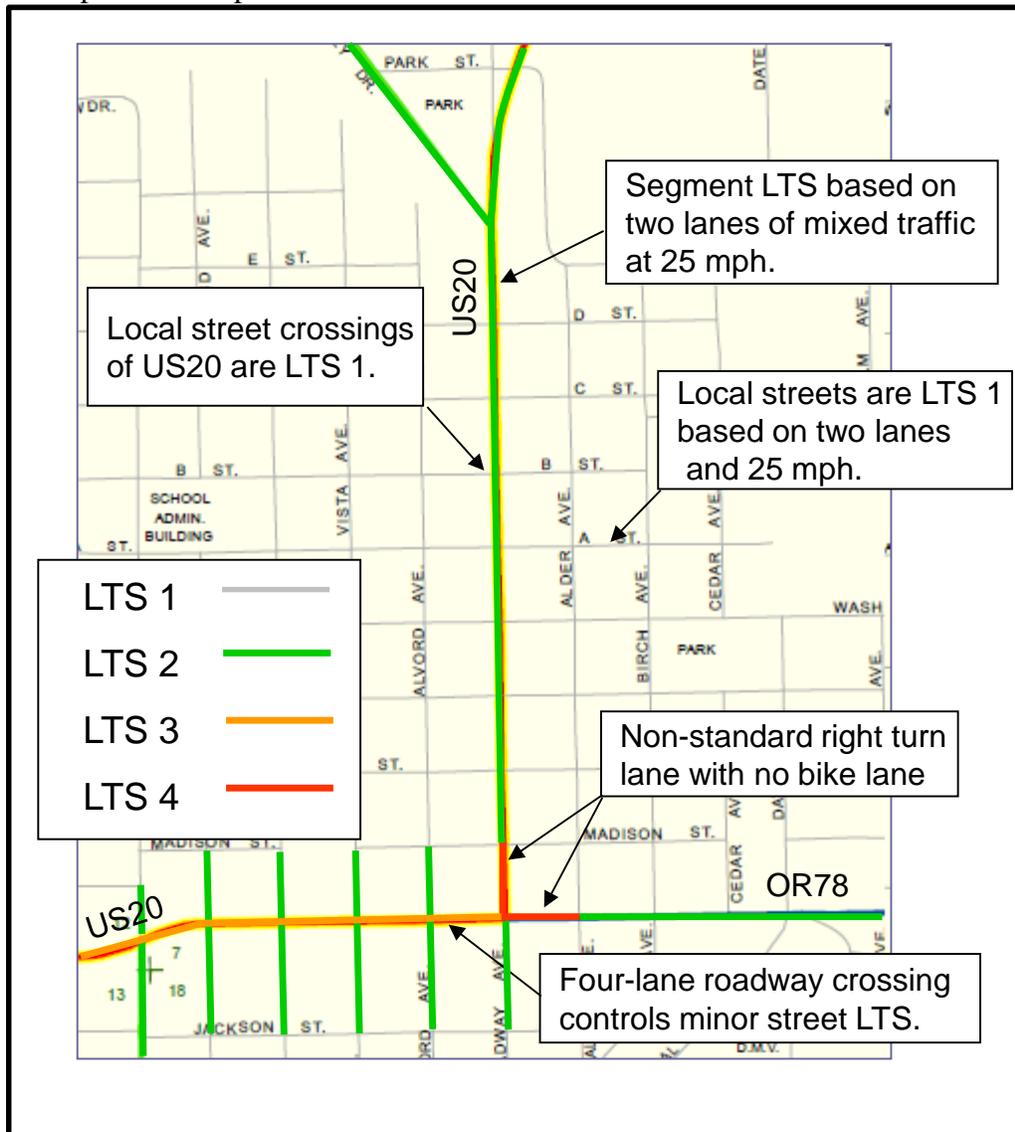
Summary:

Since the highest LTS controls, and using the US20/OR78 intersection as an example, the approach criteria is greater than the segment or crossing criteria, except for the eastbound approach where it matches the LTS 3 value. The resulting LTS at the intersection can be seen in the figure below.

Most of the roadway system in the example is LTS 1 or 2. The long right turn lanes coupled with the absence of bike lanes on US20 and OR78 approaching the highway junction convert a potential route using these roadways into LTS 4, which most bicyclists will avoid. While the various parts of the city are generally well connected with LTS 1 or LTS 2 networks, it is easy to

see the disconnect created along the primary arterials by the intersection of US 20 and OR 78.

Example LTS Map



14.5 Pedestrian Level of Traffic Stress

14.5.1 Purpose

The purpose of the Pedestrian Level of Traffic Stress (PLTS) is to create a high-level inventory and a walkability/connectivity performance rating of pedestrian facilities in a community without needing a significant amount of data. The Pedestrian Level of Traffic Stress methodology classifies roadway segments according to the level of pressure or strain experienced by pedestrians and other sidewalk users. Other users include non-motorized forms of transportation

as well as motorized power chairs, scooters, and other wheeled mobility devices which are permitted and assumed to use pedestrian facilities¹. The PLTS method would typically be used during the creation of a Regional Transportation Plan (RTP), or Transportation System Plan (TSP). It can also be used for screening in a facility plan or project (See Section 14.2 for more information on applications). This methodology is intended for use in urban areas. It can be used in rural conditions where pedestrian facilities exist, however the method will yield a high PLTS where there is higher speed traffic.

14.5.2 Methodology

PLTS was created to be a companion with the Bicycle Level of Traffic Stress (BLTS)². Both methods group facilities into four different stress levels for segments, intersection approaches and intersection crossings. It is recommended that BLTS and PLTS be performed at the same time to completely understand the multimodal and intermodal deficiencies of an area. New techniques were developed to support the pedestrian segment method while the intersection crossings are adapted from the BLTS method, as these were based on a pedestrian's view of comfort and perceived safety. Like BLTS, the PLTS methodology does not require extensive data collection; much of the data is collected routinely and some of the data collected for PLTS overlaps with BLTS.

Segment data:

- Sidewalk condition 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 average daily traffic (ADT) [optional]
- Sidewalk ramps
- Median refuge & illumination presence
- Signalized general intersection features

¹ A non-motorized form of transportation refers to vehicles that would not use the roadway to travel on a roadway. Motorized power chairs, scooters, and other wheeled mobility devices are permitted and assumed to use pedestrian facilities.

² The BLTS methodology is based on the paper, *Low Stress Bicycling and Network Connectivity*, Mineta Transportation Institute, Report 11-19, May 2012 that was adapted by the Oregon Department of Transportation in 2014. This version can be found in the "[Analysis Procedures Manual](#)," Oregon Department of Transportation, Version 2, June 2015.

For state highways, a good portion of the data needed is available in ODOT's databases including the on-line TransGIS application. Sidewalk condition and width, buffer presence, bike lane width, numbers of lanes, posted speeds, functional class, traffic volumes, and sidewalk ramps are available. Other jurisdictions may have existing TSP or public works inventories of some of these items. Use of Internet-based aerial imagery and street-level tools will capture any remaining widths or presence variables such as parking and buffer widths or intersection/mid-block crossing features. Sidewalk condition will likely require some sort of field inventory if it not available from other sources. Volumes, if used, should be from existing sources, or already counted as part of the same study. Streets with similar characteristics with known volumes can be used as proxy for other streets in the study area. PLTS uses four levels of traffic stress with PLTS 1 being the lowest stress level:

- **PLTS 1-** Represents little to no traffic stress and requires little attention to the traffic situation. This is suitable for all users including children 10 years or younger, groups of people and people using a wheeled mobility device (WhMD³). The facility is a sidewalk or shared-use path with a buffer between the pedestrian and motor vehicle facility. Pedestrians feel safe and comfortable on the pedestrian facility. Motor vehicles are either far from the pedestrian facility and/or traveling at a low speed and volume. All users are willing to use this facility.
- **PLTS 2-** Represents little traffic stress but requires more attention to the traffic situation than of which young children may be capable. This would be suitable for children over 10, teens and adults. All users should be able to use the facility but, some factors may limit people using WhMDs. Sidewalk condition should be good with limited areas of fair condition. Roadways may have higher speeds and/or higher volumes. Most users are willing to use this facility.
- **PLTS 3-** Represents moderate stress and is suitable for adults. An able-bodied adult would feel uncomfortable but safe using this facility. This includes higher speed roadways with smaller buffers. Small areas in the facility may be impassable for a person using a WhMD and/or requires the user to travel on the shoulder/bike lane/street. Some users are willing to use this facility.
- **PLTS 4-** Represents high traffic stress. Only able-bodied adults with limited route choices would use this facility. Traffic speeds are moderate to high with narrow or no pedestrian facilities provided. Typical locations include high speed, multilane roadways with narrow sidewalks and buffers. This also includes facilities with no sidewalk. This could include evident trails next to roads or 'cut through' trails. Only the most confident or trip-purpose driven users will use this facility.

It should be noted that the trip purpose and route options affect the level of stress a person is willing to experience. A person making a work-based trip is typically willing to experience a greater stress level than a person using the facility for recreation or exercise. Other elements including time of day, cost associated with other modes, ownership of vehicles, etc., influence

³ A wheeled mobility device (WhMD) includes walkers, manual wheelchairs, power base chairs, and light weight scooters. Each of these devices requires the operator to maneuver and set the direction of travel. All of these devices can be operated independently and do not require additional people to maneuver the device. The American with Disability Act (ADA) (1990) sets limits on the vertical change in a surface to 0.5 inches.

the level of stress a person is willing to experience.

Additional Pedestrian Considerations

PLTS does not include some additional factors that may influence the overall level of traffic stress. These considerations may be somewhat subjective and may not be easily measured. These factors include, but are not limited to, steep grades, neighborhood crime/personal security, access density, crash history, and heavy bicycle use (on sidewalk or path). If desired, the methodology could be modified to include these factors. If one or more negative conditions apply to a roadway, the final score can be further downgraded with proper documentation. Additional notation should be included if the downgrade was based on subjective observations.

14.5.3 PLTS Targets

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 ideal.

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.

14.5.4 PLTS Criteria

PLTS measures are derived from the physical characteristics of the roadway segment and intersection crossing. Pedestrians will go either direction on a sidewalk. If there is not a sidewalk, pedestrians typically walk in the opposite direction of traffic and both sides of the roadway should be classified.

The PLTS is broken into a number of different segment and crossing tables based on several physical characteristics of the corridor.

Variable Definitions: To complete the segment PLTS analysis, information on six different variables is used. The variable definitions are listed below:

Sidewalk⁴ Width: The physical width of the solid smooth surface (typically poured concrete, but could be asphalt, brick, or concrete paver blocks) that pedestrians use. This does not include solid surfaces that contain vegetation, additional lighting, street furniture, parking meters, etc. If a sidewalk has frequent obstructions (posts, poles, mailboxes, and encroaching vegetation) that limit the usable width, use the narrower or effective width instead of the physical width.

Sidewalk Condition: The sidewalk condition is a visual high-level classification process (see Exhibit 14-15). Sidewalk condition can vary within a block segment. Use the worst sidewalk condition, as a section of poor sidewalk can block some users from using the facility.

The criteria and pictures for each category are based off the Good-Fair-Poor (GFP) Pavement Condition Rating Manual for Bicycle and Pedestrian Facilities and the Pavement Distress Survey Manual developed by ODOT's Pavement Services Unit. These values are also generally compatible with the sidewalk condition ranking in ODOT's TransGIS tool. For each corridor segment the general pavement condition should be considered. A sidewalk segment that contains a mix of different conditions should be rated using the worst condition. For example, a sidewalk is smooth with only minor cracking but has a very large fault caused by a tree root. The sidewalk would be considered in "Very Poor" condition. For a sidewalk to be considered in "Fair" condition, none of the properties can be "Poor" or "Very Poor" and at least one is in the "Fair" category. For a sidewalk to be considered "Good" all of the criteria must be met and it must be of relatively new construction. Additional examples are located in Appendix B.



If obtaining data from ODOT's online FACS_STIP or TransGIS tools for use in a PLTS analysis, please be aware that there is no "Very Poor" equivalent at this time. Analysts will need to field verify sidewalk sections marked as "Poor" to ensure that there are no "Very Poor" sections within them.

⁴ Sidewalk refers to sidewalks, shared-use paths, and pedestrian paths. The methodology was designed to be used for sidewalks but, can apply to other pedestrian facilities.

Exhibit 14-15 Sidewalk Condition Rating

Rating	Facility Properties	Example
Good	<ul style="list-style-type: none"> • No minor cracking • No patching or raveling and has a very smooth surface • No faulting • New construction 	
Fair	<ul style="list-style-type: none"> • Minor cracking (generally hairline) • Minor patching and possibly some minor raveling evident. Surface is generally smooth • Minor faulting (less than ¼") 	
Poor	<ul style="list-style-type: none"> • Minor cracking in several locations • Rough areas present but not extensive • Faulting may be present but less than ½" (No major faulting) 	
Very Poor	<ul style="list-style-type: none"> • Major cracking patterns • Rough conditions (major deterioration, raveling, loose aggregate, missing pavement, etc.) • Faulting greater than ½" 	

Rating	Facility Properties	Example
No sidewalk	<ul style="list-style-type: none"> No solid and smooth surface is present on the side of the roadway. Pedestrians use the travel lane, paved shoulder, or soil shoulder to travel along the roadway. 	

Physical Buffer Type: The physical buffer is the distance from the outside edge of sidewalk to the edge of pavement or curb. The buffer type is categorized into six major groups. This area is also referred to as the furniture or planter zone.

No Buffer: The narrower sidewalk (<10 ft in width) is adjacent to the curb (curb tight). The facility may still include a bike lane and/or on street parking (see total buffering width distance).



Solid Surface: The buffer is a hard surface that can contain buffering elements such as lighting, street furniture, parking meters, and bicycle racks. If the buffer is wide enough, street trees can also be present which help improve the walking experience. The buffer still allows people to maneuver to the roadway edge without leaving the solid surface. The surface material can also change to indicate a buffer (i.e., stamped concrete, pavers). Purely decorative buffers usually do not have any “furniture elements” in them. A wide sidewalk (10+ feet) can also be itself a buffer even if there is no extra delineation.

Landscaped: the area between the edge of the sidewalk and the curb includes a soil area with low shrubs or vegetation. The vegetation does not create a wall or reduce pedestrian sight distance. These can also have a ditch, slope, or other topographical feature.

Landscaped with trees: The area between the edge of the sidewalk and the curb includes trees. Once the trees are mature, a canopy effect is created over the pedestrian facility and the edge of roadway. Trees are spaced for healthy growing and sight distance is not limited. This buffer type tends to be wider than a regular landscaped buffer and also can have a ditch, slope, or other topographical feature included.

Vertical: A vertical buffer (i.e. retaining wall) elevates the pedestrian facility higher than the roadway surface. This typically contains an additional fence or pedestrian buffer facility.

Prevailing or Posted Speed: The prevailing (or average) speed is the recommended speed to be used in the methodology. If prevailing speed data is not available posted speed should be used.

Total Buffering Width: The total buffering width is the distance from the edge of the sidewalk to the edge of the travel lane. This includes but is not limited to:

- the physical buffer (above),
- on-street parking, if parking is not striped then assume the standard parking distances (six to eight feet) for the facility type
- Bicycle facility, and
- Shoulder



Total Number of Travel Lanes: The total number of travel lanes includes the total number of lanes on the segment. This includes the number of thru lanes for both directions, two-way left turn lanes (TWLTL), and continuous right turn lanes. For example, a five-lane roadway could have two thru lanes in each direction and one two-way left turn lane. Note: This category is different than used in the BLTS method because pedestrians can use either side of the roadway to go either direction and are not limited by one-way streets.

General Land Use

The general land use of an area with the corresponding building placement, amenities, and attractions/destinations affects the overall desired walkability of a segment. Areas that are more pedestrian-friendly typically have more destinations for walking trips, a higher pedestrian presence, and the corresponding expectation from a vehicle driver's perspective. Land use types are grouped by the likelihood for a high number of origins and/or destinations, likely pedestrian presence, perceived attractiveness and exposure, noise, heavy vehicle use, and directness.

Intersection variable definitions:

Functional Class – This is the local or state functional class assigned to a roadway. These are typically included in a Transportation System or Regional Transportation Plan document.

Average Daily Traffic – This is the total daily traffic in both directions. These can be obtained from ODOT's Transportation Volume Tables, local counting programs, calculated from traffic counts or estimated from shorter duration counts. See APM Chapters 3 and 5. If ADTs are not readily available, the methodology allows a mid-range value to substitute.

14.5.5 PLTS Classifications

The PLTS criteria are broken into two primary sections. Table-based criteria are applied separately for segments and intersection crossings. The follow sections outline the nine tables used to classify the PLTS for a roadway. The first four tables are the roadway segment criteria and the last five are for roadway intersections. The methodology uses the worst overall PLTS value for each segment and intersection crossing. The worst (highest) PLTS value of a series of segments and crossings will control a route.

Sidewalk Criteria

The condition and geometry of the sidewalk is the first criterion in the PLTS methodology. The criterion splits sidewalks into greater than five feet and less than five feet in width. The five foot condition is based on federal and state design codes and recommendations. The federal standard for a sidewalk is five feet. In Oregon, the Oregon Bicycle and Pedestrian Design Guide (OBPDG) states that the standard pedestrian zone is six feet and those five feet may be acceptable in some areas (local and residential streets). Short (<200') sections can have widths as narrow as four feet. While sidewalks along a state highway may need to be wider, sidewalks in central business districts of heavy used pedestrian areas may also need to be wider. Guides such as the OBPDG and the Highway Design Manual (HDM) should be referenced for more information.

Exhibit 14-16 uses the overall condition and the effective (useable) width of the sidewalk. The purpose is to rate which groups of users can safely and comfortably utilize a facility. A narrow (from obstructions or actual width) or low quality sidewalk will not be passable for all user groups. The actual sidewalk width, especially if it is less than five feet, will impact the use by disabled people while effective width rates the comfort and flow of pedestrians along a sidewalk. The effective width is the simple average clear width of a sidewalk segment rather than following the more-detailed Highway Capacity Manual procedure.

Use the actual sidewalk width first in Exhibit 14-16 to see if the minimum actual width is present, then check the effective width if the sidewalk is at least six feet wide to determine the appropriate PLTS. If the effective width is less than five feet use the corresponding actual width rows as obstructions will still cause impediments to disabled users. A PLTS 1 sidewalk must be accessible to all users, have six effective feet or wider path, and in good or fair condition. If a segment does not have illumination, consider increasing the PLTS up one level. The impact of darkness requires increased awareness for safety/security and especially if the sidewalk is in poor condition or is not present.

Exhibit 14-16 Sidewalk Condition ^{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 3	PLTS 4	PLTS 4
Effective	≥6 ⁴	PLTS 1	PLTS 1	PLTS 2	PLTS 3	PLTS 4

¹Can include other facilities such as walkways and shared-use paths

²Effective width is the available/useable area for the pedestrian. Does not include areas occupied by store fronts or curb side features.

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

⁴Effective 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).

14.5.6 Physical Buffer Type Criteria

The treatment of buffers is split into two parts: the physical buffer type and the total buffering width, which includes the physical buffer and any on-street areas outside the travel lanes (parking, bike lanes, and shoulders). The HDM and the OBPDG have standards and guidance pertaining to buffers. There are several advantages of having a buffer or furniture zone on a facility. The advantages include an increase in a pedestrian's sense of security, sidewalks that stay level over driveways, and improved drainage. Exhibit 14-17 shows stress levels associated with varying buffer types.

Exhibit 14-17 Physical Buffer Type

Physical Buffer Type				
Buffer Type ¹	Prevailing or Posted Speed			
	≤25 MPH	30 MPH	35 MPH	≥40 MPH
No Buffer (curb tight)	PLTS 2	PLTS 3	PLTS 3	PLTS 4
Solid surface	PLTS 2 ²	PLTS 2	PLTS 2	PLTS 2
Landscaped	PLTS 1	PLTS 2	PLTS 2	PLTS 2
Landscaped with trees	PLTS 1	PLTS 1	PLTS 1	PLTS 2
Vertical				

¹Combined buffers: If two or more of the buffer conditions apply, use the most appropriate, typically the lower stress level.

²If street furniture, street trees, lighting, planters, surface change, etc. are present then the PLTS can be lowered to PLTS 1.

14.5.7 Total Buffering Width Criteria

Exhibit 14-18 considers the stress associated with the total distance from the pedestrian to the vehicular traffic on one side of the roadway. The number of lanes is used to imply the level of the traffic volumes and functional classification of the roadway.

Exhibit 14-18 Total Buffering Width

Total Number of Travel Lanes (both directions)	Total Buffering Width (ft) ¹				
	<5	≥5 to <10	≥10 to <15	≥15 to <25	≥25
2	PLTS 2	PLTS 2	PLTS 1	PLTS 1	PLTS 1
3	PLTS 3	PLTS 2	PLTS 2	PLTS 1	PLTS 1
4 - 5	PLTS 4 ²	PLTS 3	PLTS 2	PLTS 1	PLTS 1
6	PLTS 4 ²	PLTS 4 ²	PLTS 3	PLTS 2	PLTS 2

¹Total Buffering Width is the summation of the width of buffer, width of parking, width of shoulder and width of the bike lane on the side same side of the roadway as the pedestrian facility being evaluated.

²Sections with a substantial physical barrier/tall railing between the travel lanes and the walkway (like might be found on a bridge) can be lowered to PLTS 3.

14.5.8 General Land Use Criteria

The general land use can create an overall positive effect on walkability and use of certain facilities if destinations are frequent and convenient. Higher pedestrian use leads to a greater driver expectation and driving behaviors typically reflect such (i.e. more likely to yield). Conversely, land use can create a dampening effect to the point that it will not matter how well the facilities are laid out or constructed, the desire to walk on a segment is diminished if the facility goes through a perceived unattractive/unsecure/noisy/too-busy area. Areas that are more auto-oriented have lower driver expectations for pedestrians so yielding behaviors are much less likely. Exhibit 14-19 groups typical land use types by PLTS level with more pedestrian-friendly walkable areas getting lower PLTS levels.

Exhibit 14-19 General Land Use

PLTS	Overall Land Use
1	Residential, central business districts (CBD), neighborhood commercial, parks and other public facilities, governmental buildings/plazas, offices/office parks
2	Low density development, rural subdivisions, un-incorporated communities, strip commercial, mixed employment
3	Light industrial, big-box/auto-oriented commercial
4	Heavy industrial, intermodal facilities, freeway interchanges

14.5.9 Crossing Criteria

Unsignalized crossings at intersections or at mid-block can act as barriers to pedestrians, especially where there are a high number of lanes or higher speeds. The crossing can be an impediment to travel if the pedestrian has to cross four or more lanes at any speed or has to cross a 35 mph (or greater) street. The criteria for unsignalized intersection crossings depend on the functional class of the roadway, average daily traffic, speed limit, number of lanes, and presence of a median of sufficient width to provide for a two-stage crossing. Average daily traffic (ADT)

of the roadway being crossed can be optional if data is not available by using the footnoted columns in the following exhibits. Over or underpasses are considered as separate facilities and are PLTS 1.

For functionally classified local and collector streets use Exhibit 14-20 for crossing with and without a pedestrian median refuge. The vast majority of these roadways should be under the 5,000 ADT limit for the table, but if it is known that a facility has an abnormally high amount of traffic for its functional class (there also should be a count performed on this section; See APM Chapter 3), it should be compared with Exhibit 14-23 or 14-24. Also, if a collector-level roadway has more than two lanes or is one-way, then Exhibit 14-23 or 14-24 should be used.

Unsignalized crossings on functionally classified minor/major/principal arterial roadway sections should use Exhibit 14-21 for crossings without pedestrian median refuges. Sections with pedestrian refuge islands or are one-way should use Exhibit 14-23 and 14-24. If ADT is not available for a section (or not possible to be estimated), use the midrange columns (as per table footnote) in these exhibits to find an appropriate PLTS. Enhanced arterial crossings (with or without refuge islands) can use Exhibit 14-22 to lower the PLTS to a maximum two level reduction or minimum PLTS 2.

When a crossing lacks “standard” modern ramps, the facility is limited to able-bodied users. A standard modern ramp will have a flatter grade, may have a level landing surface, and some sort of detectable surface for visually impaired pedestrians (usually an etched-in cross hatching). Current ADA-standard ramps have a thermoplastic “truncated dome” insert attached to the ramp surface, so these are relatively easy to spot. Older ramps with short and or steep grades (these almost never have any detectable surfaces) are considered equivalent to no ramp at all. Impaired users will either not use the facility or will be forced into an uncomfortable position by using the street via a nearby driveway. In these cases, the minimum PLTS is 3.

Pedestrian median refuges need to be at least six feet in width (10 feet for PLTS 1 eligibility) and have some sort of a raised concrete or vegetated island for protection. Crossings at roundabouts should use PLTS 1 for a single lane crossing of an entry or exit assuming that the splitter island is at least 10 feet wide, otherwise use PLTS 2. Two-lane exits and entries are PLTS 2.

Increase the PLTS by one level (to a maximum PLTS 4) if the intersection or mid-block crossing is not illuminated in Exhibits 14-20, 21, 23, and 24. Unlit crossings require more awareness by the pedestrian as they are harder for drivers to see and/or expect in darkness.

Exhibit 14-20 Collector & Local Unsignalized Intersection Crossing ^{1, 2, 3, 4}

Prevailing Speed or Speed Limit (mph)	No Median Refuge		Median Refuge Present
	Total Lanes Crossed		Maximum One Through/Turn Lane Crossed per Direction
	1 Lane	2 Lanes	
≤ 25	PLTS 1	PLTS 1	PLTS 1 ⁵
30	PLTS 1	PLTS 2	PLTS 1
35	PLTS 2	PLTS 2	PLTS 2
≥ 40	PLTS 3	PLTS 3	PLTS 3

¹For street being crossed.

²Minimum PLTS 3 when crossing lacks standard ramps.

³Use Exhibit 14-23 or 14-24 for one-way streets, when ADT exceeds 5,000, or total number of lanes exceeds two.

⁴Street may be considered a one-lane road when no centerline is striped and when oncoming vehicles commonly yield to each other.

⁵Refuge should be at least 10 feet for PLTS 1, otherwise use PLTS 2 for refuges 6 to <10 feet.

Exhibit 14-21 Arterial Unsignalized Intersection Crossing Without a Median Refuge ^{1, 2}

Prevailing Speed or Speed Limit (mph)	Total Lanes Crossed (Both Directions) ³					
	2 Lanes			3 Lanes		
	<5,000 vpd	5,000-9,000 vpd ⁴	>9,000 vpd	<8,000 vpd	8,000-12,000 vpd ⁴	>12,000 vpd
≤ 25	PLTS 2	PLTS 2	PLTS 3	PLTS 3	PLTS 3	PLTS 4
30	PLTS 2	PLTS 3	PLTS 3	PLTS 3	PLTS 3	PLTS 4
35	PLTS 3	PLTS 3	PLTS 4	PLTS 3	PLTS 4	PLTS 4
≥ 40	PLTS 3	PLTS 4	PLTS 4	PLTS 4	PLTS 4	PLTS 4

¹For street being crossed.

²Minimum PLTS 3 when crossing lacks standard ramps.

³For one-way streets, use Exhibit 14-10 and 14-24.

⁴Use these columns when ADT volumes are not available

Exhibit 14-22 Adjustments for Crosswalk Enhancements

Treatment	Deduction	Treatment	Deduction
Markings ¹	0.5	In-street signs	1.0
Roadside signage ¹	0.5	Curb extensions	0.5
Lighting	0.5	Raised crosswalk	1.0
RRFB	1.0		

¹Not applicable for roadways with pedestrian median refuges as crosswalk markings and roadside signage assumed as part of the basic installation.

Exhibit 14-23 Arterial Unsignalized Intersection Crossing (1 to 2 lanes) with a Median Refuge^{1,2}

Prevailing Speed or Speed Limit (mph)	Maximum Through/Turn Lanes Crossed per Direction			
	1 Lane	2 Lanes		
	Any	<5,000 vpd	5,000-9,000 vpd ⁴	>9,000 vpd
≤ 25	PLTS 1 ³	PLTS 1 ³	PLTS 2	PLTS 2
30	PLTS 2	PLTS 2	PLTS 2	PLTS 2
35	PLTS 2	PLTS 2	PLTS 2	PLTS 3
≥ 40	PLTS 3	PLTS 3	PLTS 3	PLTS 4

¹For street being crossed.

²Minimum PLTS 3 when crossing lacks standard ramps.

³Refuge should be at least 10 feet for PLTS 1, otherwise use PLTS 2 for refuges 6 to <10 feet.

⁴Use these columns when ADT volumes are not available.

Exhibit 14-24 Arterial Unsignalized Intersection Crossing (3 or more lanes) with a Median Refuge^{1,2}

Prevailing Speed or Speed Limit (mph)	Maximum Through/Turn Lanes Crossed per Direction			
	3 Lanes			4+ Lanes
	<8,000 vpd	8,000-12,000 vpd ⁴	>12,000 vpd	Any
≤ 25	PLTS 1 ³	PLTS 2	PLTS 3	PLTS 4
30	PLTS 2	PLTS 2	PLTS 3	PLTS 4
35	PLTS 3	PLTS 3	PLTS 4	PLTS 4
≥ 40	PLTS 4	PLTS 4	PLTS 4	PLTS 4

¹For street being crossed.

²Minimum PLTS 3 when crossing lacks standard ramps.

³Refuge should be at least 10 feet for PLTS 1, otherwise use PLTS 2 for refuges 6 to <10 feet.

⁴Use these columns when ADT volumes are not available.

The PLTS to cross the major street is applied to the minor street in the direction of travel along the route. If the crossing PLTS has a higher stress level than the minor street segment PLTS, the crossing PLTS applies (controls) to that minor street segment.

Signalized crossings usually provide a protected way across the roadway and are typically rated at PLTS 1 (i.e. midblock crossings with regular or HAWK-type signals). The PLTS will be higher in areas if the following are evident:

- Permissive left or right turns. Pedestrians will need to be more wary about the potential for increased conflicts, so PLTS 2 is typically given in these cases.
- Missing basic features such as lighting or countdown pedestrian signal heads will increase the PLTS to PLTS 2.
- Presence of complex elements will increase the PLTS to PLTS 3:

- Multiple or narrow (less than six feet) refuge islands,
- No standard ramps,
- More than six total lanes crossed at once,
- Non-standard geometry (more than four legs, or highly skewed approaches),
- Closed or limited crosswalks available; Free-flow or yield-controlled channelized right turns



If the distance between crossing opportunities (i.e. signalized or a low-stress unsignalized) is greater than approximately 0.10 mile, then the resulting out-of-direction travel incurred by a pedestrian may be too great. This may deter or impede travel along a segment if the desired route includes a major street crossing.

14.5.10 Results

Mapping the PLTS for a community is a typical result from the analysis and can be easily done using GIS. The map shows the gaps and barriers in the system which can be used to inform stakeholders when creating a list of prioritized projects. The maps can also be included in planning documents and used to help inventory the pedestrian facilities.

14.5.11 Solutions to Decrease PLTS Level

There are several ways reduce PLTS and reach the chosen target for a roadway. Several publications including the Oregon Bicycle and Pedestrian Design Guide, the ODOT Traffic Manual, and the ODOT Highway Design Manual, includes design considerations for pedestrian facilities. A few examples of actions that can reduce PLTS:

- Installing pedestrian facilities, or expanding facilities where pedestrian routes exist
- Create paved surfaces where there are trails or worn paths are evident
- Improving the condition of the sidewalk, including limiting vertical change and smoothing the surface
- Infilling gaps in sidewalk to create connectivity
- Redesigning roadway to include wider or buffered sidewalks
- Creating a multi-use path on high speed roadway
- Significantly changing the roadway character and reducing speed limit
- Installing additional crossing enhancements at unsignalized crossings (beacons, lighting, curb extensions, etc.), r
- removing barriers to connectivity
- Redesigning buffer to include trees, large vegetation, and/or street furniture
- Land use changes over time to encourage more pedestrian-scale developments

Example 14-4 Pedestrian Level of Traffic Stress

The following section shows examples of corridor sections for each PLTS. All of the examples are pedestrian facilities within the Salem city limits. The purpose of the example is to illustrate different PLTSs.

Center Street at High Street



Street Name		Center St at High St
Sidewalk	Condition	Fair
	Width (ft)	12
Buffer	Width (ft)	0
	Buffer Type	Solid Surface; street trees present
Bike Lane	Width (ft)	0
Parking	Width (ft)	8
Roadway	Number of Lanes	4
	Posted Speed (mph)	30
Land Use	Type	Central business district
Total Buffering Width (ft)		16

Center Street at High Street is located on a major roadway in downtown Salem. This segment is within the Salem Center Mall District with storefronts along the street. The segment contains a large 12 foot sidewalk with an effective width at least six feet and a solid surface buffer with street trees which leads to PLTS 1 ratings in the sidewalk and buffer type criteria. The total buffering width is just large enough to counteract the effect of the four-lane roadway so the PLTS is 1. This location is within a central business district so the general land use PLTS is 1. All of the categories are PLTS 1 so the overall PLTS is 1.

Street Name	Center St at High St
Sidewalk Condition	PLTS 1
Physical Buffer Type	PLTS 1
Total Buffering Width	PLTS 1
General Land Use	PLTS 1
Final PLTS	PLTS 1

If a mid-block crossing of Center Street was to be analyzed, then the functional class of the roadway would need to be obtained. In this case, Center Street is an arterial. This is a one-way four-lane section so ADT is not needed in the methodology. One-way sections need to use the tables for arterial streets with median refuges as the total lanes crossed are all in a single direction. The resulting PLTS would be 4 for a midblock crossing. This compares to the PLTS of 2 for the adjacent signalized intersections with permissive turns.

Chemeketa Street between Capitol Street and 12th Street



Street Name		Chemeketa St. between Capitol St & 12th St
Sidewalk	Condition	Good
	Width (ft)	5
Buffer	Width (ft)	10
	Buffer Type	Landscaped with trees
Bike Lane	Width (ft)	0
Parking	Width (ft)	15
	Number of Lanes	2
Roadway	Posted Speed (mph)	25
	Type	Office/Residential
Total Buffering Width (ft)		25

Chemeketa Street serves as a low volume street connecting 12th Street to parking areas around the Capitol mall area. The sidewalk condition is rated as good as it is of newer construction and

has an actual width of five feet. This makes the facility a PLTS 2 under the sidewalk condition. The physical buffer type is landscaped with trees and the roadway has a 25 mph posted speed which makes the buffer PLTS 1. The total buffering width on this side of the roadway is 25 feet and there are two lanes on the roadway. This leads to the PLTS 1 for the total buffering width category. The general land use on this segment is offices and high density residential so the PLTS is 1. The sidewalk condition controls so the overall PLTS for this segment is 2.

Street Name	Chemeketa St. between Capitol & 12th St
Sidewalk Condition	PLTS 2
Physical Buffer Type	PLTS 1
Total Buffering Width	PLTS 1
General Land Use	PLTS 1
Final PLTS	PLTS 2

If the adjacent intersection at 12th and Chemeketa were added to the segment, as would be done if a route was being investigated, the intersection’s PLTS would not control over the segment’s PLTS 2. This signalized intersection has permissive left turns, but is free of complex elements, so the PLTS is 2, which is equal to the final segment PLTS.

13th Street at Chemeketa Street



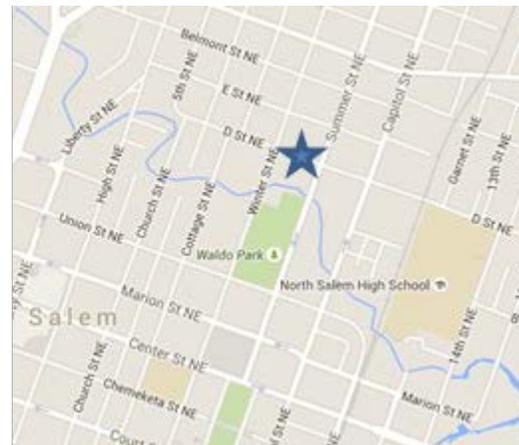
Street Name		13th St at Chemeketa St
Sidewalk	Condition	Good
	Width (ft)	5
Buffer	Width (ft)	4
	Buffer Type	Landscaped with trees
Bike Lane	Width (ft)	0
Parking	Width (ft)	0
Roadway	Number of Lanes	2
	Posted Speed (mph)	25

Land Use	Type	Office/Residential
Total Buffering Width (ft)		4

13th Street at Chemeketa Street is located in the transition between downtown Salem and residential areas. With a sidewalk condition of good as it is of newer construction and a width of five feet the sidewalk condition PLTS is rated at 2. The buffer type is trees with a posted speed of 25 MPH which categories the facility at a PLTS 1. The total buffering width category is a PLTS 2. This is because the total buffering width is less than five feet and there are two travel lanes. This is in a mainly residential/office location so the general land use PLTS is 1. The final PLTS for this facility is PLTS 2.

Street Name	13th St at Chemeketa St
Sidewalk Condition	PLTS 2
Physical Buffer Type	PLTS 1
Total Buffering Width	PLTS 2
General Land Use	PLTS 1
Final PLTS	PLTS 2

D Street between Summer Street and Capitol Street (near Parrish Middle School)



Street Name		D St between Summer St & Capitol St
Sidewalk	Condition	Fair
	Width (ft)	5
Buffer	Width (ft)	0
	Buffer Type	n/a
Bike Lane	Width (ft)	0
Parking	Width (ft)	0
Roadway	Number of Lanes	2
	Posted Speed (mph)	30
Land Use	Type	Residential

Total Buffering Width (ft)	0
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D Street between Summer Street and Capitol Street is located on the edge of downtown Salem and Parrish Middle School in a residential area. The sidewalk is in fair condition. There is no buffer between the sidewalk and the roadway. This, combined with the posted speed of 30 mph, categorizes this facility at a PLTS 3 and is the controlling PLTS.

Street Name	D St between Summer & Capitol St
Sidewalk Condition	PLTS 2
Physical Buffer Type	PLTS 3
Total Buffering Width	PLTS 2
General Land Use	PLTS 1
Final PLTS	PLTS 3

If a crossing of D Street was to be analyzed, then the following additional information would be gathered:

- Functional Class = Collector
- ADT = 1600 vehicles per day
- Median refuge = Not present

Since D Street is a collector, ADT is not needed other than as a check to see that it is under the 5000 veh/day limit (typically it can be assumed that collectors and lower are under the limit without needing an ADT count to verify). Since there is no pedestrian median refuge, both lanes are crossed at once on this 30 mph roadway which is a PLTS 1.

Chemeketa Street at 14th Street



Street Name		Chemeketa St at 14 th St
Sidewalk	Condition	Very Poor
	Width (ft)	5
Buffer	Width (ft)	8
	Buffer Type	Landscaped with trees
Bike Lane	Width (ft)	0
Parking	Width (ft)	7
Roadway	Number of Lanes	2
	Posted Speed (mph)	25
Land Use	Type	Residential
Total Buffering Width (ft)		15

Chemeketa Street at 14th Street is an old residential street with poor sidewalk condition. The sidewalk condition is very poor with several areas of substantial uplift and large cracks. This leads to the PLTS rating of 4 for sidewalk condition as it will make it impassable for disabled pedestrians and even difficult in spots for non-impaired individuals. The posted speed is 25 mph and the buffer is a treed planter zone, so the buffer type is rated as PLTS 1. The general land use is residential so this is a PLTS 1. The total buffer width is 15 feet and the number of travel lanes is 2 for the roadway and because of these attributes the total buffer distance PLTS is 2. The overall PLTS for this segment is PLTS 4.

Street Name	Chemeketa St at 14 th St
Sidewalk Condition	PLTS 4
Physical Buffer Type	PLTS 1
Total Buffering Width	PLTS 2
General Land Use	PLTS 1
Final PLTS	PLTS 4

12th Street between Marion Street and Center Street



Street Name		12 th St at Center St
Sidewalk	Condition	Poor
	Width (ft)	3
Buffer	Width (ft)	0
	Buffer Type	N/A
Bike Lane	Width (ft)	0
Parking	Width (ft)	0
Roadway	Number of Lanes	4
	Posted Speed (mph)	30
Land Use	Type	Mixed employment
Total Buffering Width (ft)		0

The 12th Street corridor is a moderate speed and volume facility in a mixed commercial/office area. The sidewalks along the west side of the roadway are narrow at three feet and in poor condition. This leads to a PLTS of 4 for sidewalk condition. There is no buffer and speed of 30 mph on the roadway which leads to a PLTS 3 for the buffer type. The total buffer distance is zero feet and the total number of travel lanes is four, which is a PLTS 4 in the total buffer distance category. The general land use is a mix between commercial uses, offices and large employee parking lots, so this would be generally PLTS 2. With one or more categories at PLTS 4, the segment of roadway is a PLTS 4.

Street Name	12 th St at Center St
Sidewalk Condition	PLTS 4
Physical Buffer Type	PLTS 3
Total Buffering Width	PLTS 4
General Land Use	PLTS 2
Final PLTS	PLTS 4

If the adjacent intersections at 12th/Center and 12th/Marion were added to the segment as would be done if a route was being investigated, neither intersection's PLTS would control the overall segment. Both signalized intersections have permissive turns, but are free of complex elements and would have a PLTS of 2, but these are still lower than the PLTS 4 for the segment.

14.6 Multimodal Level of Service

The Level of Service (LOS)–based methods presented in this section and Section 14.6 are intended for use when a detailed analysis is desired such as in facility plans or projects when a no-build alternative is compared to one or more build alternatives. These methods are not meant for defining overall needs or making prioritization decisions, so those sorts of applications should use the Qualitative Multimodal Assessment or Level of Traffic Stress methodologies instead (see sections 14.2 to 14.4).

The Auto mode is not included as analysis at this level of detail would typically be done at intersections with applications such as Synchro, Highway Capacity Software, or Vistro. Application of the methodologies is via Excel-based calculators available on the [Transportation Development – Planning Technical Tools](#) webpage.

14.6.1 Re-estimated Pedestrian & Bicycle Methodology Application

The pedestrian and bicycle procedures in this section are re-estimated versions of the link-level full *Highway Capacity Manual (HCM) 2010* Multimodal Level of Service (MMLOS) methodologies. The use of probabilistic methodologies with the original research data allowed the number of variables to be significantly reduced while maintaining or improving accuracy of the results. These simplified procedures will still produce a Level of Service (LOS) letter grade, will indicate the current “state of the system, and can be done in a fraction of the time that the full MMLOS methodology requires”.



These methodologies only include link-level detail. There are a number of issues with the intersection-level LOS in the full HCM MMLOS method that create non-intuitive results when combined with the link-level LOS by obscuring or limiting changes (the full method is rather insensitive to change compared to the links-only portion). Non-HCM but consistent analysis procedures for capturing the LOS for unsignalized and signalized street crossings for the bicycle and pedestrian modes will be added at a later date.

These procedures are intended for application on urban arterial (excluding freeways)/collector-classed roadways. Roadways are segmented to ensure demand, control, and geometry are relatively uniform within each segment. Caution should be exercised if applying these on functionally classified local streets as results may not be intuitive. The Qualitative Multimodal Assessment (QMA, see Section 14.3) should be used for applications in other areas such as unincorporated communities and rural areas.

14.6.2 Pedestrian & Bicycle LOS Criteria

LOS scoring threshold criteria for pedestrian and bicycle modes are shown in Exhibit 14-25 which is based on the updated HCM values.

Exhibit 14-25 Pedestrian and Bicycle LOS Criteria

LOS	Pedestrian & Bicycle LOS Score
A	≤1.5
B	>1.5 – 2.5
C	>2.5 – 3.5
D	>3.5 – 4.5
E	>4.5 – 5.5
F	>5.5

Multimodal LOS scores are based on user perceptions (traveler satisfaction) and are graded from best (LOS A) to worst (LOS F). This kind of perception-based rating varied from the many test respondents (there is no one single definition of a multimodal LOS grade) and was eventually grouped into LOS ranges. The methodology results represent the probability that a user (or the population of users) will pick a given LOS (or a range of LOS). Better conditions will result in better LOS scores. For example, narrower slower streets will rate better than wider faster ones for pedestrian and bicycle modes. Presence of sufficient-width sidewalks and bike lanes will score better than streets without them. Since these methodologies are a prediction of the user perception of quality of service, the LOS results need to be evaluated in context with other planning considerations (e.g. available funding for improvements, land use context, etc.).

14.6.3 Pedestrian LOS

Methodology Summary

This methodology is based on a re-estimation of the original video clip data used to create the HCM Pedestrian LOS (*National Cooperative Highway Research Program (NCHRP) Project 3-70 and Report 616 Multimodal Level of Service Analysis for Urban Streets*). Details on the research and methodology approach can be found in the paper *Cumulative Logistic Regression Model for Pedestrian Level of Service Rating* by Ali, Cristei, and Flannery, George Mason University (undated). By re-estimating the model using the individual response surveys instead of averages of *NCHRP Project 3-70's* data, the researchers were able to isolate the variables that most significantly impact the pedestrian LOS. This allowed a significant reduction in the number of independent variables needed while creating a better LOS estimate using probability-based ranges.

Of the seven sidewalk-related independent variables in the full HCM method (i.e. sidewalk width, buffer width, presence of barriers, etc.), the strongest variable influencing pedestrian comfort was sidewalk width. The major traffic-related independent variables (same direction traffic volumes, number of traffic lanes, and speed limit) were all found to have strong negative impacts on pedestrian comfort. All of the variables used in the model have categorized ranges of data input, so it is only necessary to know on what side of a threshold a data item lands, rather than the actual absolute amount.

Data Needs and Definitions

The simplified methodology uses four variables to estimate Pedestrian LOS. The analysis is intended to be applied on road segments on a per direction basis like most HCM-based methods. The variables and their category values are shown below:

- Sidewalk (Actual) Width (0-5 ft or >5 ft)
- Directional Traffic Volume (0-500 vph, 500-1500 vph, or >1500 vph)
- Number of (Through) Traffic Lanes per direction (1, 2, 3, or 4)
- (Posted) Speed Limit (20-40 mph or >40 mph)

Segments are at least defined between major (signalized) intersections or where the threshold values change between categories. For example, a change from 30 to 35 mph would not be significant in this method, but a change from 40 to 45 mph would be as the value changes categories and a new segment would also need to be created. Similarly, if a street had no sidewalks (zero feet in width) but had a section of six foot sidewalk in the middle, then the street section would be broken into three segments (two 0-5 ft width sections and one >5 ft width section). However, if the sidewalk section was a substandard three foot width, then one overall segment would suffice.

Sidewalk width is the actual width, not the effective or clear width. The methodology implicitly assumes the larger sidewalk widths may also include increased buffer space with physical barriers (bike racks, meters, trees, etc.). These buffers and barriers generally increase the overall comfort (assuming that any elements do not intrude into the walking space) for a pedestrian resulting in better LOS levels.

The Directional Traffic Volume is intended to be consistent with the analysis peak hour used for other analysis tasks, such as vehicle v/c ratio or LOS. It is possible that the final pedestrian LOS may be different between different peak hours such as AM and PM. Creation of the existing or future volumes should follow Chapter 5 or 6 using hourly counts or appropriate reductions from daily counts.

The number of lanes per direction considers the impact of through and shared through/turn lanes only. Ignore any center two-way left-turn lanes or exclusive turn lanes as this methodology is only for segments and not for crossings. There is no difference in the methodology between one-way and two-way segments except that all through lanes would be considered on a one-way segment for each side of the roadway this is where the three and four lanes per direction will be mostly applied to), instead of just half. The speed limit used to select the category should be the posted or statutory limit (i.e. 20 mph for downtown or 25 mph for residential areas, etc.).

The data values should be easily obtainable from inventories or aerial photographs. Results can be shown in tables or in a GIS-created map figure. A network-wide LOS could be estimated using a travel demand model with custom variables or expressions. The directional volumes, speeds, and lanes are common base variables. The sidewalk variable could be assumed, based on field data, or obtained from the model if it considered pedestrian trips in greater detail.

The values are entered into the calculator to obtain the cumulative probabilities which are subtracted from one another to obtain the LOS probabilities. The highest probability is chosen as the most-likely LOS. Check to see if any probabilities fall within a (0.90 x the highest probability) range. If the next highest probability is within this range, assume that this is a LOS range (i.e. LOS E-F) with a total probability that is the sum of the individual probabilities.

Example 14-5 Pedestrian LOS



A segment of a five-lane suburban arterial is analyzed for the afternoon peak hour as part of a local transportation system plan. The roadway has a peak month ADT of 31,000 and has a 35 mph speed limit. Six-foot sidewalks and bike lanes exist on both sides of the street. The roadway traverses a commercial district so there are a substantial number of driveways on both sides. From count data at nearby intersections, there is 50/50 directional split (D-factor) and the percent of the daily traffic as part of the peak hour (K-factor) is 9%.

The ADT is converted into an approximate peak hour volume by multiplying the ADT by the segment K-factor. The peak hour volume is then converted into a directional volume by multiplying it by the directional split. (See Chapter 5 for more information on determining peak hour volumes).

$$\begin{aligned}\text{Directional volume (vph)} &= \text{ADT} * \text{K-Factor} * \text{D-factor} = 31,000 * 0.09 * 0.50 \\ &= 1395 \text{ vph which falls into the 500-1500 vph category}\end{aligned}$$

From the existing conditions data given, sidewalks are greater than five feet, there are two lanes per direction, and the speed is between 20 and 40 mph.

These four pieces of data are entered into the calculator and the highest probable result is LOS C at 25.51%. Other close LOS possibilities indicated are LOS B at 21.48%, LOS D at 21.29% and LOS E at 20.12%. The 10% significance check value (90% of the LOS C value) is 22.96% which

is greater than any of the other LOS probabilities, so the LOS C value is reported as the final result for the first direction. The calculator will always provide multiple segment probabilities for the purpose of helping the user decide which LOS to report, rather than reporting just the highest probability.

Final LOS Probabilities						Max	Probability	Final
F	E	D	C	B	A	Probability	90% Check	LOS
0.0832	0.2012	0.2129	0.2551	0.2148	0.0329	0.2551	0.2296	C

LOS C has the greatest chance of selected as the user-perceived value. This also can be thought over the percentage of the population that would view this as LOS C. Adding in other ranges; about 50% would view this section as acceptable as LOS A-C while 50% would view this section poorly as LOS D-F. LOS C is the approximate middle ground. A 50% poor probability is significant so some improvement is likely necessary for this segment. The analysis is repeated for the second direction which will have the same answer in this case as the conditions are symmetrical.

14.6.4 Bicycle LOS

Methodology Summary

This methodology is based on a re-estimation of the original video clip data used to create the HCM Bicycle LOS in *NCHRP Project 3-70* and *Report 616*. Details on the research and methodology approach can be found in the paper *Using Cumulative Logistic Regression Model for Evaluating Bicycle Facilities on Urban Arterials*” by Ali, Cristei, and Flannery, George Mason University (undated).

By re-estimating the model using the individual response surveys instead of averages of *NCHRP Project 3-70*’s data, the researchers were able to isolate the variables that most significantly impact the Bicycle LOS. This allowed a significant reduction in the number of independent variables needed while creating a better LOS estimate using probability-based ranges. In addition, the issue with the coefficients in the full MMLOS method, which generally prevent obtaining LOS A or B, has been eliminated.

Of the 13 independent variables in the full HCM method (e.g., volume, pavement condition, etc.) in *Project 3-70*, only four were found to be significant in the re-estimation. In addition, based on the validation in the research, it appears utilizing the other nine variables does not warrant the level of effort needed to obtain them. In other words, the time spent calculating pavement condition, heavy vehicles, percentage of on-street occupied parking, etc. does not enhance the ability to obtain an accurate LOS. This means, for many applications, there is no need to conduct further more-detailed Bicycle LOS analysis.

The method in this section is only meant for analysis applications on roadway sections with shared-use vehicle lanes or regular bike lanes because of limitations in the original research data set. Higher speed/volume roadways will most likely score poorly and indicate the need for some

sort of separation of bicyclists from vehicular traffic. Following future sections will be applicable to other facility types. The LOS of this section would need to be compared with the generated LOS for other facility types to either establish operational ranges or a single LOS for an alternative (LOS with shared lane, LOS with bike lane, LOS with shared path, etc.). The Qualitative Assessment (see Section 14.3) may be the best choice if more factors are desired to be included in a facility plan analysis (See Section 14.2) without the limitations of the full MMLOS method. The simplified re-estimated methodology is also consistent with the Bicycle Level of Traffic Stress (see Section 14.4) if that method is used as a screening tool in a detailed refinement plan or project effort as poor LOS levels will result in poor segment stress levels and vice versa.

The major bicycle-related variables are presence or absence of a bike lane/usable paved shoulder and the number of unsignalized conflicts per mile, both of which are responsible for most of the variation in the LOS ratings from the response surveys and thus will have the biggest impact on the LOS results. For example, a section of roadway without any unsignalized driveway approaches could have a LOS D while the presence of driveways drops the section to a LOS F. The most significant vehicle-traffic related variables are the number of through traffic lanes and the posted speed limit, both of which have a negative impact on bicyclist comfort. All of the variables used in the model have categorized ranges of data input, so it is only necessary to know on which side of a threshold is the particular data item, rather than the absolute value.

Data Needs and Definitions

The methodology uses four variables to estimate Bicycle LOS. The analysis is intended to be applied on road segments on a per direction basis like most HCM-based methods. Segments can be defined between major intersections or as desired. The variables and their category values are shown below:

- Number of Through Traffic Lanes per direction (1 or >1)
- Bike Lane or Paved Shoulder Present (Yes or No)
- (Posted) Speed Limit (≤ 30 mph or >30 mph)
- Unsignalized Conflicts (Yes or No)

Like with the Pedestrian LOS, segments should be created at least between major intersections or when the variables change categories. For example, if the bike lane disappears along a roadway then reappears later; a new segment is needed every time this happens. Short sections should be highlighted and documented especially if they are due to narrow bridges or other physical obstructions.

The number of lanes per direction is for through and shared through/turn lanes only. An exclusive turn lane could be considered if it extends the length of the segment. Ignore any center two-way left-turn lanes or exclusive turn lanes as this methodology is only for segments and not for crossings. A bike lane is assumed where there is a striped lane or where a useable paved shoulder that allows the bicyclist to be direct conflict with traffic exists. Mixed traffic conditions where there is no striped bike lane or shoulder stripe should be assumed to fall into the “No” category. The speed limit used to select the category should be the posted or statutory limit (i.e.

20 mph for downtown or 25 mph for residential areas, etc.).

The unsignalized conflicts account for the impact of any unsignalized intersections or driveways in the segment. All driveways (residential/commercial/industrial) should be accounted for as each creates potential conflict locations regardless of driveway volume.

The data values should be easily obtainable from inventories or aerial photographs. Results can be shown in tables or in a GIS-created map figure. A network-wide LOS could be estimated using a travel demand model with some use of custom variables or expressions. The directional speeds and lanes are common base variables. The unsignalized conflict variable would likely need to be defaulted to “yes” unless the facility segments were access-controlled and still legally allowed bikes. The bike lane variable could be assumed, based on field data, or obtained from the model if it considered bicycle trips in greater detail.

The values are entered into the calculator to obtain the cumulative probabilities which are subtracted from one another to obtain the LOS probabilities. The highest probability is chosen as the most-likely LOS. Check to see if any probabilities fall within a (0.90 x the highest probability) range. The calculator will highlight any probability that falls within 90% of the highest value. If the next highest probability is within this range, assume that this is a LOS range (i.e. LOS E-F) with a total probability that is the sum of the individual probabilities.

This modal methodology has the highest occurrence of LOS ranges. Probabilities that are greater than 10% apart can also be reported as a range. For example, LOS A is not possible as a reported final LOS with the most favorable parameters, but it does have a good likelihood of occurring. In this case, the final result could be reported as LOS B or LOS A-B depending on the engineer’s judgment of the overall context of that particular segment.

Example 14-6 Bicycle LOS

This example uses the same segment of roadway as described in the Pedestrian LOS section. A segment of a five-lane suburban arterial is analyzed for the afternoon peak hour as part of a local transportation system plan. The roadway has a 35 mph speed limit. Six-foot sidewalks and bike lanes exist on both sides of the street. The roadway traverses a commercial district so there are a substantial number of driveways on both sides.

From the given data, the number of traffic lanes per direction exceeds one, there is a bike lane present, the speed limit exceeds 30 mph and there are unsignalized intersection and driveway conflicts.

The four data elements are added into the calculator and the highest probable result is LOS F at 27.11% for the first direction. The 10% significance check (90% of LOS F) is 24.40%, which is about equal to the LOS E value at 24.41%. The calculator highlighted the highest probability and any that fall within 90% of that value. The overall reported result is a range and the probabilities added together which results in a 51% chance of a LOS E-F.

Final LOS Probabilities						Max	Probability	Final
F	E	D	C	B	A	Probability	90% Check	LOS
0.2711	0.2441	0.2081	0.1724	0.0832	0.0210	0.2711	0.2440	F

The calculator will always provide multiple probabilities for every segment for the purpose of helping the user decide which LOS to report rather than just reporting the highest probability. In this case, the “Final LOS” column would need to be manually overridden (as per the spreadsheet directions) to reflect a LOS E-F so it can be shown correctly on the summary output sheet. The same LOS E-F result is computed for the second direction as conditions are the same.

14.6.5 Separated Bikeways

The separated bikeway methodology augments the re-estimated HCM bicycle methodology of the previous section by adding new facility types. Low-stress tolerant users desire a greater degree of separation between them and the adjacent traffic stream. The standard bike lane or even a buffered bike lane does not offer the amount of separation needed especially for roadways with higher volume and/or speeds. Separated bikeways (also known as cycle tracks or protected bike lanes) offer additional comfort (lower stress) to the bicyclist by creating a vertical delineation between the bicycle lane and the vehicle lanes and are a step up from a buffered bicycle lane. Vertical delineation can be simple as a line of posts (candlesticks), to large planters, to physically separating the bikeway with the vehicle parking strip. Exhibit 14-26 illustrates the differences in separation for the typical bicycle facilities from least to most.

The LOS is relatively poor for sections of standard bike lanes on higher speed and/or volume urban roadways, so adding a separated bikeway will allow for a better LOS. If a previously conducted Bicycle Level of Traffic Stress analysis indicated system needs, adding a separated bikeway on major routes can further enhance or help establish a low-stress network. For separated bikeways to have the greatest benefit, they need to intersect other lower-stress bicycle facilities such as bike boulevards, streets with standard bike or buffered lanes, or even low-speed routes with sharrows rather than being an isolated facility. Routes with established substantial bicycle volumes or more direct routes that have limited use because of high-stress elements may be good candidates for separated bikeways. Separated bikeways appeal to the largest segment of current and potential bicyclists, so having them in certain high-connectivity corridors should help to increase the overall mode share along a route and increase the total amount of users.

The context of the corridor should be considered on whether separated bikeway is the appropriate treatment. Not all roadways are suitable for separated bikeways. Separated bikeways have the greatest benefit on roadways with no or limited driveways and wider spaced intersections to maximize bicycle flow and minimize potential conflicts. Every intersection and driveway is a point of conflict and can introduce safety and operational issues especially when paired with adjacent parking. Parking between the travel lane and the separated bikeway can create sight distance issues. If sight distance is not maintained sufficiently (by prohibiting parking close to the intersection/driveway) then this may encourage vehicles to creep out and block the bikeway while waiting to turn. Higher volume and/or many driveways can substantially impede operations of bikes and increase the risk of collisions. The parking can also

create visibility issues for drivers to see oncoming bicyclists (could be in both directions for a two-way bikeway) as they turn into a driveway and across the bikeway. If access management solutions to consolidate/minimize driveways are not possible, then a buffered bike lane may be more appropriate in a parking and /or driveway dense location.

A constrained right-of-way, and/or existing features (e.g. number of driveways or parking needs) may pose design challenges. This analysis should not be done in isolation as safety shall be evaluated whether the features associated with the separated bikeway treatment may affect bike users or another transportation mode's safety. For example, more substantial separators such as bollards or large planters could create a fixed-object hazard for vehicles as they are close to the lane edge especially with higher speeds. The analyst needs to discuss the applicability of separated bikeways with Region, Traffic-Roadway Section, or local jurisdiction roadway/bicycle-pedestrian staff (as appropriate) before pursuing a separated bikeway treatment.

Methodology Summary

This methodology is based on the paper, *A Level-of-Service Model for Protected Bike Lanes* by Foster, Monsere, Dill and Clifton, Portland State University, 2014. The research was based on recent video-clip data obtained in a similar manner as previous HCM research efforts. The methodology uses the same cumulative logistic model form as the re-estimated bike lane method (Section 14.5) so results will be consistent between the two. The methodology is limited to segments only. Intersection crossings will be covered in future sections.

The methodology does not cover roadways that have a substantial amount of driveways and/or higher volume driveways as most of the research was based in central business districts or residential areas where high numbers of driveways or high-volume driveways or were uncommon. The most significant variables for estimating the performance of separated bikeways are buffer type, direction of travel, and adjacent vehicle speed and daily volume. The resulting LOS scores are based on user perceptions of each video clip and are graded from best (LOS A) to worst (LOS F). The methodology results represent the probability that a user (or the population of users) will pick a given LOS (or a range of LOS). Better conditions will result in better LOS scores. An Excel-based [calculator](#) is available on ODOT's Planning Section webpage.

Data Needs and Definitions

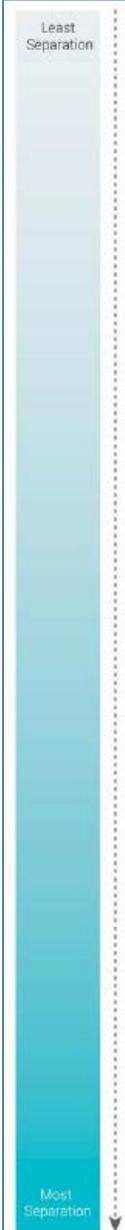
The methodology uses the following four variables to estimate the separated bikeway LOS. The analysis is intended to be applied on road segments on a per direction basis like most HCM-based methods. Segments with two-way separated bikeways only need to be evaluated in one direction. The variables and their category values are shown below:

- Buffer type (posts, planters, parking strip, raised/parking)
- Direction of (bikeway) travel (one-way or two-way)
- Adjacent vehicle speed (25 – 35 mph)
- Average daily volume in both directions (9,000 – 30,000) vehicles per day

Segments are at least defined between major (signalized) intersections or where the threshold values change between categories. For example, a change from 25 to 30 mph or a change in

vertical delineation type would be significant and a new segment would be needed.

Exhibit 14-26 Bicycle Facility Separation⁵



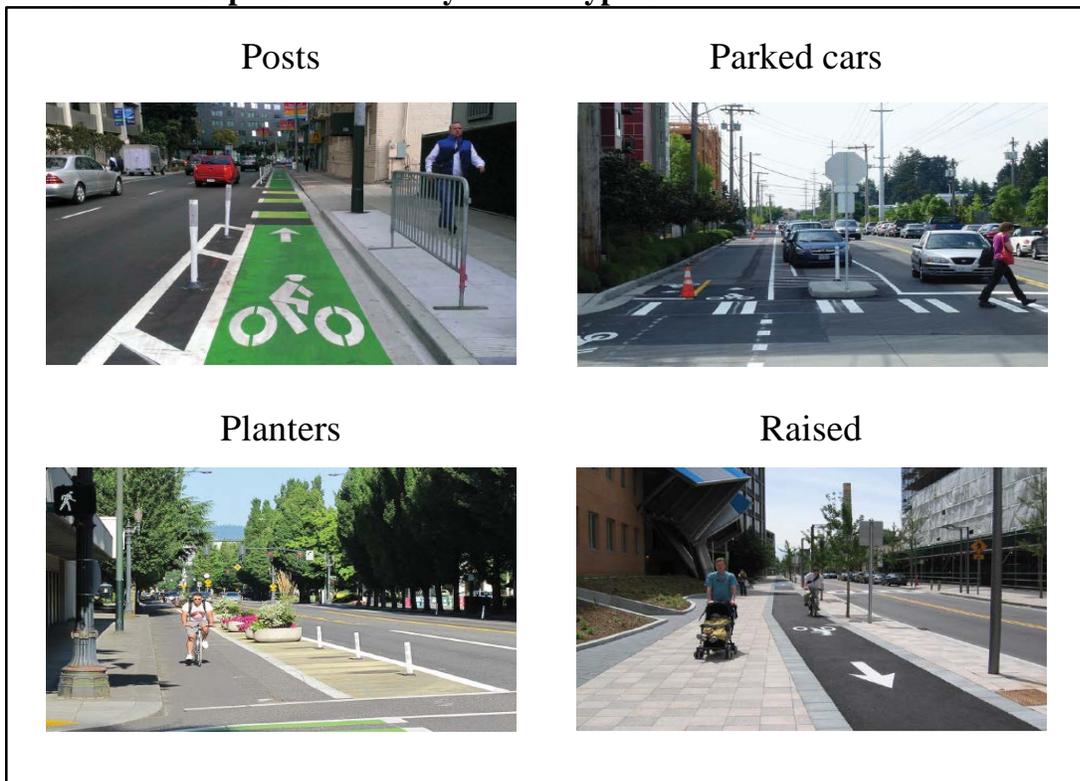
	Signed Routes (No Pavement Markings) A roadway designated as a preferred route for bicycles.
	Shared Lane Markings A shared roadway with pavement markings providing wayfinding guidance to bicyclists and alerting drivers that bicyclists are likely to be operating in mixed traffic.
	On-Street Bike Lanes An on-road bicycle facility designated by striping, signing, and pavement markings.
	On-Street Buffered Bike Lanes Bike lanes with a painted buffer increase lateral separation between bicyclists and motor vehicles.
	Separated Bike Lanes A separated bike lane is an exclusive facility for bicyclists that is located within or directly adjacent to the roadway and that is physically separated from motor vehicle traffic with a vertical element.
	Off Street Trails / Sidepaths Bicycle facilities physically separated from traffic, but intended for shared use by a variety of groups, including pedestrians, bicyclists, and joggers.

Exhibit 14-27 illustrates the different kinds of buffer types used in this methodology. Post-type

⁵ Separated Bike Lane Planning and Design Guide, FHWA, May 2015, p.14.

(candlestick) buffers are the easiest to implement however they do not have the same sort of separation benefits as more physical barriers such as planters. The planter type buffer in the methodology is for substantially sized planters such as shown in Exhibit 14-27. Smaller planters are typically paired with posts so these should use the post-type buffers instead. The parked cars buffer type occurs when the parking is placed between the motor vehicle lanes and the bikeway. There should be enough buffered space so open vehicle doors do not interfere with the bicyclist's path. Some designs have the separated bikeway raised slightly higher than the adjacent travel lanes but less than the adjacent sidewalk. If parking is provided along this type then the parking is raised to the same level as the bikeway. This configuration is also known as a raised bike lane. Raised bike lanes were included in the study but not called out as their own buffer type as there were not enough separate sites. These should use the "raised/parking" buffer type as an equivalent.

Exhibit 14-27 Separated Bikeway Buffer Types⁶



Most separated bikeways are one-way in the direction of roadway travel but there are situations such as on a one-way street where a contra-flow bikeway is desired to limit out-of-direction travel. Separated bikeways in these cases are typically two-way facilities. Two-way separated bikeways require more considerations regarding intersections and driveways, so coordination with ODOT Region and/or Traffic-Roadway Section staff is necessary.

The methodology is limited to speeds between 25 and 35 mph and ADT values between 9,000 and 30,000 vehicles per day and thus will be limited in most cases to arterials in denser urban

⁶ Images from Separated Bike Lane Planning and Design Guide, FHWA, May 2015, pp. 83-87.

locations. Use caution if values extend outside of these limits. Higher volumes and speeds than the methodology limits will tend to make the LOS better than expected while lower volumes and speeds will make the LOS worse than expected. Lower speed and lower volume roadways will be more applicable to shared markings, a standard bike lane, or buffered bike lanes. Roadway applications with higher volumes or speeds should gravitate toward total separation with a shared-use path (Section 14.7).

The values are entered into the calculator to obtain the cumulative probabilities which are subtracted from one another to obtain the LOS probabilities. The highest LOS probability is chosen as the most-likely LOS. The calculator will also flag any values within 10% of the highest probability. Check the LOS probabilities in the calculator for any highlighting. The highlighting will indicate the potential for a LOS range (i.e. LOS A-B) with a total probability that is the sum of the individual probabilities. Judgement based on the overall project context is required to decide to leave the LOS as calculated or override it to a lower/higher LOS or create a LOS range.

Example 14-7 Separated Bikeway LOS

This example uses the same segment of roadway as described in the previous sections on Pedestrian and Bicycle LOS. The roadway has five lanes, a 35 mph speed limit and a peak month ADT of 31,000. The roadway currently has six foot bike lanes on both sides. The previous Bicycle LOS analysis indicated a LOS E-F for the no-build conditions with just standard bike lanes. It was desired to improve the bicycle network in this area with the addition of a separated bikeway using a post-type buffer.

From the given data, the buffer type is posts, the direction is one-way, the speed is 35 mph and the ADT is 31,000. It was noted that the ADT was slightly outside of the top range (30,000) but judged close enough not to have too much LOS overestimation (at 30,000 ADT the highest probability is LOS B at 38.44%) or any non-intuitive results.

The four data elements are added into the calculator and the highest probable result is LOS B at 38.27%. The 10% significance check (90% of LOS B) also captures LOS A at 37.40% so a LOS range is possible. The calculator will always provide multiple probabilities for every segment for the purpose of helping the user decide which LOS to report rather than just reporting the highest probability. However, because of the chance of some LOS A overestimation with the high ADT, the LOS was left at LOS B instead of going to LOS A-B as seen below.

Final LOS Probabilities						Max	Probability	Final
A	B	C	D	E	F	Probability	90% Check	LOS
0.3740	0.3827	0.1757	0.0428	0.0160	0.0087	0.3827	0.3445	B

14.6.6 Buffered Bike Lanes

Buffered bike lanes offer additional comfort to the bicyclist by providing separation from the

vehicle lanes using a striped and/or hatched buffer. Buffered bike lanes can be used when speeds exceed 20 mph or when volumes are in excess of 1,500 ADT and should be used when speeds reach 40 mph and/or 7,500 ADT⁷. This type of bike lane will allow a more acceptable LOS grade than a standard bike lane for higher volume and speed facilities, such as most urban state highways. Buffered bike lanes may also be a good compromise in areas with a substantial amount of driveways that would make operations of a separated bikeway difficult or create a number of safety issue locations because of visibility/sight distance.

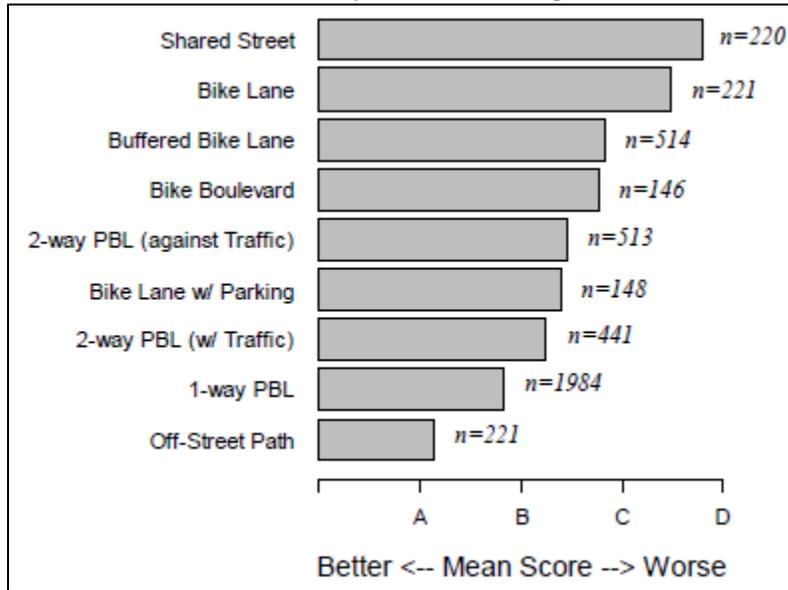
Methodology Summary

The methodology for the estimation of a buffered bike lane LOS is based on an extension of Exhibit 14-28. The LOS of a buffered bike lane falls in the LOS B-C range which is approximately halfway between the LOS of a standard bike lane at LOS C-D and a separated (one-way) bikeway at LOS A-B. The estimated buffered bike lane LOS is obtained from averaging the LOS scores of both the bike lane and separated bikeway since both methods use the same cumulative logistic regression model form. This procedure is considered an interim method until better facility-specific methodologies are available. An Excel-based [calculator](#) is available on ODOT's Planning Section webpage which combines both methodologies for a quick but separate (i.e. the presence of unsignalized conflicts only applies to the standard bike lane methodology) comparison.

This estimated method is best applicable within the ranges of the separated bikeway methodology (speeds 25-35 mph & 9,000-30,000 AADT). Higher volumes and speeds (vice versa for low speeds/volumes) will tend to make the separated bikeway LOS better while the bike lane LOS becomes worse which will generally make the differences balance out between them.

⁷ Urban-Suburban Separation Matrix, [Oregon Bicycle and Pedestrian Design Guide](#), 2011, p 1-3.

Exhibit 14-28 Bike Facility LOS Ranking⁸



The standard bike lane and separated bikeway variables are entered into the calculator to obtain the cumulative probabilities which are subtracted from one another to obtain the LOS probabilities. The highest LOS probability is chosen as the most-likely LOS. The calculator will also flag any values within 10% of the highest probability. Check the LOS probabilities in the calculator for any highlighting. The highlighting will indicate the potential for a LOS range (i.e. LOS A-B) with a total probability that is the sum of the individual probabilities. Judgement based on the overall project context is required to decide to leave the LOS as calculated or override it to a lower/higher LOS or create a LOS range.

Once the base LOSs for the standard bike lane and separated bikeway are calculated and optionally adjusted, the LOS grades are converted into scores which are averaged together and then reconverted into an estimated buffered bike lane LOS. Application is best for future scenarios as the LOS for a standard bike lane, buffered bike lane, and separated bikeway will all be shown for comparison, but can also be used for an existing buffered bike lane (use posts buffer and a one-way bikeway).

Example 14-8 Buffered Bike Lane LOS

This example uses the same segment of roadway as described in the previous sections. The roadway has five lanes, a 35 mph speed limit and a peak month ADT of 31,000. The roadway currently has six foot bike lanes on both sides and goes through a commercial area with a substantial amount of driveways. The previous Bicycle LOS analysis (Example 14-6) indicated a LOS E-F for the no-build conditions with just standard bike lanes. Example 14-7 calculated a LOS B for a separated bikeway. An additional alternative for a buffered bike lane was also needed to be analyzed as the higher amount of driveways was thought by project staff to potentially create too much interference for good operation of the separated bikeway. .

⁸ Foster, N., C. Monsere, J. Dill, K. Clifton, A Level-of-Service Model for Protected Bike Lanes, Figure 2, p. 7-8.

The additional bike lane data of greater than one travel lane in each direction and the presence of unsignalized conflicts are added into the calculator input tab supplementing the separated bikeway data.

The additional data elements are added into the calculator and by checking the bike lane results show a LOS F at 27.11%. The 10% significance check also captures the LOS E level at 24.41%. The final LOS is overridden in the bike lane LOS columns, so it will be reported correctly on the output sheet and in the overall buffered bike lane calculations.

The calculator averages the bike lane and separated bikeway results and provides an estimated buffered bike lane value at LOS C-D which would also be an improvement over a standard bike lane as seen below.

APM Example 14-8		Protected Bikeway /Buffered Bike Lane MMLOS				06/23/16
E.N. Gineer		Segment LOS Output Summary				
Roadway	Dir	From-To	Prot. Bikeway LOS	Buffered Bike Lane Estimated LOS	Bike Lane LOS	
Example Ave	S	1st St - 10th St	B	C-D	E-F	

14.6.7 Shared-use Paths

Methodology Summary

This methodology is a full application of the Highway Capacity Manual (HCM) 2010 Chapter 23 method on paved shared-use (multi-use) paths. Use this methodology with caution on unpaved paths as the research only contained data from paved paths. A shared-use path is completely separated from roadway traffic for the use of non-motorized modes. Typically these paths have at least 35 feet of separation from an adjacent roadway, but they may be closer if the barrier between the path and roadway is substantial (i.e. soundwall, retaining wall, etc.) so that the effect of vehicular traffic is limited. Paths may also be on their own separate right-of-way, such as along a creek in a greenway. Paths with lesser buffers should be considered a protected bikeway or sidewalk and analyzed with the other methods in this chapter. This methodology is intended to work in concert with the other HCM-based “streamlined” and other segment and intersection methodologies in this chapter. More information on shared-use paths is available in Chapter 7 of the [Oregon Bicycle and Pedestrian Design Guide](#).

The methodology considers the impacts on pedestrians and bicyclists by other path users mainly through the accounting of passing (overtaking) and meeting events considering volumes, speeds and densities. The path segment is divided into very small 0.01 mile pieces and impact of the approaching other users (pedestrians, adult and child bicyclists, runners and inline skaters) on a bicyclist is measured for each piece and then summed across the entire path segment. Impact on pedestrian users is handled more simply by considering flow rates of all path users and the relative difference between the average pedestrian and bicycle speeds. Both bicycle and pedestrian methods measure crowding on a path segment and how much interference there will be from passing, meeting, or being forced to wait to pass. The methodology is segment-based so segments should start and end at path junctions, intersections with roadways or where path width changes substantially.

Application of the shared-use path method needs to be done via an Excel-based calculator provided on the [Transportation Development – Planning Technical Tools](#) webpage as the math and statistical work required is too much for simple hand calculations. This methodology works equally well for analysis of existing or future paths. For planning applications (proposed paths or changes to existing ones) most of the inputs can be estimated. For actual project and detailed refinement planning efforts it is recommended that most of the inputs come from actual design/field values. For analysis of intersections of shared-use paths at unsignalized or signalized roadway crossings, please refer to (future) Sections 14.5 through 14.7.

LOS Criteria

The applicable LOS criteria and descriptions for shared-use paths come from HCM Exhibits 23-4 and 23-5 which are combined into Exhibit 14-29 and 14-30 below. The LOS criteria is mainly based on recreational users which considers the influence of child bicyclists, runners, skaters and walkers in addition to the bicyclist mode. More user conflicts (passings and meetings) will result in lower LOS grades. A poor LOS indicates less user satisfaction versus a chance of a potential route shift. Since a shared path will generally offer the lowest stress route, route shifting is

unlikely unless there are nearby adjacent routes without out-of-direction travel and the path carries high amount of high-stress tolerant (commuter) bicyclists that could travel comfortably on an on-street bike facility. Poor LOS grades generally indicate that the path is too narrow for the amount of existing or projected users.

This method and LOS criteria assume that users stay on the path surface, especially while being passed. Frequent observations of side-stepping or use of the “shoulder” area may indicate a path that is too narrow and/or is reaching capacity regardless of the LOS results obtained. Also, the LOS criteria are based on user comfort and do not give any specific indication that the facility is compliant with the Americans with Disabilities Act (ADA) or other design standards.

Exhibit 14-29 Pedestrian and Bicycle LOS Criteria

LOS	Pedestrian Weighted Event Rate per hour	Bicycle LOS Score
A	<=38	>4.0
B	>38 - 60	>3.5 – 4.0
C	>60 - 103	>3.0 – 3.5
D	>103 - 144	>2.5 – 3.0
E	>144 - 180	>2.0 – 2.5
F	>180	<=2.0

Exhibit 14-30 Pedestrian and Bicycle LOS User Description

LOS	Pedestrian LOS Description	Bicycle LOS Description
A	Optimum conditions, bicycle conflicts rare	Optimum conditions, ample ability to absorb more riders
B	Good conditions, few bicycle conflicts	Good conditions, some ability to absorb more riders
C	Difficult to walk two abreast	Meets current demand, marginal ability to absorb more riders
D	Frequent bicycle conflicts	Many conflicts, some reduction in bicycle travel speed
E	Frequent and disruptive bicycle conflicts	Very crowded, significant reduction in bicycle travel speed
F	Significant conflicts, diminished experience	

Data Needs and Definitions

These are the inputs and definitions as used in the methodology and the available calculator.

Shared-use Path Volume (users per hour) – This is the total of the non-motorized mode users on the specific shared-use path segment in both directions. User modes include adult and child bicyclists, pedestrians, runners and (inline) skaters. This value may be estimated through demographics/available planning documents or from an actual count (required for design purposes) for existing conditions. Future conditions could be obtained from using historical bicycle/pedestrian count data or post-processed assignments/mode splits in a metropolitan area travel demand model. Volume changes of more than 10% should be broken into a new path

segment.

Highest Directional Split – Expressed as a decimal, this is the highest total directional flow percentage (i.e. 0.57) within the hour of analysis on the segment. Path use may be dominated by commuter, recreational, or multi-purpose flows. If directional counts and resulting flows are not available, then reasonable defaults can be assumed (0.55) for commuter and (0.50) for recreational and multi-purpose (mixed) uses.

Peak Hour Factor – See APM Section 5.8 for the definition and example calculations. For this to be obtained explicitly in this method, counts with 15-minute breakdowns are required which may not be a common specification for bike/pedestrian counts. A default PHF can be assumed where detailed counts are not available (0.90 to 1.00) depending on whether this particular path segment is subject to peaking characteristics. Highly urban areas, biking/walking friendly areas, commuter corridors, or nearby employers with high non-motorized modal users may cause noticeable peaking on certain segments.

Segment Length (miles) – This is the length of a segment between path junctions, street crossings, any location where the volume changes by more than 10%, or path surface width changes.

Path Width (feet) – This is the width of the path surface. The minimum width is eight feet and the maximum width is 20 feet as defined in this methodology. Paths less than eight feet wide become too-narrow to function as a true multi-use path as passing becomes challenging (typically a user has to step to the side) and are really closer to a pedestrian foot-path. The desirable width is 12 feet but can go as low as eight feet for pinch points with low volume and as much as 20 feet for high volume paths according to the Oregon Bicycle and Pedestrian Design Guide. A change of one foot or more should be broken into a new segment. For a given volume, changing of width on narrower paths will have more impact than on wider ones.

Centerline Presence – This indicates whether a path has a marked centerline. This is a Yes/No choice in the Input tab in the calculator tool. A marked centerline can constrain the maneuverability freedom of users and results in lower LOS scores.

User Mode Default Parameters – The calculator assumes defaults for mode split, average mode speed, mode speed standard deviation, and mode passing distance from the HCM. These can be completely updated if detailed information is available or at the very least, the mode split can be proportionally changed to reflect the typical path users or area demographics.



It is recommended that at least one count on an existing or for a future multiuse path be full featured (15-min breakdowns, directional, and by user class) so that the calculator can be customized for the specific application. Paths with significant commuter flows should be counted in the typical AM/PM peak periods. Paths that are recreational or are mixed use should have counts that cover the midday peak and/or weekend periods. It may be necessary to obtain a week-long count with daily and hourly volumes to determine when peak periods occur if this information is not available from sites with similar characteristics.

Example 14-9 Pedestrian & Bicycle LOS

A section of paved shared-use path links two arterials along a creek-side greenway. The unbroken path segment is 1.2 miles long and is 12 feet wide with no marked centerlines. A recent volume count showed 100 users of all types in the peak hour of the facility.

The count had hourly breakdowns only and it was determined in the peak hour that the highest directional flow was 60%. A PHF was estimated at 0.95 as there was not much influence from uses that would cause higher spikes in the user volume. The default modal splits and other parameters were used.

The input data was entered into the calculator tool in the yellow-shaded boxes as shown below. Mode splits, speeds, and passing distances were left as defaults in the orange-shaded boxes.

Total shared-use path users per hour =	100					
Highest directional split (decimal)=	0.60					
Peak Hour Factor (PHF) =	0.95					
Segment Length (L) (mi) =	1.20					
Path Width (min 8 - max 20 ft) =	12.0					
Does path have a marked centerline? (Yes/No)	No					
	Mode Split	Ave. Mode speed, ui	Mode Std. Dev.	Mode Passing	Flow rate , qi	Density
	(decimal)	(mph)	(mph)	Distance (ft)	users/h	users/mi
Bike	0.55	12.8	3.4	100	35	2.71
Ped	0.20	3.4	0.6	60	13	3.72
Runner	0.10	6.5	1.2	70	6	0.97
Skater	0.10	10.1	2.7	100	6	0.63
Child bike	0.05	7.9	1.9	70	3	0.40
Yellow-shaded cells are user supplied data (Directional split and PHF can be defaulted)						
Orange-shaded cells are user-changeable defaults if better information is available						
Gray-shaded cells are calculations used as inputs to other tabs						

The calculator macro tool was run and the results obtained are shown below. Both the bicycle and pedestrian modes have a LOS B which is indicative of favorable conditions on this analysis segment.

Bike LOS Calculation			
Total Meetings per Min=		2.79	
Total Active Passings per Min=		0.81	
Total Weighted Events per Min		10.87	
Delayed Passings per Min =		0.08	
Bike LOS Score =	4.00	LOS =	B
Final LOS adjustment for low volume=			B
Pedestrian LOS Calculation			
Pedestrian Events/hr =		52	
Pedestrian LOS =		B	

14.6.8 Unsignalized Intersections (TBD)

14.6.9 Crossing Enhancements (TBD)

14.6.10 Signalized Intersections (TBD)

14.7 Transit LOS

Methodology Summary

Unlike the simplified Pedestrian and Bicycle LOS methods, there is no re-estimated Transit LOS. Instead, this is a streamlined version of the regular HCM Transit LOS methodology using simplifying assumptions and specific defaults. The full transit methodology involves calculating transit vehicle running time, delay, and speeds, then determining impacts caused by waiting times, stop amenities, and pedestrian access. Like with other MMLOS methods, the methodology is done separately for each direction of travel. This simplified method should only be applied to segments within the study area that have applicable fixed-route transit.

It also would be possible to estimate the Transit LOS within a travel demand model if transit routes were considered explicitly so the frequency could be captured. The travel times for the various route segment would need to be summed across each major segment and the other inputs likely defaulted with use of some custom variables or expressions. The pedestrian LOS portion of the calculation could be computed from volumes, speeds and number of directional lanes which are common variables in a travel demand model and the sidewalk variable either assumed or based on field data.

The simplified methodology uses transit schedule speed, instead of calculating a transit travel speed, to consolidate the first three steps of the full MMLoS process. Schedule speed ultimately controls as transit vehicles will dwell at time points if they are ahead of schedule. Schedule speeds are also periodically reviewed and adjusted to account for ridership, dwell times, and traffic conditions.

For segments with heavy congestion, where travel speeds are substantially lower, the transit speed should be considered instead if the schedule does not reflect extra time for the regular peak hour congested conditions. Alternatively, the actual transit vehicle speed can be used if available from recent surveys or preferably from active GPS installations on the transit vehicles from the transit district. Note that other private data source travel times will only reflect the running speed of the average vehicle on the segment and will be too high for use as they will not reflect the transit stop delay and dwell times.

The re-estimated Pedestrian LOS (Section 14.5.3) is used in the Transit LOS calculation and is equated to an LOS score to avoid needing to calculate a full-detailed Pedestrian LOS score. The rest of the methodology uses reasonable defaults and assumptions using the HCM equations.

This method is applicable for urban street-running transit vehicles operating in an exclusive or a mixed-use lane. While the typical transit vehicle is a bus, it should not be assumed that this is always the case as this methodology also applies for bus rapid transit (BRT), streetcars, or light rail operating in mixed mode street-running conditions. Analysis of transit operating in a separated right-of-way such as adjacent to a street, in a median, or grade-separated is not covered under this methodology but in the companion *Transit Capacity and Quality of Service Manual*.

14.7.1 Transit LOS Criteria

LOS scoring threshold criteria for the transit mode is shown below in Exhibit 14-31. These are based on updated values of HCM Exhibit 17-3 and 17-4. The pedestrian LOS input has been converted from a range into an averaged single value for input into the final transit LOS equation.

Exhibit 14-31 Transit LOS Criteria

LOS	Pedestrian LOS Score, I_p	Transit LOS Score, I_t
A	0.75 ¹	≤ 2.00
B	2.00	$>2.00 - 2.75$
C	3.00	$>2.75 - 3.50$
D	4.00	$>3.50 - 4.25$
E	5.00	$>4.25 - 5.00$
F	5.75 ²	>5.00

¹The average score for LOS A is based on the minimum value of 0.00 and the highest score of 1.5.

²The average score for LOS F is based on the maximum value of 6.0 in HCM Equation 17-61 and the minimum value of 5.50.

Like with the other modes, these LOS scores are based on user perceptions (traveler satisfaction) and are graded from best (LOS A) to worst (LOS F). This kind of perception-based rating varied

from the many test respondents (there is no one single definition of a multimodal LOS grade) and was eventually grouped into LOS ranges. Better conditions will result in better LOS scores. For example, more frequent transit service will rate better than less frequent service.

Transit LOS is heavily influenced by frequency, and frequency is influenced by land use density and availability of capital (vehicles) and operating (employees) funds. Therefore, a low LOS score may simply reflect the maximum feasible capability of a transit district on a particular route and should not be immediately equated with “poor” service. Better service (and LOS) may not be possible because of restricted funding and/or the land use is not dense enough to support it. The funding context of a particular transit district needs to be taken into account when reporting Transit LOS values.

Data Needs and Definitions

Transit Schedule Speed (S_t) – This is the speed (mph) calculated by dividing a known segment length by the difference of two adjacent time points published in the route timetable. If a segment covers parts of two sets of time points, then the resulting schedule speeds should be weight averaged. If there is more than one route on a given segment, then the schedule speeds should be averaged or weight averaged if frequencies are different.

Transit Frequency (v_s) – This is the number of transit vehicles per hour on the directional segment. Sum up the frequency of all routes that may travel this segment. Start with the route that has the highest frequency during the analysis hour(s). For additional routes, note which times are offset versus ones that seem to duplicate.

For instance, a 60-minute route that runs on the same schedule as another 60-minute route will result in one vehicle following another and should only be coded as one vehicle per hour. If the two routes were offset (say one on the hour and the other on the half-hour), then code this as two vehicles per hour. The route duplication does not have the same frequency benefit for the rider compared to a more even time spacing.

For corridors with very frequent service, like with in-road bus rapid transit or light -rail transit, consider these routes to likely control the segment as the short headways (typically less than 10 minutes) makes it unlikely that additional routes will have times that do not duplicate, so there will not be any additional frequency benefit. Only consider “tripper” service (additional frequency and/or minor route changes to serve schools) if it is active during the chosen analysis period.

From the transit frequency, the headway factor (F_h) is computed from HCM Equation 17-54:

$$F_h = 4.00e^{-1.434/(v_s + 0.001)}$$

All of the following inputs are defaults with the exception of needing the Pedestrian LOS data in Section 14.5.3.

Passenger Load Factor (a_1) – For this simplified methodology, this factor is assumed to be 1.0, which represents that, on the average of all transit vehicles using that segment in the desired time

period, they are 80% or less full (0.8 passengers per seat). On congested segments where passenger per seat ratios are higher than 80% and up to 100%, use passenger load factors in Exhibit 14-32 or the 2nd case of HCM Equation 17-57. If overcrowding exists on the average where the numbers of passengers exceed the number of seats (presence of standees), please refer to the 3rd case of HCM Equation 17-57 for computing the appropriate passenger loading factor.

Exhibit 14-32 Passenger Load Factors¹

Passenger to Seat Ratio	Passenger Load Factor(a₁)
<0.81	1.00
0.85	1.05
0.90	1.10
0.95	1.14
1.00	1.19
>1.00	Use HCM Equation 17-57

¹Derived from 2010 Highway Capacity Manual Equation 17-57

Other general defaults are the threshold late time, which is the time that transit agencies typically consider a vehicle late, set at 5.0 minutes, and the proportion of transit vehicles arriving within the late time threshold, set at 0.75 (75% considered to be on-time). The late time threshold proportion value could be adjusted if it is desired to estimate reliability impacts. Both of these can be changed if more specific information is available from a transit district.

A large part of the full methodology involves calculating perceived travel time rates and factors which involves the transit speed, on-time ability, and stop amenities such as benches and shelters. Passengers generally view excess waiting time worse than slower travel speeds, but may wait longer if there are amenities.

With the above default threshold late time and the on-time arrival percentage in HCM Equation 17-59, a fixed excess wait time of 1.6 minutes is calculated. The excess wait time is converted into the excess wait time rate of 0.41 min/mi by dividing the excess wait time by the average trip length of 3.8 miles based on reported Oregon transit system data in the National Transit Database. The proportion of shelters and benches in the full methodology has been found not to be very sensitive⁹ to the final results and is ignored in this simplified method. The perceived travel time rate (HCM Equation 17-56) equation can be simplified with the above defaults and simplifications to:

$$T_{ptt} \text{ (min/mi)} = 60/S_t + 0.86, \text{ where } S_t \text{ is the transit schedule speed}$$

Use the equation form $T_{ptt} \text{ (min/mi)} = a_1[60/S_t] + 0.86$, where a_1 is the passenger loading factor, if the default 1.0 value was not used.

⁹ Carter, P., Martin, F., Nunez, M., Peters, S., Raykin, L., Salinas, J., et al. (2013). Complete Enough for Complete Streets? Sensitivity Testing of Multimodal Level of Service in the Highway Capacity Manual. *Transportation Research Record: Journal of the Transportation Research Board*, No.2395, 36-37.

The perceived travel time factor (F_{tt}) is a combination of the perceived travel time rate and the base travel time rate, which is assumed to be defaulted at 4.0 min/mi for areas below five million in population. There also is a default ridership elasticity factor of -0.40 which considers changes in the travel time rate. Using the above defaults in HCM Equation 17-55, the equation reduces to:

$$F_{tt} = (5.6 + 0.6T_{ptt}) / (1.4T_{ptt} + 2.4)$$

The final Transit LOS score (I_t) is the combination of the wait-ride score and the Pedestrian LOS score (I_p) based on HCM Equation 17-61. The wait-ride score portion of the equation is the product of the perceived travel time factor F_{tt} and the headway factor F_h .

$$I_t = 6.0 - 1.5 (F_h * F_{tt}) + 0.15I_p$$

The Pedestrian LOS (I_p) is calculated for the directional segment using the methodology in Section 14.5.3. Since the Pedestrian LOS from Section 14.5.3 is based on a probability of the entire range, the average LOS score is used for I_p in Exhibit 14-31, which is based on HCM Exhibit 17-4. If the Pedestrian LOS results in a range of levels, then the appropriate Pedestrian LOS scores in the second column in Exhibit 14-31 should be averaged together. The Transit LOS score (I_t) is then compared to the transit score range in the third column in Exhibit 14-31 to determine the final LOS for the directional segment.

Example 14-10 Transit LOS

The same suburban arterial segment from the previous examples is used to continue the multimodal analysis. There are two transit routes on this roadway segment, one on 15-minute and one on 30-minute headways. The schedules are offset enough so the 30-minute route does not directly overlap the 15-minute route. For the analysis period, both routes are operating less than 80% full.

The first step is to calculate the schedule speed of the directional segment. For the 15-minute headway route, the available transit schedule shows seven minutes to travel from time point A to B. Measurement of the distance via aerial photos between A and B results in 5405 feet. The 30-minute route shows four minutes (apparently assuming less stops) between its time points C and D that bracket the analysis segment. The distance from C to D is measured as 6150 feet.

The schedule speed (S_{t15}) for the 15-minute route is calculated as:

$$\begin{aligned} S_{t15} &= (\text{segment length in feet} / 5280 \text{ feet per mile}) / (\text{travel time in minutes} / 60 \text{ minutes per hour}) \\ &= (5405 \text{ ft} / 5280 \text{ ft/mi}) / (7 \text{ min} / 60 \text{ min/hr}) \\ &= 1.024 \text{ mi} / 0.117 \text{ hr} \\ &= 8.75 \text{ mph} \end{aligned}$$

The schedule speed (S_{t30}) for the 30-minute route is calculated as:

$$S_{t30} = (\text{segment length in feet} / 5280 \text{ feet per mile}) / (\text{travel time in minutes} / 60 \text{ minutes per hour})$$

$$\begin{aligned}
&= (6150 \text{ ft} / 5280 \text{ ft/mi}) / (4 \text{ min} / 60 \text{ min/hr}) \\
&= 1.165 \text{ mi} / 0.067 \text{ hr} \\
&= 17.48 \text{ mph}
\end{aligned}$$

The average schedule speed (S_t) is weight averaged between the two routes as the 15-minute route has four vehicles per hour (67% of total) and the 30-minute route has two vehicles per hour (33% of total) for a total of six.

$$\begin{aligned}
S_t &= 8.75(0.67) + 17.48(0.33) \\
&= 11.63 \text{ mph}
\end{aligned}$$

Next, the headway factor (F_h) is computed from the overall transit frequency (6 veh/hr):

$$\begin{aligned}
F_h &= 4.00e^{-1.434/(v + 0.001)} \\
&= 4.00e^{-1.434/(6 + 0.001)} \\
&= 3.15
\end{aligned}$$

The perceived travel time rate (T_{ptt}) is computed from the overall schedule speed:

$$\begin{aligned}
T_{ptt} &= 60/S_t + 0.86 \\
&= 60/11.63 + 0.86 \\
&= 6.02 \text{ min/mi}
\end{aligned}$$

The perceived travel time rate (T_{ptt}) is inserted into the simplified travel time factor (F_{tt}) equation:

$$\begin{aligned}
F_{tt} &= (5.6 + 0.6T_{ptt}) / (1.4T_{ptt} + 2.4) \\
&= (5.6 + (0.6 * 6.02)) / ((1.4 * 6.02) + 2.4) \\
&= 9.21 / 10.83 \\
&= 0.85
\end{aligned}$$

The final Transit LOS score (I_t) is calculated using the headway factor and the travel time factor from previous steps in addition to the Pedestrian LOS score (I_p) for the segment. The Pedestrian LOS was LOS C from the first example. This equates to an average LOS score in Exhibit 14-15 of 3.00.

$$\begin{aligned}
I_t &= 6.0 - 1.5 (F_h * F_{tt}) + 0.15I_p \\
&= 6.0 - 1.5 (3.15 * 0.85) + 0.15(3.00) \\
&= 6.0 - 4.02 + 0.47 \\
&= 2.43
\end{aligned}$$

Comparing the final LOS score with Exhibit 14-15 shows this segment to have a Transit LOS B (both directions the same).

Some of the calculator inputs and intermediate calculations done above are shown below as an example. Note that some columns are hidden.

Schedule Speed	Headway	Perceived Travel Time Rate	Perceived Travel Time	Pedestrian LOS	Transit LOS	Transit
mph	Factor	min/mi	Factor	Score	Score	LOS
11.63	3.15	6.02	0.85	3.00	2.43	B
