# 14 MULTIMODAL ANALYSIS

## 14.1 Purpose

To truly quantify the operation of a roadway segment, all 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 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 complementary, not competitive, and the methodologies 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. 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 Applications**[1]

| | | Qualitative Multimodal Assessment (QMA) | Level of Traffic Stress (LTS)[2] | Multimodal Level of Service (MMLOS) |
|---|---|---|---|---|
| Increasing Project Complexity ↓ (Increasing Detail →) | Regional Transportation Plan (RTP) | ○ | ● | |
| | Transportation System Plan (TSP) | ● | ● | |
| | Facility Plan/Interchange Area Management Plan (IAMP) | ○ | ○ | ● |
| | Project Development | | ○ | ● |
| | Development Review | | ○ | ● |

[1]Solid circles represent the preferred methodology. Outlined circles represent where methodology can also be used.
[2]Use 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 certain 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 requiring 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. Each mode should only be analyzed using one methodology, even if more than one methodology is being used in the 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. These data levels 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 considered 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 2010 and later 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 e.g. in a technical appendix. Factors can be documented for each rating in tabular form such as shown in Exhibit 14-2. This will allow for easy reference and consistent application. 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 are 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.*

**Exhibit 14-2 Sample Factor Documentation**

**Table 3: Transit Qualitative Multimodal Assessment Methodology**

| Category | Excellent | Good | Fair | Poor |
|---|---|---|---|---|
| **Frequency and On-Time Reliability** | <15-minute headways | 15 to 30-minute headways | 30 to 60-minute headways | 60+ minute headways |
| **Schedule Speed/ Travel Times** | <20% slower than driving | 20% to 40% slower than driving | 40% to 60% slower than driving | >60% slower than driving |
| **Transit Stop Amenities** | Shelter with bench and sign | Bench with sign | Sign with waiting area | No sign and/or no waiting area |
| **Connecting Pedestrian/Bicycle Network** | Wide shoulders or bike lanes and sidewalks with frequent crossing | Standard shoulders or bike lanes and sidewalks with crossings | Substandard shoulders or bike lanes and sidewalks with no crossing | No shoulders, bike lanes, or sidewalks and no crossings |

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. This methodology allows for a multimodal analysis 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 the elements below should be considered for each mode. However, not all 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 should occur as necessary but need to 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 or more separated (e.g. buffered or separated bike lanes) 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, or with marked crosswalks are rated better than locations with only two-way stop control or locations without marked crosswalks.
- **Crossing width:** Fewer turn or through travel lanes to be crossed is rated better than more turn/though 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 significantly improve the associated safety and ease when using a crossing.

### 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 less separated facilities. Wider bicycle facilities rate better than narrower or non-existent ones. Ideally, arterials (7000+ AADT) have separated bicycle lanes with vertical barriers, buffered bike lanes, or shared/multi-use paths); low-speed collectors (1500-7000 AADT) have buffered or standard 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 Section 306 in the Highway Design Manual.
- **Shoulder presence/width:** Shoulders serve bicyclists in the absence of marked 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 low volume/speed urban streets, narrower lanes are better than wider lanes for better shared lane utilization when sharrow markings are used, since the bicyclist is more likely to take the center of the lane rather than potentially being squeezed to the side.
- **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/though 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 aggregated 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 the QMA methodology 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 |
| *OR99 at Arnos Rd* | Poor | Poor | Fair | Good |
| Arnos Rd to Creel Rd | Poor | Poor | Fair | Good |
| *OR 99 at Creel Rd* | Poor | Poor | Fair | Good |
| **Scenario 1 - Five lanes** | | | | |
| Rapp Rd to Arnos Rd | Good | Fair | Fair | Good |
| *OR99 at Arnos Rd* | Fair | Fair | Fair | Good |
| Arnos Rd to Creel Rd | Good | Fair | Fair | Good |
| *OR 99 at Creel Rd* | Fair | Fair | Fair | Good |
| **Scenario 2 – Three lanes** | | | | |
| Rapp Rd to Arnos Rd | Good | Good | Fair | Good |
| *OR99 at Arnos Rd* | Good | Good | Fair | Good |
| Arnos Rd to Creel Rd | Good | Good | Fair | Good |
| *OR 99 at Creel Rd* | Good | Good | Fair | Good |

## 14.4 Bicycle Level of Traffic Stress

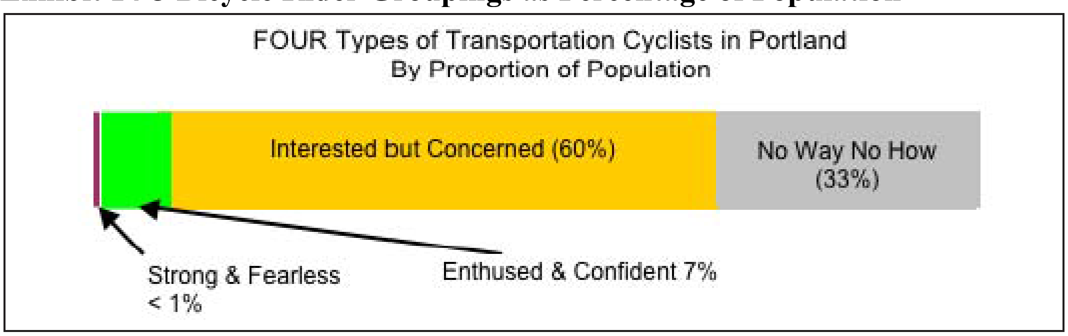
The Bicycle Level of Traffic Stress (BLTS) methodology breaks road segments into four classifications for measuring the effects of traffic-based stress on bicycle riders. The original methodology can be obtained from the paper, *"Low Stress Bicycling and Network Connectivity*", Mineta Transportation 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 and separated 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 require 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.

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. BLTS 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 when vegetation or other obstructions obscure views. 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 14-3). While the percentages may change in different cities and rural/suburban areas, the groupings are still applicable.

**Exhibit 14-3 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 "Enthused 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/5$^{th}$ 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 easily crossed 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 would be expected to deal with, 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 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 is 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 for 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 general Bicycle Level of Stress methodology does not include all the other comfort factors that may be important to bicycle riders that should be taken into consideration in application such as grades and surface conditions. Section 14.4.11 contains optional comfort measures that can be introduced as needed to add these details. Sometimes, systematic deviations are required to properly capture the overall context of a community or are relevant to a particular project area. For example, there have been cases, where the BLTS ends up being the same on all facilities as all roadways are 25 mph and two lanes, but there are noticeable differences between the subject roadways. New tables and BLTS adjustments can be created; however, as some of these can be subjective, adequate documentation needs to be provided outlining the reasons for the deviations. Where possible, these deviations should be explained in the methodology and assumptions memorandum before analysis begins but may require a separate memorandum if issues come up during the analysis.

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. Roadways where biking is prohibited, such as along certain segment of urban freeways designated in OAR 734-020-0045, should also be noted.[1]

### 14.4.2 BLTS Targets

A target level of traffic stress for the bikeway system may be identified to maximize the bicycle mode share with the available resources.  A BLTS 2 is often used as the target as it will typically appeal to the majority of the potential bike-riding population and

[1] Shoulders should be available for pedestrians to access the nearest exit during mechanical incidents or after collisions, but it is not preferred to accommodate bicycle or pedestrian travel on shoulders on urban limited access facilities. Instead, pedestrian and bicycle travel should be accommodated on a parallel multi-use path, separated bikeway, or parallel streets. Limited access highway shoulders should only be used as a primary pedestrian and bicycle accommodation in low volume rural areas and/or where physical constraints and sparse surrounding network make a parallel route infeasible.

maximize the available bicycle mode share. Other BLTS levels may also be used as targets depending on a jurisdiction's needs and maturity of the available bike network.

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

### 14.4.3 BLTS Criteria

The traffic stress criteria in the BLTS methodology are applied from lookup tables in three categories: 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). 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. One-way streets might have different conditions on either side, so either both sides or the worst condition should be reported. 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.

The methodology uses the worst overall BLTS value for each overall segment. For example, if a segment has a BLTS 2 but there is an intersection approach at the end of the segment at BLTS 4, then the whole segment is coded BLTS 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 BLTS 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 BLTS 4 will render a route unacceptable to most people even though the rest of the route is at BLTS 2.

### 14.4.4 BLTS Segment Criteria

The BLTS 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 separated bike lanes which may be separated from motor vehicles by landscaped buffers, curbs, bollards, bioswales, on-street parking, or other vertical delineators. Physically-separated bike paths and lanes (assuming full bike standards) are generally classified as BLTS 1 regardless of the number of lanes or speed on a segment. Note that separated bike lanes may be combined with buffered or standard bike lanes on separate sides of a street (either one or two-way).

Marked bike lanes have different criteria depending on whether they are adjacent to a parking lane, as shown in Exhibit 14-4 and Exhibit 14-5. 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 14-5 to account for their increased positive separation effects. Existing bike lanes without a useable width of at least 4' (caused by striped too-narrow widths, drainage grates, poor curb-gutter/pavement interfaces, etc.) should be recorded as mixed traffic instead. Bike lanes less than 4' do not provide adequate separation from motor vehicles.

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). The methodology uses the worst overall BLTS value for each overall segment: 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 BLTS 3 which overrides the BLTS 1 values of the other components. The segment length default for urban areas would typically be on a block-by-block basis but could be defined on a larger scale if desired. A trade-off for longer segment lengths will be a loss of detail which could make it harder to determine the controlling worst condition (e.g. a missing section may not have the same influence in a longer segment versus the default length).

**Exhibit 14-4 BLTS Criteria for Segment with Bike Lane and Adjacent Parking Lane**

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

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

**Exhibit 14-5 BLTS Criteria for Segment with Bike Lane, no Adjacent Parking Lane**

| Prevailing or Posted Speed | 1 Lane per direction | | | | ≥2 lanes per direction | |
|---|---|---|---|---|---|---|
| | ≥ 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 | BLTS 1 | BLTS 1 | BLTS 2 | BLTS 3 | BLTS 1 | BLTS 3 |
| 35 mph | BLTS 2 | BLTS 3 | BLTS 3 | BLTS 3 | BLTS 2 | BLTS 3 |
| ≥40 mph | BLTS 3 | BLTS 4 | BLTS 4 | BLTS 4 | BLTS 3 | BLTS 4 |

[1]Typically 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), or existing bike lanes with useable width < 4'. Designated bike boulevards or "sharrow" markings present also fall under mixed traffic conditions. Markings and signs give bicyclists more perceived safety and warn drivers about bicycles potentially being in the roadway, which tends to lower overall speeds. 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, and the two-way average daily traffic (ADT) or functional class if ADT is not available as shown in Exhibit 14-6 and Exhibit 14-7[2].

While not a main focus of this method, biking is allowed on Interstate highways and freeways in certain urban areas. However, even with wider shoulders, due to high vehicle and heavy truck volumes as well as high-speed conflicts at ramps, the level of traffic stress should be coded as BLTS 4 for these sections. Certain freeway sections in Portland and Medford prohibit bicycles as shown in Oregon Administrative Rule OAR 734-020-0045, so these sections should show the BLTS as not applicable ("N/A").

**Exhibit 14-6 Criteria for Urban/Suburban Mixed Traffic Segment – 30 mph or less**

| Number of Lanes | ADT (vpd)[1] | Functional Class | Posted or Prevailing Speed (mph) | | |
|---|---|---|---|---|---|
| | | | ≤20 | 25 | 30 |
| Unmarked Centerline | ≤750 | Local | BLTS 1 | BLTS 1 | BLTS 2 |
| | 750 - ≤1,500 | Local /Collector | BLTS 1 | BLTS 1 | BLTS 2 |
| | 1,500 - ≤3,000 | Collector | BLTS 2 | BLTS 2 | BLTS 2 |
| | >3,000 | Arterial | BLTS 2 | BLTS 3 | BLTS 3 |
| 1 through lane per direction | ≤750 | Local | BLTS 1 | BLTS 1 | BLTS 2 |
| | 750 - ≤1,500 | Local /Collector | BLTS 2 | BLTS 2 | BLTS 2 |
| | 1,500 - ≤3,000 | Collector | BLTS 2 | BLTS 3 | BLTS 3 |
| | >3,000 | Arterial | BLTS 3 | BLTS 3 | BLTS 3 |
| 2 through lanes per direction | ≤8,000 | Arterial | BLTS 3 | BLTS 3 | BLTS 3 |
| | >8,000 | Arterial | BLTS 3 | BLTS 3 | BLTS 4 |
| 3+ though lanes per direction | Any ADT | Arterial | BLTS 3 | BLTS 3 | BLTS 4 |

[1]ADT is both directions for two-way streets. For one-way streets use 1.5*ADT.

[2] Furth, P., Level of Traffic Stress Criteria for Road Segments, Version 2.0, Northeastern University, June 2017.

**Exhibit 14-7 BLTS Criteria for Urban/Suburban Mixed Traffic Segment – 35 mph or more**

| Number of Lanes | ADT (vpd)[1] | Functional Class | Posted or Prevailing Speed (mph) | | |
|---|---|---|---|---|---|
| | | | 35 | 40 | >45 |
| Unmarked Centerline | ≤750 | Local | BLTS 2 | BLTS 3 | BLTS 3 |
| | 750 - ≤1,500 | Local /Collector | BLTS 3 | BLTS 3 | BLTS 4 |
| | 1,500 - ≤3,000 | Collector | BLTS 3 | BLTS 4 | BLTS 4 |
| | >3,000 | Arterial | BLTS 3 | BLTS 4 | BLTS 4 |
| 1 through lane per direction | ≤750 | Local | BLTS 2 | BLTS 3 | BLTS 3 |
| | 750 - ≤1,500 | Local /Collector | BLTS 3 | BLTS 3 | BLTS 4 |
| | 1,500 - ≤3,000 | Collector | BLTS 3 | BLTS 4 | BLTS 4 |
| | >3,000 | Arterial | BLTS 3 | BLTS 4 | BLTS 4 |
| 2 through lanes per direction | ≤8,000 | Arterial | BLTS 3 | BLTS 4 | BLTS 4 |
| | >8,000 | Arterial | BLTS 4 | BLTS 4 | BLTS 4 |
| 3+ though lanes per direction | Any ADT | Arterial | BLTS 4 | BLTS 4 | BLTS 4 |

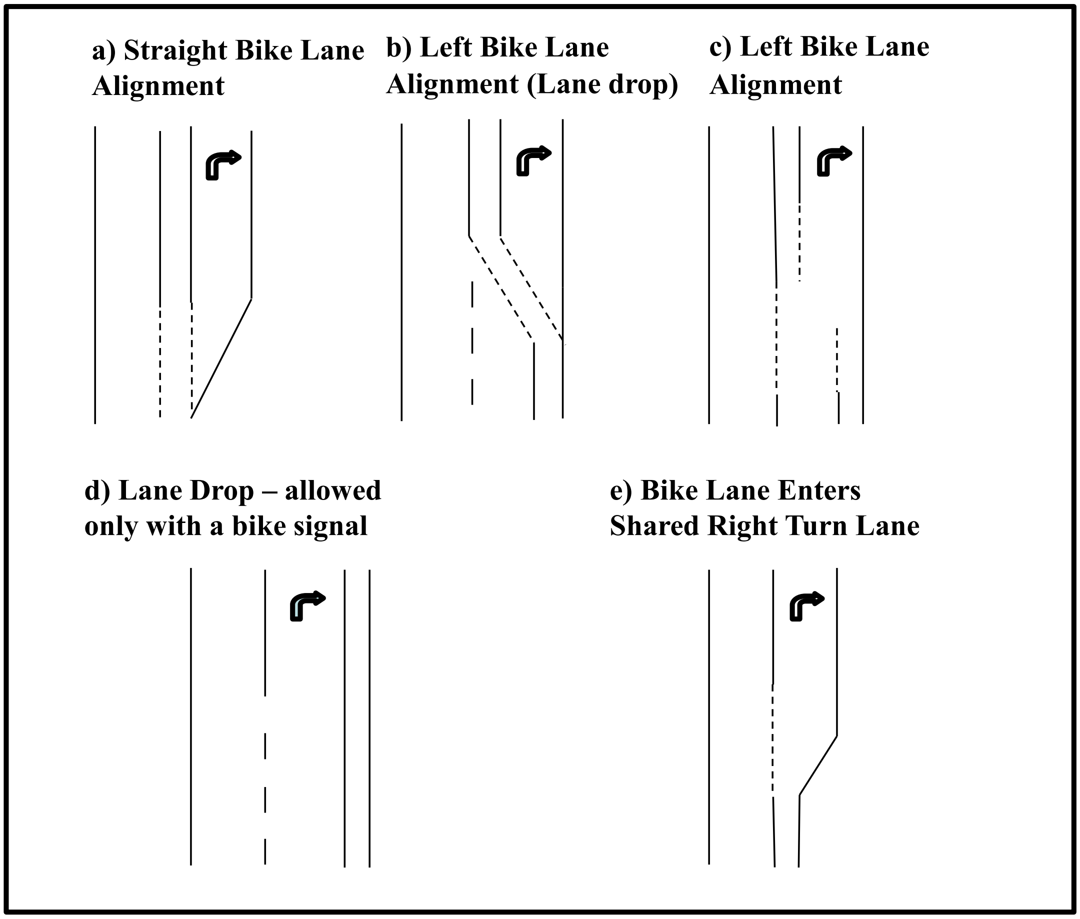
[1]ADT is both directions for two-way streets. For one-way streets use 1.5*ADT.

### 14.4.5 BLTS 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 & Pedestrian 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 move into the turn lane and yield to bicyclists across a marked dashed bike lane in advance of the intersection (see Exhibit 14-8a). 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 14-8b or c). Exhibit 14-8b shows an older marking style while Exhibit 14-8c is the current version. 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 14-8d), 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 (e.g. T-intersections, roundabouts) and re-appear on the other side of the intersection (Exhibit 14-8e).

**Exhibit 14-8 Right Turn Lane Types**




The right turn BLTS 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 BLTS 2 as seen in Exhibit 14-9. Longer turn lanes, higher turning speeds or at skewed intersections will result in a BLTS 3 rating. Turn lanes more than 300' can create a "sandwich" effect on the bicyclist especially under higher volume and speed conditions resulting in BLTS 4. Dual shared or exclusive right turn lanes are typically in very high-volume locations which add additional stress and are BLTS 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 100' including taper) then there is no impact on the BLTS. If speeds are 20 mph or less and sharrow markings are present in the shared turn lane then the BLTS can be reduced by one level. Approaches with bike signals (as would be the case as shown in Exhibit 14-8d) can be BLTS 1 unless there is excessive delay, high non-compliance, or other issues present.

If a separated bike lane uses a protected intersection design where the bike lane is separated by the same distance or bends out further away from the travel lane, then this is BLTS 1. Approaches that "bend-in" the bike lane to be adjacent to the travel lane have more vehicle proximity stress and are BLTS 2. Approaches that require the separated bike lane to have a leftward lateral shift in which vehicles also cross are similar to Exhibit 14-8b and ones that terminate the bike lane into a shared "mixing zone" with right turning traffic are similar to Exhibit 14-8e.

**Exhibit 14-9 BLTS Right Turn Lane Criteria[1]**

| Right-turn lane configuration | Right-turn lane length[2] (ft) | Bike Lane Approach Alignment | Vehicle Turning Speed (mph)[3] | BLTS |
|---|---|---|---|---|
| Exhibit 14-7a | ≤ 150 | Straight | ≤ 15 | BLTS 2 |
| Exhibit 14-7a | >150 to 500' maximum | Straight | ≤ 20 | BLTS 3 |
| Exhibit 14-7b or c | <150 | Shift to Left | ≤ 15 | BLTS 3 |
| Exhibit 14-7d | N/A | N/A | N/A | BLTS 1 |
| Exhibit 14-7e | ≤ 75 | Straight | ≤ 15 | BLTS 2 |
| Exhibit 14-7e | >75' to 150' maximum | Straight | ≤ 15 | BLTS 3 |

[1]Use BLTS 4 for any lengths, speeds, or configurations (e.g. dual right turns or Exhibit 14-8d) not shown in the table.
[2]For the purposes of this methodology, the right turn lane length includes the length of the taper.
[3]This 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 Mineta methodology did not consider the impact of left turn lanes. Left turn lane criteria are 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 the higher the stress level, especially in higher speed locations, as both longitudinal and lateral mixing with traffic are increased, as shown in Exhibit 14-10.

Shared through-left lanes where a bike lane is present can act like 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. 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 should be BLTS 4.

If bicyclists typically use a lower stress two-stage left turn maneuver using the crosswalks or facilitated with special bike box or left turn queue box markings, then the BLTS is controlled by the appropriate intersection crossing criteria in Exhibit 14-11 and Exhibit 14-12 for each of the crossed roadways instead of the left turn criteria shown in Exhibit 14-10. Low-speed signalized intersections that are set up for bicyclists to make two-stage left turns with regular and left-turn queue bike boxes can be BLTS 1.

*For rating routes, only include the effect of the left turn lane if the route requires a left turn and typically uses the vehicle lane versus a two-stage movement. For through and right turn movements, include the effect of the right turn criteria.*

**Exhibit 14-10 BLTS Left Turn Lane Criteria[1]**

| Prevailing Speed or Speed Limit (mph) | No lane crossed[2] | 1 lane crossed | 2+ lanes crossed |
|---|---|---|---|
| ≤25 | BLTS 2 | BLTS 3 | BLTS 4 |
| 30 | BLTS 3 | BLTS 4 | BLTS 4 |
| ≥ 35 | BLTS 4 | BLTS 4 | BLTS 4 |

[1]Use BLTS 4 for any shared/exclusive dual left turn lane configuration.
[2]For shared through left lanes or where mixed traffic conditions occur (no bike lanes present)

### 14.4.6 BLTS Intersection Crossing Criteria

#### Unsignalized Intersections

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 five or more lanes at any speed or has to cross a 35 mph (or greater) four-lane street. The criteria for unsignalized intersection crossings include consideration of 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 BLTS 1.

Where there is no median refuge, the BLTS depends on the speed and two-way average daily traffic (or functional class if ADT is not available), as seen in Exhibit 14-11.

**Exhibit 14-11 BLTS Criteria for Unsignalized Intersection Crossing without a Median Refuge[1]**

| Prevailing Speed or Speed Limit (mph) | Total Through/Turn Lanes Crossed (Both Directions)[2] | | | | | |
|---|---|---|---|---|---|---|
| | ≤ 3 Lanes | | | 4 -5 Lanes | | ≥ 6 Lanes |
| | Functional Class/ADT (vpd) | | | | | |
| | Local | Collector | Arterial | Arterial | | Arterial |
| | ≤ 1,200 | 1,200 - ≤3,000 | >3,000 | ≤ 8,000 | >8,000 | Any ADT |
| ≤ 25 | BLTS 1 | BLTS 1 | BLTS 2 | BLTS 3 | BLTS 4 | BLTS 4 |
| 30 | | BLTS 1 | BLTS 3 | BLTS 3 | BLTS 4 | BLTS 4 |
| 35 | | BLTS 2 | BLTS 3 | BLTS 4 | BLTS 4 | BLTS 4 |
| ≥ 40 | | BLTS 3 | BLTS 4 | BLTS 4 | BLTS 4 | BLTS 4 |

[1]For street being crossed.
[2]For one-way streets use Exhibit 14-12.

To 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 14-12 for one-way street applications.

Exhibit 14-12 has the maximum number of lanes a bicyclist encounters on each side of a median refuge. The presence of a median refuge generally implies a roadway with a substantial amount of traffic volume, so specific ADT values are not included in the exhibit, adding a median refuge of at least six feet in width (10 feet for BLTS 1 eligibility) will decrease the BLTS versus when a refuge is not present. The presence of turn lanes is also accounted for as they add conflict points and vehicle paths to the awareness needs.

**Exhibit 14-12 BLTS Criteria for Unsignalized Intersection Crossing with a Median Refuge[1]**

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

[1]For street being crossed.
[2]Refuge should be at least 10 feet to accommodate a wide range of bicyclists (i.e. bicycle with a trailer) for BLTS 1, otherwise BLTS=2 for refuges 6 to <10 feet.

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

Roundabouts

Calculation of the traffic stress at roundabouts will determine if bicyclists are expected to use a shared sidewalk that surrounds it or if they will ride in the vehicular lanes under mixed traffic conditions[3]. For a sidewalk to serve as a potential bicycling path, all the following criteria must be met. If both routes are possible, evaluate both options and use the lower stress option as the controlling BLTS.

For bicyclists to be expected to use a shared sidewalk, it must meet the following criteria:

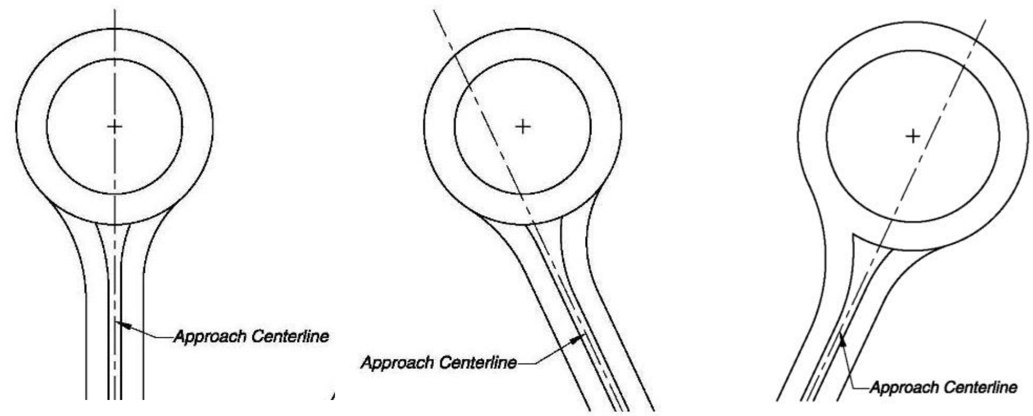
- Minimum six-foot clear width (allows slow-speed passing assuming no obstructions that would prevent a cyclist from riding close to the edge of the walkway).
- Offset from edge of circulating roadway to path crossing should be no more than 30' to minimize out-of-direction travel.
- Path geometry should have no turns greater than 90 degrees and allow a cyclist to see (without looking behind them) if it is safe to cross within 10' from the crossing (allows for minimum 5 mph travel speed).
- Separate bike ramps need to be provided to transition riders between the sidewalk and street (or bike lane) on entry and exit legs in a reasonably direct manner and provide a safe re-entry. If a single ramp is intended to provide both bicycle and pedestrian traffic, then it needs to be wider than the standard (8-10') pedestrian curb ramp.

A separate 8'+ path or sidewalk surrounding a roundabout will be normally BLTS 1 for the segments between the leg crossings. Narrower 6' sidewalks are BLTS 2 as it is more difficult to overtake pedestrians or bicyclists traveling in the same direction or allow opposing traffic to pass. Each of the roundabout leg crossings will need to be evaluated as that will be the source of traffic stress for bicyclists using the sidewalk crossing as shown in Exhibit 14-14. All the individual leg crossing BLTS's are compared, and the highest one will be used to represent the roundabout BLTS.

Leg crossings will generally control over the mixed traffic condition (check in Exhibit 14-6) except in cases where tangential legs are used, or higher volumes are present (See Exhibit 14-13b or c). Tangential legs occur when the approach centerline does not go through the roundabout center. These have little deflection in the vehicle path and results in much higher speeds through the pedestrian crossing. Most roundabouts should have non-tangential approaches as shown in Exhibit 14-13a. The highest BLTS from Exhibit 14-14 or Exhibit 14-16 will be used in this case.

[3] Furth, P. Level of Traffic Stress (LTS) Criteria for Roundabouts, Northeastern University, March 2014.

**Exhibit 14-13 Roundabout Approach Geometry**




gure from NCHRP Report 672, Roundabouts: An Informational Guide, 2nd Edition, Transportation Research Board, 2010.

**Exhibit 14-14 Roundabout Leg Crossing BLTS**

| Entry/Exit Type | Non-Tangential[1] | Tangential[1] |
|---|---|---|
| Single entry lane | BLTS 1 | BLTS 2 |
| Single exit lane | BLTS 1 | BLTS 3 |
| Dual entry lane | BLTS 1 | BLTS 3 |
| Dual exit lane | BLTS 3 | BLTS 4 |

[1]An exit/entry lane is tangential if a driver does not have to turn to the right when entering or exiting. This is a non-standard design.

If there is no adequate alterative path or sidewalk to use, then the bicyclist will need to use the vehicle lane under mixed traffic conditions through the roundabout. The BLTS is computed for these cases in Exhibit 14-6. Dual-lane roundabouts will always be BLTS 4 as these always have at least one multilane exit which sets up a potentially hazardous conflict between circulating bicyclists and exiting traffic from the inside lane. Partial two-lane roundabouts are considered to have two circulating lanes for the purposes of this methodology as stress level is controlled by the worst condition.

Right-turn bypass lanes outside of the roundabout (Exhibit 14-15a) should be considered as mixed traffic conditions as in Exhibit 14-6 or possibly Exhibit 14-7 for higher speed movements. Right-turn bypass lanes within the roundabout (Exhibit 14-15b) would be considered as right turn lanes as shown in Exhibit 14-9.

**Exhibit 14-15 Roundabout Bypass Lane Types**

a) Bypass Lane Outside of Roundabout    b) Bypass Lane Inside of Roundabout

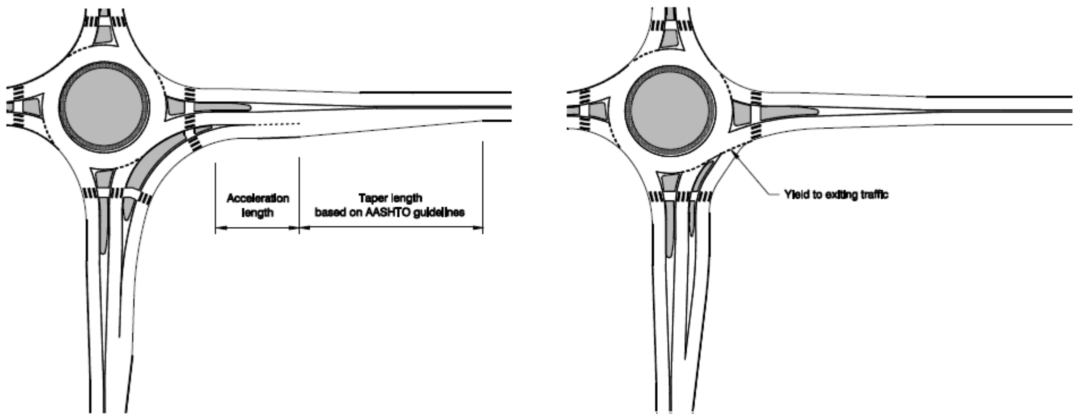



Figure from NCHRP Report 672, Roundabouts: An Informational Guide, 2nd Edition, Transportation Research Board, 2010.

**Exhibit 14-16 Roundabout Circulating BLTS**

| Number of circulating lanes | Total Entry Leg ADT (vpd) | LTS |
|---|---|---|
| 1 | ≤ 4,000 | BLTS 1 |
| 1 | 4,000 - ≤ 6,000 | BLTS 2 |
| 1 | >6,000 | BLTS 3 |
| 2+ (Partial or full) | Any | BLTS 4 |

Signalized Intersections

As signalized crossings usually do not create a barrier as the signal provides a protected way across, BLTS 1 is generally assumed for the crossing movements. Note that in the presence of turn lanes, this criterion generally will not control. Pretimed intersections and isolated or coordinated activated signalized intersections with working specific bicycle detection loops/ other activation technology will preserve the BLTS 1 rating. Signalized intersections do pose risks for right-turn “hook” crashes, however, especially where right turn lanes are not present.

At certain locations, bicyclists may have difficulty triggering the signal detection (where no specific bicycle detection is in place) or an intersection may not have the proper striping, ramps, and push button accommodations for bicyclists. These crossing locations force the bicyclist to use the crosswalk like a pedestrian instead and should be BLTS 2. Permissive left and right turns with or without turn lanes introduce conflicts as bicyclists are harder to see versus oncoming vehicles, so these will increase the crossing to BLTS 2. There may be other areas where engineering judgment is required in assigning stress levels higher than BLTS 1 at signalized intersections such as the combination of shorter phase length and longer crossing distances or complex geometry (e.g. more than four legs, high skews) which could push potentially to BLTS 3. The reasons for higher signalized BLTS levels should be documented. The presence of bike signals or regular and left-turn bike boxes may be a mitigating factor in higher-risk areas thus keeping the BLTS at 1.

### 14.4.7 BLTS Application Example

**Example 14-2 Level of Traffic Stress**

This example illustrates the use of BLTS 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 were quickly obtained by using available state highway inventory data and views from commercial aerial photos.

**Segment BLTS:**
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, use Exhibit 14-5. BLTS 3 for the two-lane major roadways (US20 and OR78) is based on the average daily traffic (3,300 for US20 and 2,600 for OR78), BLTS is 3 for the four-lane section of US20, and BLTS is 1 for the local streets (no marked centerlines).

**Approach BLTS:**
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 BLTS 4, see Exhibit 14-8. The adjacent shared left-through lanes on both approaches would have a BLTS of 2, but the BLTS 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 BLTS. The adjacent shared though-left lane would be BLTS 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 BLTS 2 will override the segment BLTS 1 value.

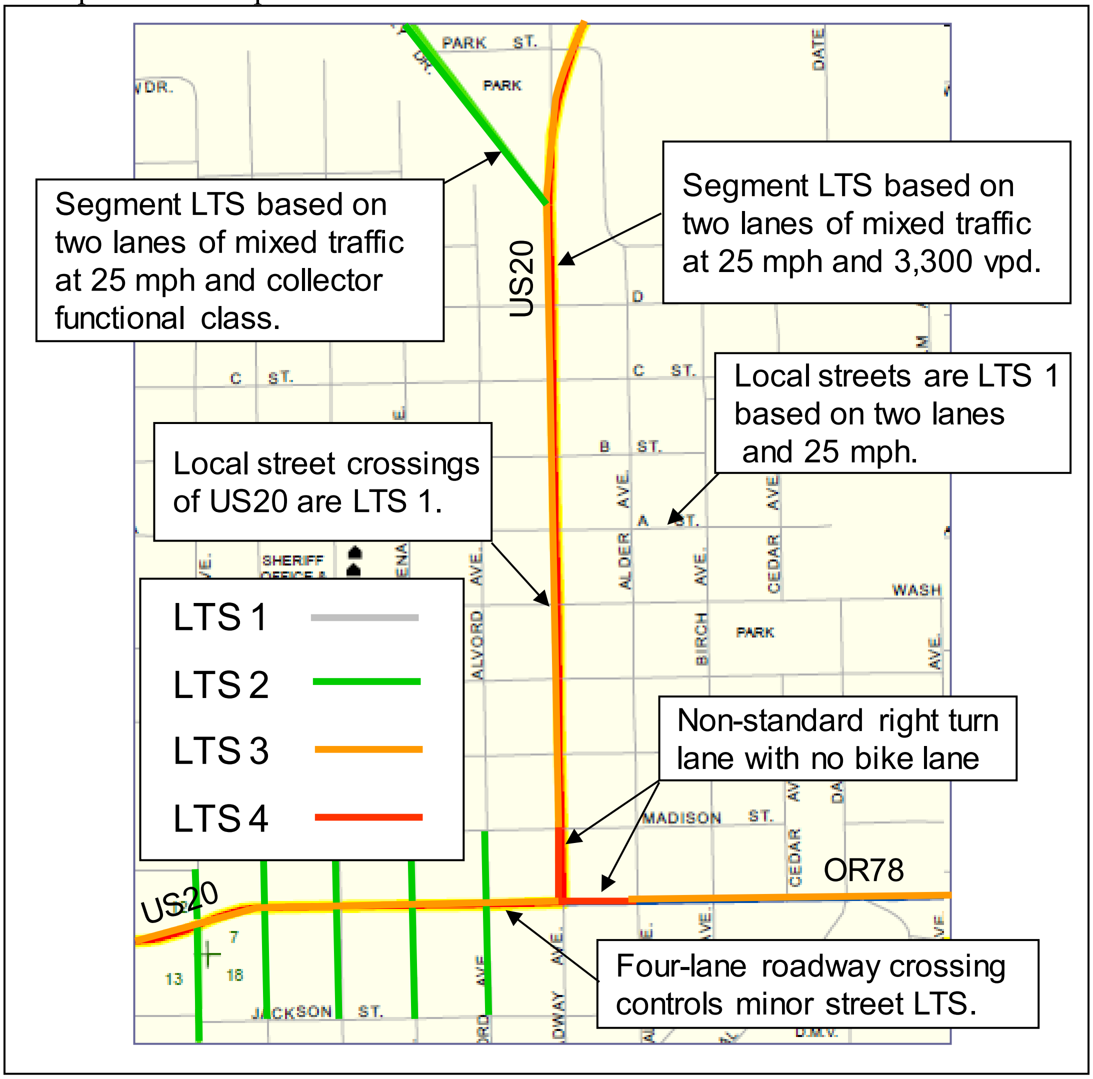
The eastbound approach has a left-lane drop lane where the left turn lane is a full block long with an adjacent through-right lane. Since mixed traffic conditions exist, the bicyclist would just move into the left turn lane. As seen in Exhibit 14-5, with ADT of 2600 and 25 mph speed, this would be BLTS 2, but the segment BLTS 3 level would still control.

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

**Summary:**
Since the highest BLTS controls, 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 BLTS 3 value. The resulting BLTS at the intersection can be seen in the figure below.

Most of the roadway system in the example is BLTS 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 BLTS 4, which most bicyclists will avoid. While the various parts of the city are generally well connected with BLTS 1 or BLTS 2 networks, it is easy to see the disconnect created along the primary arterials by the intersection of US 20 and OR 78.

Example BLTS Map




## 14.4.8 Rural Applications

The rural roadway environment is substantially different from the urban. High speeds are assumed, and vehicular operation is unpredictable as drivers are not expecting bicycles in or near the travel lanes. Paved shoulders when provided can narrow in guardrail sections and through bridges and tunnels creating higher potential conflict areas especially where volumes are higher. Gravel, cinders, and other debris is common in the shoulders which may limit their use and force the bicyclist to use the travel lanes. Given the geometric and operational differences, the rural bicyclist must be more aware and is likely higher stress tolerant than their urban counterpart. The BLTS rural nomenclature uses a “R” prefix to help set off the environmental difference, as an urban BLTS 2 is not the same experience as a rural BLTS R2 for the reasons above.

**Rural <45 mph**

While the original methodology was designed only for urban applications, it can also 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. BLTS will be primarily based on speed in these cases. Use the regular BLTS mixed traffic criteria shown in Exhibit 14-6 and Exhibit 14-7 for these roadways and Exhibit 14-11 through Exhibit 14-16 for intersections. Approach criteria will probably not be applicable because low volume roadways generally do not have turning lanes. Add the "R" suffix to designate a rural roadway to the BLTS values in the tables. Segment lengths should be defined between significant intersections/locations at a minimum.

**Rural ≥45 mph**

Application of the BLTS methodology to the typical higher-speed rural environment requires considering paved shoulder widths and volumes. Daily bi-directional (combined) volumes are necessary for this method. This can be AADT for initial scoping-level assessments, but most analyses should take seasonal adjustment into account especially for coastal and summer recreational routes as most bike travel occurs in the summer months. The normal BLTS methodology tops out at 40 mph, while most typical state and county rural roadways are posted at 45 - 55 mph; some eastern Oregon state highways have higher speed limits. Segment lengths would be ideally based on paved shoulder width and AADT volume bin changes in Exhibit 14-17 or between significant intersections at a minimum.

Interstate highways are a special case and while they typically have shoulders of 10' or more, the posted speed limits can be up to 70 mph, and high traffic and truck volumes are a normal occurrence making the overall environment not very inviting to cyclists. Rural Interstate highways are coded as BLTS R4. Where no parallel routes exist, (e.g. certain sections of I5 in southern Oregon and I84 in eastern Oregon) there is a need to create separated facilities instead of attempting to widen shoulders as that would likely have limited likelihood to increase use.

A large portion of 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 at any speed. Paved shoulders less than four feet in width are not considered rideable (even when clear of debris or obstacles) because there is effectively no opportunity to move out of the travel lane while riding on these segments. This is a high stress environment to ride in unless volumes are very low (<400 vehicles per day). Even with low volumes, a bicyclist is generally unable to move into the shoulder or could encourage unsafe/illegal close passing behavior.

Shoulders between four and six feet in width do allow riding in the shoulder continuously when clear of debris. The clear riding space may be constrained by debris or obstacles, but there is some space to navigate around occasional obstacles without leaving the shoulder. Where there is continuous debris, it is probably still physically possible to move out of the travel lane when vehicles approach. The shoulder may also pinch down for short segments (e.g. bridges), but there should generally be a wide enough shoulder approaching these pinch points that a bicyclist could wait in the shoulder for a gap in traffic before proceeding.

Shoulder width greater than six feet should generally provide room to ride and navigate around debris without leaving the shoulder, although it might require the bicyclist to get in closer proximity to the vehicular traffic. Shoulders greater than six feet can accommodate ODOT's common placement of rumble strips adjacent to the fog line, while still providing at least four feet of shoulder on the outside of the rumble strips. While rumble strips encroach on the clear rideable space, they also discourage cars from encroaching into the shoulder, which can improve bicyclist comfort.

Long-term debris in the shoulder (like leftover cinder from winter maintenance), limiting or preventing shoulder use, should be coded as no shoulder. However the true shoulder width (and resulting BLTS) should also be retained for documentation. Unless an adjacent separated multi-use path/bike lane is provided (BLTS R1), most rural roadways do not have bike lanes and bicyclists will depend on paved shoulders. Exhibit 14-17 shows the BLTS for typical rural conditions for higher speed rural roadways.

**Exhibit 14-17 BLTS Rural Segment Criteria with posted speeds 45 mph or greater[1,2,3]**

| Daily Volume (vpd) | Paved Shoulder Width | | |
|---|---|---|---|
| | **0 – <4 ft** | **4 - <6 ft** | **≥6 ft** |
| <400 | BLTS R2 | BLTS R2 | BLTS R2 |
| 400 - 1500 | BLTS R3 | BLTS R2 | BLTS R2 |
| 1500 - 7000[4] | BLTS R4 | BLTS R3 | BLTS R2 |
| > 7000 | BLTS R4 | BLTS R4 | BLTS R3 |

[1] Based on Figure 900-4 from the Highway Design Manual, 2025.
[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 may be needed to determine what impact this will have on the BLTS 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 BLTS by one, minimum BLTS R2.
[4]Over 1500 AADT, the Oregon Bicycle and Pedestrian Design Guide indicates the need for shoulders.

Rural high speed intersection crossing stress levels will be typically based on approach volumes and number of lanes (Exhibit 14-18). 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 for cyclists, the minimum BLTS is R2.

**Exhibit 14-18 BLTS for Unsignalized Rural Intersection Crossing with posted speeds 45 mph or greater[1]**

| Daily Volume (vpd) | ≤ 3 Lanes | 4 -5 Lanes | ≥ 6 Lanes |
|---|---|---|---|
| <400 | BLTS R2 | | |
| 400 - 1500 | BLTS R2 | | |
| 1500 - 7000 | BLTS R2 | BLTS R3 | |
| > 7000 | BLTS R3 | BLTS R4 | BLTS R4 |

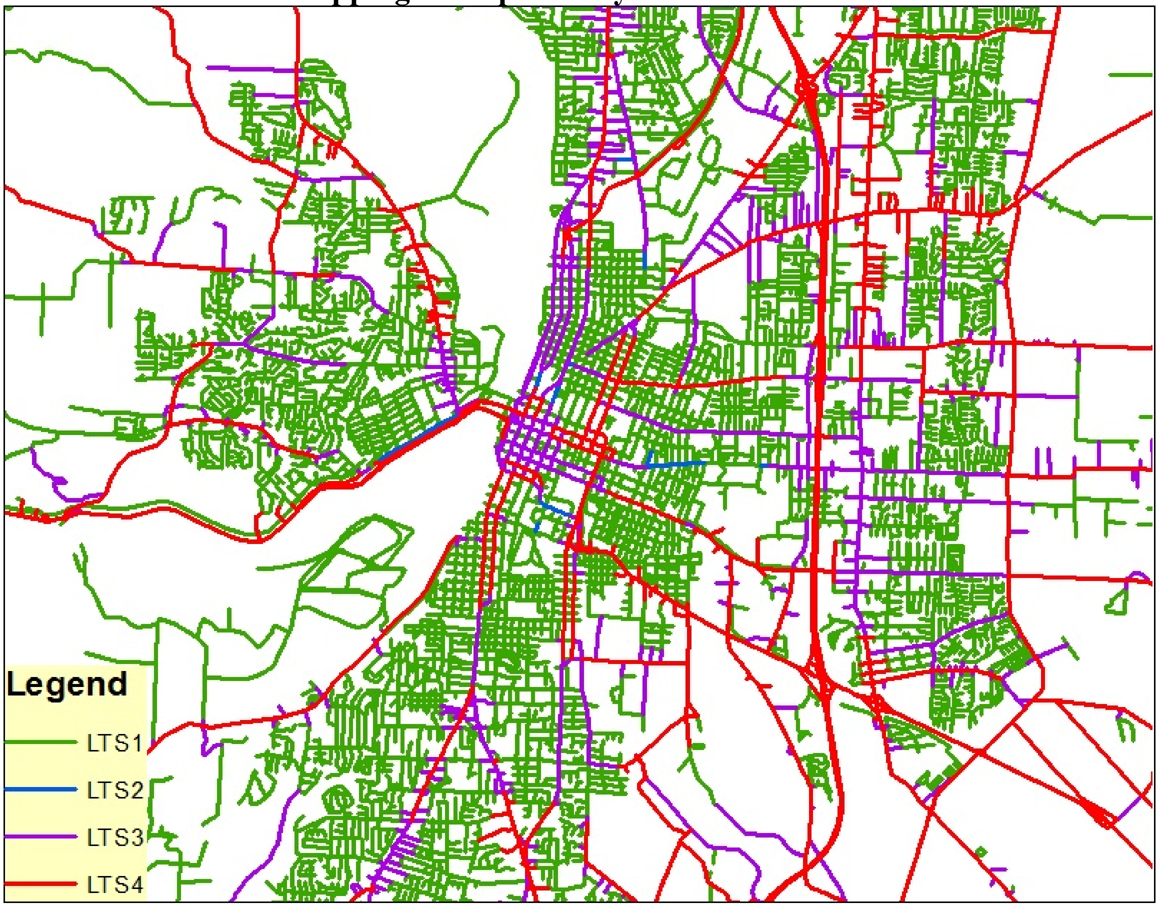
[1]For roadway being crossed.

For intersection approaches, the presence of left or right lanes will increase the BLTS 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.

### 14.4.9 Route Connectivity using BLTS

The BLTS 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 BLTS values exceeding a desired level that may then be targeted for improvements. Ideally, the displayed BLTS should be directional as it may differ on each side of a street. This will require some work with link offsets and layers to get this to show properly in GIS mapping software. Exhibit 14-19 shows an example of using BLTS showing the different stress levels. The high stress routes can easily be contrasted against the lower stress ones.

**Exhibit 14-19 BLTS Mapping Example – City of Salem[1]**

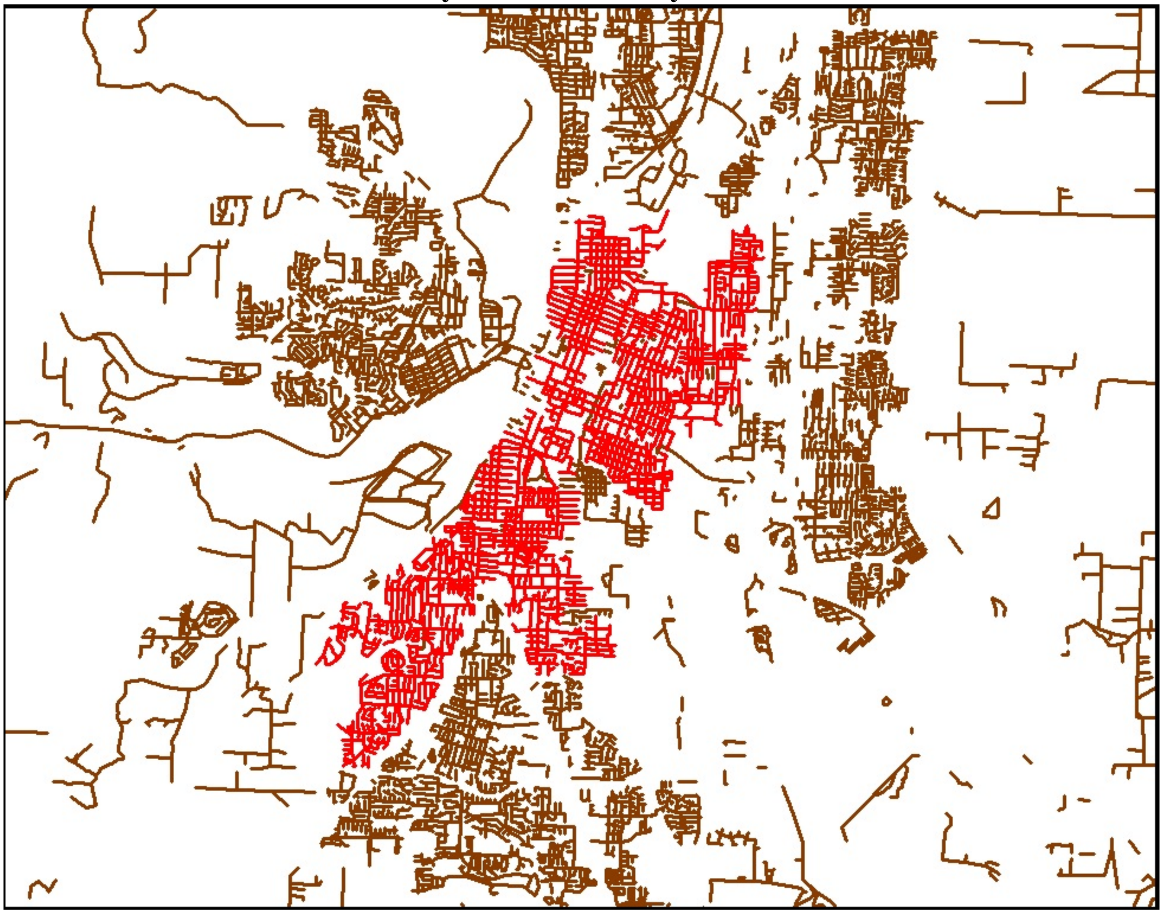



[1]Source: Haizhong Wong, Matthew Palm, Jonathan Mueller, Salem BLOS Application, OSU, 2012.

Another significant advantage of the BLTS methodology is that it allows the identification of connectivity “islands”, surrounded by higher BLTS 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 14-20 shows an example of mapping just the BLTS 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 14-20 BLTS Connectivity “Islands” – City of Salem[1]**



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

14.4.10 Specific Routes and Out-of-Direction Travel

Instead of tracking an entire jurisdiction/area of individual segments and crossings, the BLTS 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 BLTS of key links. For example, if a BLTS 4 crossing is located along a route where all segments are at BLTS 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 distance of 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 report[4], 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 approximately ¼ mile which represents about one and a half minutes of travel time at 10 mph[5]. 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:

$L_k/L_4 \leq 1.25$; OR
$L_k - L_4 \leq 1{,}430$ feet (0.27 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 BLTS 4 (but not including links where riding is prohibited).

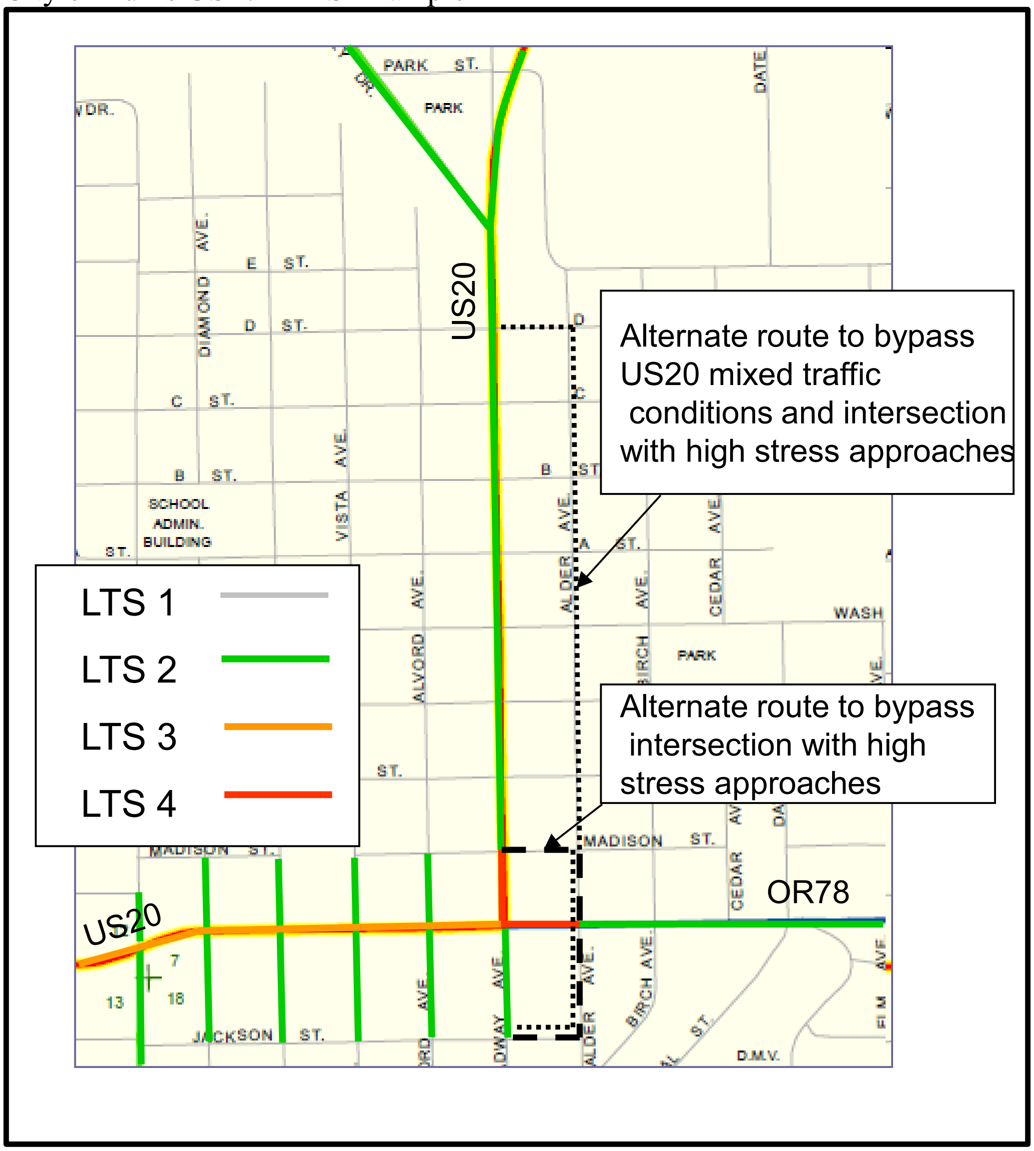
Note: Some routes with hills or many stops (or any of the previously mentioned additional considerations) may decrease desirability even though the criteria above are met.

[4] Low-Stress Bicycling and Network Connectivity, Mekuria, Furth, & Nixon, Mineta Transportation Institute, May 2012, pp14-15.
[5] Understanding and Measuring Bicycle Behavior: A Focus on Travel Time and Route Choice, Dill & Gliebe, Portland State University, December 2008.

## Example 14-3 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 BLTS 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 1,430 feet, the overall extra trip distance as a proportion of the total is not, as 1300 feet/700 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

BLTS 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 feet/2,650 feet is 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.

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### 14.4.11 Additional Comfort Measures

Some rider factors are better classified as "level of comfort" than a stress-based measure as they do not directly affect the bicyclist's position on the bicycle facility or the general proximity to adjacent motor vehicle speeds and volumes. These comfort measures can be used as a "tiebreaker" in areas where the overall BLTS is generally the same to introduce nuance, where local input has indicated that it is not the same riding experience throughout that area. These measures could also be used to analyze off-street facilities such as multi-use and greenway paths as they are generally not subject to the motor vehicle spacing, speed, and volume stress factors (generally coded as BLTS 1).

These also can be used for additional detail that can be layered as considerations for the existing or future conditions or when identifying solutions or prioritizing improvements. These measures are optional to the overall method as they will increase the overall data collection needs but could be mostly done through evaluation of aerial mapping products and some "windshield" field observations. The measures are coded similarly to BLTS as they go from 1 to 4 with 1 being the best with an average condition on a segment controlling as these comfort levels will vary depending on the segment length. Longer segments may benefit from breaking into smaller pieces if conditions vary greatly or if it is difficult to establish a general average condition. None of the individual measures control over the others. While general guidance is provided below on categorizing comfort measures, these by their nature will be qualitative or judgment based. There should be explanation or documentation of any assumptions or conditions that are used to create these measures.

**Surface Condition**

One of the most important factors after vehicular volume, speed, and separation is surface condition. Poorly maintained pavement or debris (e.g. wet leaves, gravel) or even frequent ponding on rainy days can be a deterrent to cycling on a particular route especially for less confident riders. Poor surface conditions require more attention to the wearing surface rather than surrounding traffic by the bicyclist to maintain their position and speed. If conditions are such that they must move into the adjacent buffer or travel lane, this will create significant discomfort and potential hazards.

Drainage grates or gutter pan sections that are set lower than the pavement surface or if the grates lack transverse bars represent potential hazards for the bicyclist. Gutters can also present hazards if they are non-uniform in width and/or cross-slope, either due to settlement or by design, which could impede into the bike lane or shoulder.

Gutters and drainage grates can also collect debris such as leaves, pinecones, and leftover sand/cinders which can be a hazard if it builds up without regular maintenance sweeping. Wet leaves can be as slippery as ice and sand/cinders can also make riding difficult and even puncture tires. Built-up debris can also block inlets which can cause ponding during rain events which can extend across a bike facility or down a block for an extended distance. Ponding can also be caused by settlement or upheaval of the gutter or curb which could also be a debris collection location during drier periods. Debris and ponding both can obscure the view of the underlying pavement conditions which could mask additional hazards such as potholes.

Railroad/light-rail/streetcar tracks crossing, or along paved roadways also create potential hazards of dropping a wheel into the flangeway which could cause a fall if they are not crossed at or near 90 degrees. Manhole, meter, and valve covers in addition to pavement joints/patches can create slippery conditions when wet or can create unexpected bumps or riding hazards if pavement is raised or settled.

Pavement condition classification and pictures in Exhibit 14-21 and summarized in Exhibit 14-22 are based on the Good-Fair-Poor Pavement Condition Manual and the Pavement Distress Survey Manual from the ODOT Pavement Services Unit. The comfort levels can be used as-is for the evaluation of existing conditions. For future no-build or build conditions, the comfort level should be based on the pavement condition only as debris coverage and occurrence will be generally unknown, and seasonally variable unless there is knowledge of maintenance practices for the facility or local area. When the width of the facility also incorporates the width of a gutter pan, the condition of the gutter also needs to be considered.

**Exhibit 14-21 Pavement & Debris Rating**

S1 – New pavement which includes a very smooth surface with no cracking/roughness/patching or faulting. No debris in the bike facility or outside travel lane/shoulder (for mixed conditions). Bicycle facility-related striping should be clean, new, and complete. Transitions from the paved surface to the gutter pan should be smooth and with consistent cross-slopes.

S2 – Good pavement which includes smooth surfaces with minor hairline cracking/occasional patching evident but with smooth transitions and negligible differential settlement of curbs or gutters. Striping should be complete and well visible with little wear. Occasional debris in the bike facility or shoulder with no more than 25% coverage by area which can be avoided without moving into an adjacent buffer or travel lane no more than a couple times per city block or no more than 20 times in a mile in a rural segment.

.

S3 – Fair pavement which includes minor cracking, some patching/sealing/cold jointing evident or some raveling/spalling /rough areas. The cross-slope may be uneven with inconsistent transitions. Frequent transitions with differing surface wearing course changes (i.e. different pavement types or subtypes such as chip seal, open graded aggregate, etc.) or where the bicycle facility crosses over valve, meter or manhole covers may be evident. Striping is well-worn and in need of repainting and may be missing in small areas. Some debris in the bike facility or travel lane/shoulder with no more than 50% coverage by area which may require repositioning to the outer edge of the bikeway or occasionally into the adjacent buffer or travel lane more than a few times per segment (i.e. 3-4 instances per city block or 30-40 instances per rural mile). Evidence or observation of less than 50% coverage of the facility by runoff pounding during moderate or heavy rain events, due to inadequate drainage.

S4 – Poor pavement which includes potholes, large cracks (e.g. alligatoring), heavy raveling with loose aggregate, broken/lifted slabs, spalling, and generally has rough riding. There could be evidence of saw cuts or significant patching in the bicycle wheel path, overall uneven patching, noticeable differential settlement (e.g. resulting from tree roots), or poorly constructed joints. Bicycle facility striping is heavily worn or completely/partially missing. Frequent debris in the bike lane/shoulder with 75% or more covered by area requiring movement into the adjacent buffer or travel lane for most of the segment distance. Evidence or observation of more than half of the width of the facility covered by runoff pounding during moderate or heavy rain events, due to inadequate drainage.

**Exhibit 14-22 Surface Condition Comfort Measure**

| Comfort | Surface Condition | Debris/Obstacles |
|---|---|---|
| S1 | New | None |
| S2 | Good | Occasional |
| S3 | Fair | Some |
| S4 | Poor | Frequent |

Built Environment

The overall built environment can either enhance or degrade the overall biking experience. Higher use can increase driver expectations and improve driver behaviors around bicyclists while environments that are less conducive to riding such as in noisy heavy industrial areas with lots of large trucks or commercial areas with lots of driveway accesses and related conflicts can dampen the desire to travel on certain routes. Exhibit 14-23 shows typical built environment/ land uses and related bicycle comfort measures.

**Exhibit 14-23 Built Environment Comfort Measure**

| Comfort | Overall Environment |
|---|---|
| BE1 | Residential, central business districts, neighborhood commercial areas, parks/ public facilities, offices/office parks |
| BE2 | Rural subdivisions, unincorporated communities, small-scale strip commercial, mixed employment areas |
| BE3 | Light/medium industrial, auto-oriented (big-box) commercial |
| BE4 | Heavy industrial, truck-oriented facilities, interchange areas |

**Grade**

Grades can easily deter bicycle riders from certain routes or even using the bicycle mode if the alternative route has a higher level of discomfort than the rider can tolerate or has too much out-of-direction travel (see Section 14.4.9). Not all will want to walk their bike uphill assuming that there are adequate pedestrian facilities available or have access to an e-bike which can improve comfort to an acceptable level. Some areas will have all usable routes affected by grades of varying intensity, so the overall effect will be relative especially in terms of an individual's fitness level. Long periods of shallower grades may have more of an effect on the rider than shorter steeper portions on a segment. Exhibit 14-24 shows the grade comfort measure and related descriptions.

**Exhibit 14-24 Grade Comfort Measure**

| Comfort | Grade Description |
|---|---|
| G1 | Level to slight grades, 0-3%, little to no exertion by average user needed over long periods, acceptable by all |
| G2 | Moderate grade/rolling, 4-6%, some exertion by average user needed, will require downshifting to lower gears, will cause fatigue over long periods, e-bike assist optional |
| G3 | Steep grade, 7- 9%, significant exertion needed by average user, likely requires lowest gears for most riders, e-bike assist helpful but likely required for beginning cyclists |
| G4 | Very steep, 10%+,, extensive exertion required for any period of time, likely will require average user to walk bicycle, e-bike assist/or throttle-equipped use required |

**Illumination**

Illumination or lighting levels (i.e. luminaire presence) can either improve or diminish the overall comfort of the riding experience. Adequately lit roadways and other bicycle facilities such as multi-use paths increase visibility and improve safety such as from motor vehicles on a roadway or from pedestrians if on a path. Illumination may also allow greater use of a facility into the evening or night hours. Exhibit 14-25 shows the illumination comfort measure and related condition descriptions.

**Exhibit 14-25 Illumination Comfort Measure**

| Comfort | Illumination Condition |
|---|---|
| I1 | Full coverage, no dark areas; luminaires on corners and midblock locations, or pedestrian-scale lighting present |
| I2 | Limited coverage, some/occasional dark areas, luminaires on corners only |
| I3 | Ambient/indirect coverage from adjacent buildings or parking lots, frequent dark areas, scattered/occasional luminaires |
| I4 | No coverage, ambient light only, generally dark |

**Example 14-4 Comfort Measures**

A small city as part of its transportation system plan, had been evaluated for BLTS. One east-west district highway corridor was identified to need a closer look. The BLTS was the same (BLTS 2) throughout the corridor, but residents didn't feel that it was the same conditions both east and west of the main north-south highway given their experiences. The BLTS comfort measures were evaluated to see if any additional nuance could be added to the evaluation.

Surface Condition

Upon review of street-level imagery, the western segment has no bike facility or curbs, so shared lane use is present. The pavement where bikes would typically ride has is worn with some crack repairs, with some debris and ponding noted. The eastern segment is mostly curbed with no bike facilities but has some paved surface where a bicyclist could potentially travel outside of the travel lanes. The eastern segment surface condition has a rough surface with worn striping with numerous patching and crack repairs along with settling/longitudinal cracking on the edges and transitions with the wider paved areas. Significant debris is noted in the curbed areas and evidence of past ponding in the uncurbed sections. Using Exhibits 14-21 and 22, the western segment was determined to be most representative of fair conditions and coded as S3. The eastern segment has notably poorer pavement and surface conditions, so it was coded as S4.

Built Environment

Upon review of street-level and aerial imagery, the western segment is a mix of small commercial businesses, light industrial and some residences. The eastern segment is primarily residential. Using Exhibit 14-23, the western segment appears to have elements of the BE1 and BE3 classifications, however the smaller community context means that coding it at BE3 would likely be too intensive, so an average condition was set at BE2. The eastern segment was coded at BE1 since it is representing a residential zone.

Grade

Upon review of percent grade information, it was determined about half of the western segment had grades of 4-5 % with the rest at 0-3%. The eastern segment was all at 0-3%. Using Exhibit 14-24, the western segment was coded at G2 as there will be some exertion required in that section over what would be needed for the rest of the corridor (G1).

Illumination

Upon review of street-level imagery, luminaires were noted to be on corners only, with no additional ones in the middle of long blocks for both segments. This will mean that there will be illuminated intersections, but with periods of darkness only illuminated from ambient/indirect coverage from adjacent residences. Following Exhibit 14-25, both segments were coded I2.

Summary

Overall, the western segment has more challenging conditions for grades and overall driver expectancy in a more intensive built environment even though surface conditions were noted to be better than the eastern segment as shown in the table below. Bicyclists on the western segment would experience more overall discomfort than the eastern segment but may have to watch the pavement/surface conditions more for the eastern segment as they are worse.

| Comfort Measure | West Segment | East Segment |
|---|---|---|
| Surface Condition | S3 | S4 |
| Built Environment | BE2 | BE1 |
| Grade | G2 | G1 |
| Illumination | I2 | I2 |

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### 14.4.12 Solutions to Decrease BLTS Level

There are several ways to lower stress levels and to achieve a desired BLTS level on a segment, approach, or crossing. For more detail on these solutions, please refer to the ODOT Traffic Manual and the ODOT Highway Design Manual. A few examples (not exhaustive):

- Adding bike lanes, preferably buffered, and low-speed bike boulevards.
- Creating segregated bike facilities such as separated bicycle lanes or multi-use/shared paths.
- Safety measures in design, such as couplets, medians, or pedestrian refuges. If four lanes of vehicular capacity are still needed, then investigate whether a couplet may 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 roadway reconfiguration.
- Install road markings and way-finding signs.
- Addition of flashing pedestrian activated beacons (PABs) or mid-block pedestrian hybrid beacons (PHBs) 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 two-stage left-turn bike boxes
- Adding bike signals to clarify bike movements.
- Reducing speeds, enforcement of speeds limit or education about speed.

## 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 facilities[6]. 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)[7]. 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 evaluate 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 those 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 needed data is collected routinely and some of the PLTS data collection 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

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[6] A non-motorized form of transportation refers to vehicles that would not use the roadway to travel on a roadway.

[7] 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.

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

For state highways, a good portion of the data needed are 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 is 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 (WhMD[8]). 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

[8] 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 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.

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 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 most users. Higher stress levels may be acceptable in limited areas depending on the land use, population types, and roadway classifications, but they will generally not be comfortable for most users. Each land use has specific needs for the pedestrian network and study areas should have multiple targets for the different areas.

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

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

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

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

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 several 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:

Sidewalk[9] 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.

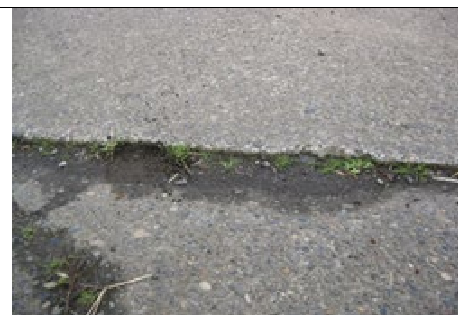
Sidewalk Condition: The sidewalk condition is a visual high-level classification process (see Exhibit 14-26). Sidewalk condition can vary within a block segment. Use the worst sidewalk condition, as a section of poor sidewalk can block some users from using the facility.

[9] 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.

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 that is smooth with only minor cracking, but has a very large fault caused by a tree root, 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 must be in the "Fair" category. For a sidewalk to be considered "Good"' all the criteria must be met, and it must be of relatively new construction. Additional examples are 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 currently. Analysts will need to field verify sidewalk sections marked as "Poor" to ensure that there are no "Very Poor" sections within them.*

**Exhibit 14-26 Sidewalk Condition Rating**

| Rating | Facility Properties | Example |
|---|---|---|
| **Good** | • No minor cracking<br>• No patching or raveling and has a very smooth surface<br>• No faulting<br>• New construction |  |
| **Fair** | • Minor cracking (generally hairline)<br>• Minor patching and possibly some minor raveling evident. Surface is generally smooth<br>• Minor faulting (less than ¼”) |  |
| **Poor** | • Minor cracking in several locations<br>• Rough areas present but not extensive<br>• Faulting may be present but less than ½” (No major faulting) |  |
| **Very Poor** | • Major cracking patterns<br>• Rough conditions (major deterioration, raveling, loose aggregate, missing pavement, etc.)<br>• Faulting greater than ½” |  |
| **No sidewalk** | • 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. |  |


<u>Physical Buffer Type</u>: 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 five major groups. This area is also referred to as the furniture or planter zone.

*No Buffer*: The narrower sidewalk (<10 feet 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 heathy growing and sight distance is not limited. This buffer type tends to be wider than a regular landscaped buffer and 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. Private probe speed data are a good source for prevailing speeds (See Chapter 3). If prevailing speed data are 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 or 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. The segment length default for urban areas would typically be on a block-by-block basis but could be defined on a larger scale if desired. A trade-off for longer segment lengths will be a loss of detail which could make it harder to determine the controlling worst condition (e.g. a missing section may not have the same influence in a longer segment versus the default length).

### 14.5.6 PLTS 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 that 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. Refer to the ODOT Highway Design Manual for more information.

Exhibit 14-27 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. A sidewalk needs to have at least six feet of space with no obstructions, like signs and poles, to be eligible for the effective width. 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 14-27 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. For example, a seven-foot sidewalk in fair condition would be eligible for a PLTS 2 as the actual width is greater than five feet, but if the effective (or clear) width was judged to be at least six feet then PLTS 1 would be used. A PLTS 1 sidewalk must be accessible to all users, have six effective feet or wider path, and in good or fair condition.

However, in-sidewalk obstructions will impede disabled users if the clear width is less than five feet, so use the corresponding actual width rows to determine the PLTS. Given the same seven-foot fair condition sidewalk above, if the effective (clear) width was only three feet because of a building column then PLTS 4 would be used.

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 14-27 PLTS based on Sidewalk Conditions [1,3]**

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

[1]Can include other facilities such as walkways and shared-use paths
[2]Effective width is the available/useable area for the pedestrian clear of obstructions. Does not include areas occupied by store fronts or curb side features.
[3]Consider increasing the PLTS one level higher (Max PLTS 4) for segments that do not have illumination. Darkness requires more awareness especially if sidewalk is in fair or worse condition.
[4]Effective width should be proportional to volume as higher volume sidewalks should be wider than the base six feet. Use a minimum PLTS 2 for higher volume sidewalks that are not proportional (include documentation).

### 14.5.7 PLTS 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 increased pedestrian sense of security, sidewalks that stay level over driveways, and improved drainage. Exhibit 14-28 shows stress levels associated with varying buffer types.

**Exhibit 14-28 PLTS based on 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<br>Vertical | PLTS 1 | PLTS 1 | PLTS 1 | PLTS 2 |

[1]Combined buffers: If two or more of the buffer conditions apply, use the most appropriate, typically the lower stress level.
[2]If street furniture, street trees, lighting, planters, surface change, etc. are present then the PLTS can be lowered to PLTS 1.

### 14.5.8 PLTS Total Buffering Width Criteria

Exhibit 14-29 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 14-29 PLTS based on 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 |

[1]Total 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.
[2]Sections 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.

### 14.5.9 PLTS 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 vehicle oriented have lower driver expectations for pedestrians so yielding behaviors are much less likely. Exhibit 14-30 groups typical land use types and the land use contexts used in the ODOT Highway Design Manual by PLTS level with more pedestrian-friendly walkable areas getting better PLTS levels.

If the PLTS analysis will be covering existing or future no-build conditions, then the General Land Use criteria should be included to fully show the impacts to the pedestrians. If alternatives are being analyzed, then this criterion **should not** be included if additional targets are not identified. This will avoid accidentally eliminating the benefits of a solution due to the overall land use not changing. However, this criterion can be included for large-scale alternatives/developments that do change the overall land use.

Impacts of this criterion can be mitigated by identifying additional desired target levels as mentioned in Section 14.5.3. For example, PLTS 3 could be identified as the target for commercial and industrial areas reflecting the surrounding land use while lower targets are in use in commercial and residential areas. Even PLTS 4 could be acceptable as a target for small areas that are difficult to mitigate like in interchanges and heavy industrial areas. The PLTS 4 target in this case should be noted that it is for land use, and not used to legitimize missing or substandard facilities.

**Exhibit 14-30 PLTS based on General Land Use**

| PLTS | Overall Land Use | HDM Land Use Context |
|---|---|---|
| PLTS 1 | Residential, central business districts (CBD), neighborhood commercial, parks and other public facilities, governmental buildings/plazas, offices/office parks | Traditional Downtown/CBD<br>Urban Mix<br>Residential Corridor |
| PLTS 2 | Low density development, rural subdivisions, un-incorporated communities, strip commercial, mixed employment | Suburban Fringe<br>Rural Community |
| PLTS 3 | Light industrial, big-box/auto-oriented commercial | Commercial Corridor |
| PLTS 4 | Heavy industrial, intermodal facilities, freeway interchanges | |

### 14.5.10 PLTS 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 must 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 are 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 14-31 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 14-34 or Exhibit 14-35. If a collector-level roadway has more than two lanes or is one-way, then Exhibit 14-34 or Exhibit 14-35 should be used.

Unsignalized crossings at intersections or mid-block on functionally classified minor/major/principal arterial roadway sections should use Exhibit 14-32 for crossings without pedestrian median refuges. Sections with pedestrian refuge islands or are one-way should use Exhibit 14-34 and Exhibit 14-35. 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 14-33 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 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 14-31 through 14-35. Unlit crossings require more awareness by the pedestrian as they are harder for drivers to see and/or expect in darkness.

**Exhibit 14-31 PLTS on 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 |

[1]For street being crossed.
[2]Minimum PLTS 3 when crossing lacks standard ramps.
[3]Use Exhibit 14-34 or Exhibit 14-35 for one-way streets, when ADT exceeds 5,000, or total number of lanes exceeds two.
[4]Street may be considered a one-lane road when no centerline is striped and when oncoming vehicles commonly yield to each other.
[5]Refuge should be at least 10 feet for PLTS 1, otherwise use PLTS 2 for refuges 6 to <10 feet.

**Exhibit 14-32 PLTS on 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 |

[1]For street being crossed.
[2]Minimum PLTS 3 when crossing lacks standard ramps.
[3]For one-way streets, use Exhibit 14-34 and Exhibit 14-35. Use PLTS 4 for crossings of four or more lanes.
[4]Use these columns when ADT volumes are not available

**Exhibit 14-33 PLTS Adjustments for Arterial Crosswalk Enhancements[1]**

| Treatment[2] | Adjustment | Treatment | Adjustment |
|---|---|---|---|
| Markings[3] | -0.5 | In-street signs | -1.0 |
| Roadside signage[3] | -0.5 | Curb extensions | -0.5 |
| Illumination | -0.5 | Raised crosswalk | -1.0 |
| PAB (e.g. RRFB) | -1.0 | Standard 12" flashing beacon | -0.5 |

[1]2.0 Maximum reduction or PLTS 2. Not intended for application at roundabouts.
[2]Pedestrian hybrid beacons (PHB) are equivalent to signalized crossings.
[3]Not applicable for roadways with pedestrian median refuges as crosswalk markings and roadside signage assumed as part of the basic installation.

**Exhibit 14-34 PLTS 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 |

[1]For street being crossed.
[2]Minimum PLTS 3 when crossing lacks standard ramps.
[3]Refuge should be at least 10 feet for PLTS 1, otherwise use PLTS 2 for refuges 6 to <10 feet.
[4]Use these columns when ADT volumes are not available.

**Exhibit 14-35 PLTS 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 |

[1]For street being crossed.
[2]Minimum PLTS 3 when crossing lacks standard ramps.
[3]Refuge should be at least 10 feet for PLTS 1, otherwise use PLTS 2 for refuges 6 to <10 feet.
[4]Use 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. These also include midblock crossings with regular or PHB-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 where a pedestrian is not shielded or could wait,
  - No standard ramps,
  - Excessive crossing distance (>72'): more than six total lanes or lane equivalents such as allowances for parking, bike facilities, or painted medians 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.*

### 14.5.11 Results

Mapping the PLTS for a community is a typical result from the analysis and can be readily done using GIS. Ideally, the displayed PLTS should be directional as it may differ on each side of a street. This will require some work with link offsets and layers to get this to show properly in GIS mapping software. 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.

### 14.5.12 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, and the ODOT Traffic Manual. The ODOT Highway Design Manual includes design considerations for pedestrian facilities. A few examples of actions that can reduce PLTS:

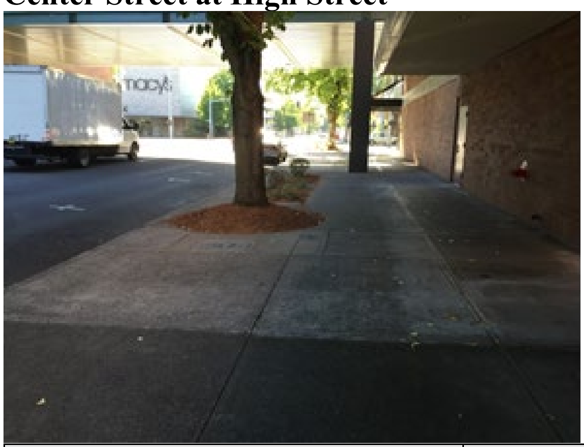
- Install pedestrian facilities, or expand facilities where pedestrian routes exist
- Create paved surfaces where there are trails or worn paths are evident
- Improve the condition of the sidewalk, including limiting vertical change and smoothing the surface
- Upgrade sidewalk ramps to current standards
- Infill gaps in sidewalk to create connectivity
- Redesign roadway to include wider or buffered sidewalks
- Create a multi-use path on a high-speed roadway
- Significantly change the roadway character and reduce speed limit

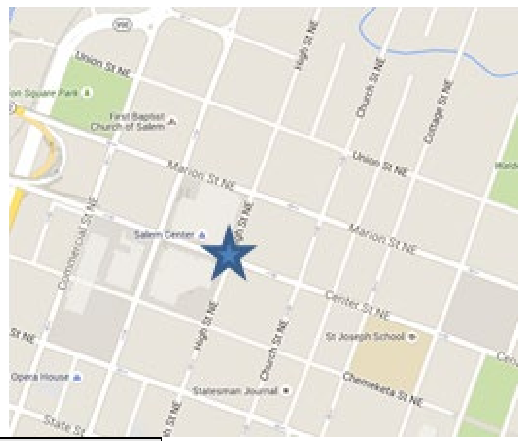
- Install additional crossing enhancements at unsignalized crossings (e.g. beacons, lighting, curb extensions)
- Remove barriers to connectivity
- Redesign buffer to include trees, large vegetation, and/or street furniture
- Land use changes over time to encourage more pedestrian-scale developments

**Example 14-5 Pedestrian Level of Traffic Stress**

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

**Center Street at High Street**






| Street Name | | Center St at High St |
|---|---|---|
| **Sidewalk** | Condition | Fair |
| | Width (ft) | 6+ |
| **Buffer** | Width (ft) | 6 |
| | 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** | **Referring to:** |
|---|---|---|
| Sidewalk Condition | PLTS 1 | Exhibit 14-21 |
| Physical Buffer Type | PLTS 1 | Exhibit 14-22 |
| Total Buffering Width | PLTS 1 | Exhibit 14-23 |
| General Land Use | PLTS 1 | Exhibit 14-24 |
| **Final PLTS** | **PLTS 1** | |

If a mid-block crossing of Center Street were 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**

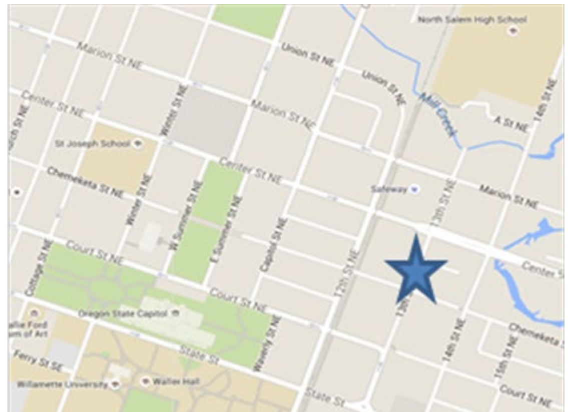
| Street Name | | Chemeketa St. between Capitol St & 12$^{th}$ St |
|---|---|---|
| **Sidewalk** | Condition | Good |
| | Width (ft) | 5 |
| **Buffer** | Width (ft) | 10 |
| | Buffer Type | Landscaped with trees |
| **Bike Lane** | Width (ft) | 0 |
| **Parking** | Width (ft) | 15 |
| **Roadway** | Number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

Chemeketa Street serves as a low volume street connecting 12$^{th}$ 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 & 12$^{th}$ St | Referring to: |
|---|---|---|
| Sidewalk Condition | PLTS 2 | Exhibit 14-21 |
| Physical Buffer Type | PLTS 1 | Exhibit 14-22 |
| Total Buffering Width | PLTS 1 | Exhibit 14-23 |
| General Land Use | PLTS 1 | Exhibit 14-24 |
| **Final PLTS** | **PLTS 2** | |

If the adjacent intersection at 12$^{th}$ and Chemeketa were added to the segment, as would be done if a route was being investigated, the segment PLTS would not change. 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**

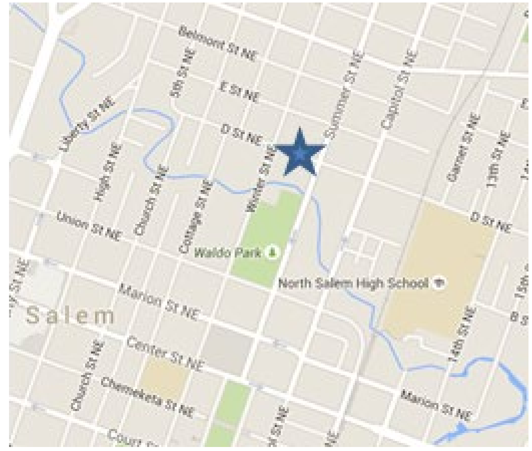



| Street Name | | 13th St at Chemeketa St |
|---|---|---|
| **Sidewalk** | Condition | Good |
| | Width (ft) | 5 |
| **Buffer** | Width (ft) | 4 |
| | Buffer Type | Landscaped with trees |
| **Bike Lane** | Width (ft) | 0 |
| **Parking** | Width (ft) | 0 |
| **Roadway** | Number of Lanes | 2 |
| | Posted Speed (mph) | 25 |
| **Land Use** | Type | Office/Residential |
| **Total Buffering Width (ft)** | | 4 |

13th Street at Chemeketa Street is 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 | Referring to: |
|---|---|---|
| Sidewalk Condition | PLTS 2 | Exhibit 14-21 |
| Physical Buffer Type | PLTS 1 | Exhibit 14-22 |
| Total Buffering Width | PLTS 2 | Exhibit 14-23 |
| General Land Use | PLTS 1 | Exhibit 14-24 |
| **Final PLTS** | **PLTS 2** | |

**D Street between Summer Street and Capitol Street**




| 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 |

D Street between Summer Street and Capitol Street is located on the edge of downtown Salem 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 | Referring to: |
|---|---|---|
| Sidewalk Condition | PLTS 2 | Exhibit 14-21 |
| Physical Buffer Type | PLTS 3 | Exhibit 14-22 |
| Total Buffering Width | PLTS 2 | Exhibit 14-23 |
| General Land Use | PLTS 1 | Exhibit 14-24 |
| **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.

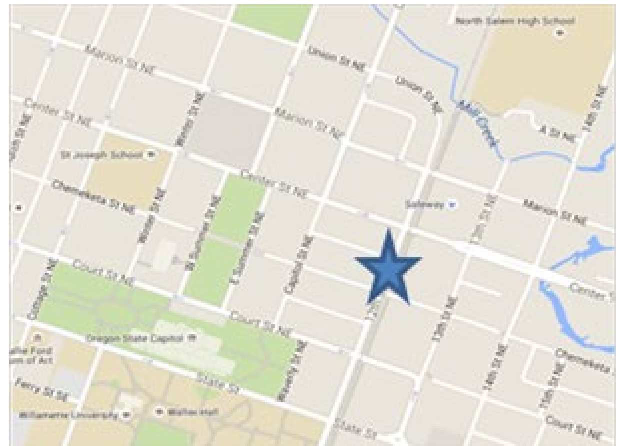
**Chemeketa Street at 14th Street**

| **Street Name** | | **Chemeketa St at 14th 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 14th St** | **Referring to:** |
|---|---|---|
| Sidewalk Condition | PLTS 4 | Exhibit 14-21 |
| Physical Buffer Type | PLTS 1 | Exhibit 14-22 |
| Total Buffering Width | PLTS 2 | Exhibit 14-23 |
| General Land Use | PLTS 1 | Exhibit 14-24 |
| **Final PLTS** | **PLTS 4** | |

**12th Street between Marion Street and Center Street**

| Street Name | | 12th 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 | 12th St at Center St | Referring to: |
|---|---|---|
| Sidewalk Condition | PLTS 4 | Exhibit 14-21 |
| Physical Buffer Type | PLTS 3 | Exhibit 14-22 |
| Total Buffering Width | PLTS 4 | Exhibit 14-23 |
| General Land Use | PLTS 2 | Exhibit 14-24 |
| **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.

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## 14.6 Multimodal Level of Service

The Level of Service (LOS)–based methods presented in this section 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, those types 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.

The full MMLOS methods as published in the HCM (Urban Street Method) have issues with being overly data-intensive. The following ODOT modified versions of MMLOS analysis are to be used. Some of these are simplified versions of the HCM methods which eliminate the onerous parts of the calculations, while others provide more specific procedures, default values and/or tools. Exhibit 14-36 summarizes the ODOT MMLOS methods including the APM sections and calculators for each.

**Exhibit 14-36 ODOT Multimodal Level of Service Methods in the APM**

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

## 14.7 Re-estimated Pedestrian & Bicycle Link Level Methodology Application

The pedestrian and bicycle procedures in Sections 14.9 to 14.12 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 several 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.

## 14.8 Link Level Pedestrian & Bicycle LOS Criteria

LOS scoring threshold criteria for pedestrian and bicycle modes shown in Exhibit 14-37Se are based on the updated HCM values.

**Exhibit 14-37 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.).

## 14.9 Segment Pedestrian LOS

### 14.9.1 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 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.
14.9.2

### 14.9.3 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.

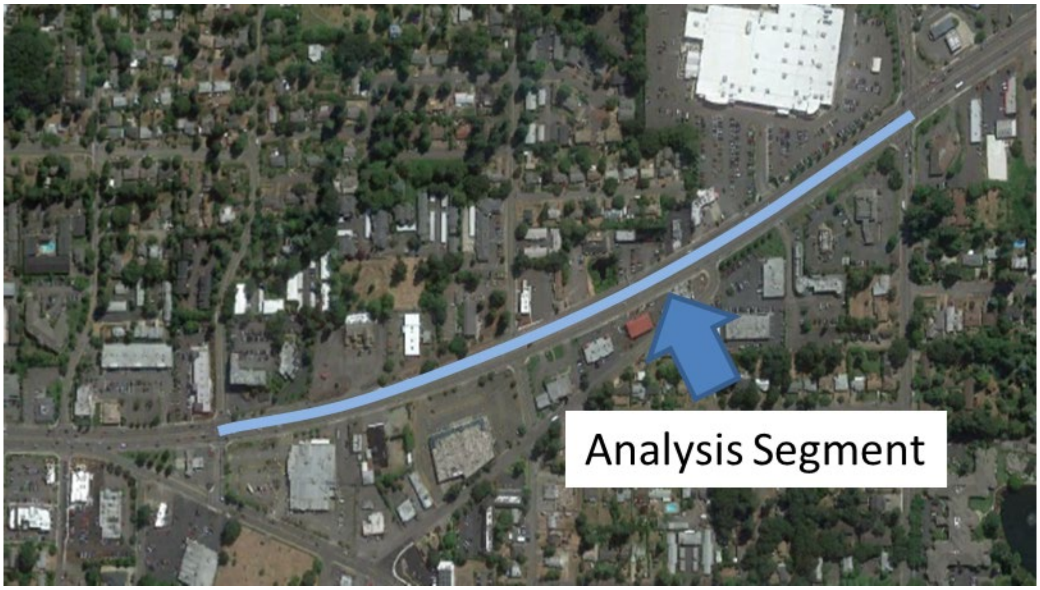
The Directional Traffic Volume is intended to be consistent with the analysis peak hour used for other analysis tasks, such as vehicle v/c ratio or LOS. It is possible that the final pedestrian LOS may be different between different peak hours such as AM and PM. Creation of the existing or future volumes 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), 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 Excel 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 14-6 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).

Directional volume (vph) = ADT * K-Factor * D-factor = 31,000 * 0.09 * 0.50
= 1395 vph which falls into the 500-1500 vph category

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.

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## 14.10 Segment Bicycle LOS

### 14.10.1 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 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 dataset. 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 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.

### 14.10.2 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 14-7 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.

## 14.11 Separated Bicycle Lanes

The separated bike lane 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 bicycle lanes (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), bollards, to large planters, to physically separating the bikeway with the vehicle parking strip. Exhibit 14-38 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 bike lane will allow for a better LOS. If a previously conducted Bicycle Level of Traffic Stress analysis indicated system needs, adding a separated bike lane on major routes can further enhance or help establish a low-stress network. For separated bicycle lanes 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 bicycle lanes. Separated bicycle lanes 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 a separated bike lane is the appropriate treatment. Not all roadways are suitable for separated bicycle lanes. Separated bicycle lanes 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 bike lane 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 bike lane 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 bike lane) as they turn into a driveway and across the bike lane. 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 bike lane 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 bicycle lanes with Region, Traffic-Roadway Section, or local jurisdiction roadway/bicycle-pedestrian staff (as appropriate) before pursuing a specific separated bike lane treatment.

### 14.11.1 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 14.7) 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 number 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 bicycle lanes 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.

### 14.11.2 Data Needs and Definitions

The methodology uses the following four variables to estimate the separated bike lane 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 bicycle lanes 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.

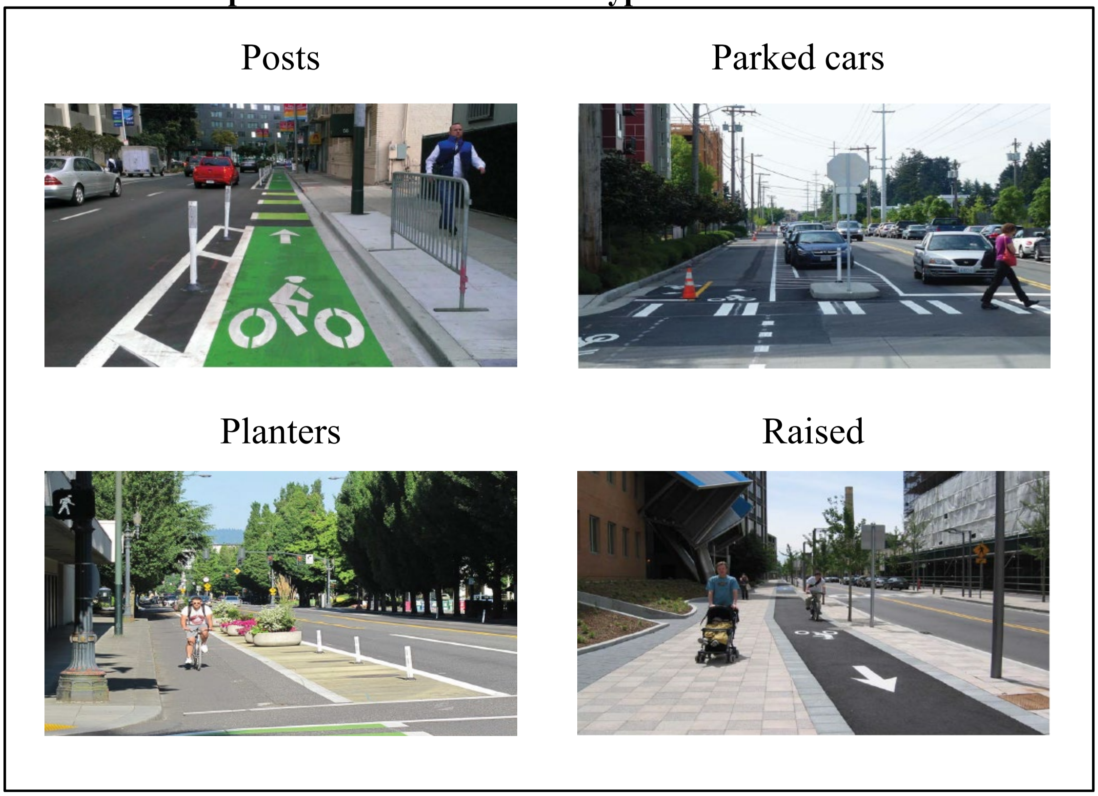
**Exhibit 14-38 Bicycle Facility Separation**[10]


Exhibit 14-39 illustrates the different kinds of buffer types used in this methodology. Post-type (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 14-39. 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 bike lane. There should be enough buffered space, so open vehicle doors do not interfere with the bicyclist's path. Some designs have

[10] Separated Bike Lane Planning and Design Guide, FHWA, May 2015, p.14.

the separated bike lane 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 bike lane. 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 14-39 Separated Bike Lane Buffer Types[11]**




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

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

speeds should gravitate toward total separation with a shared-use path (Section 14-13).

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 14-8 Separated Bike Lane 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 of 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 |

## 14.12 Buffered Bike Lanes

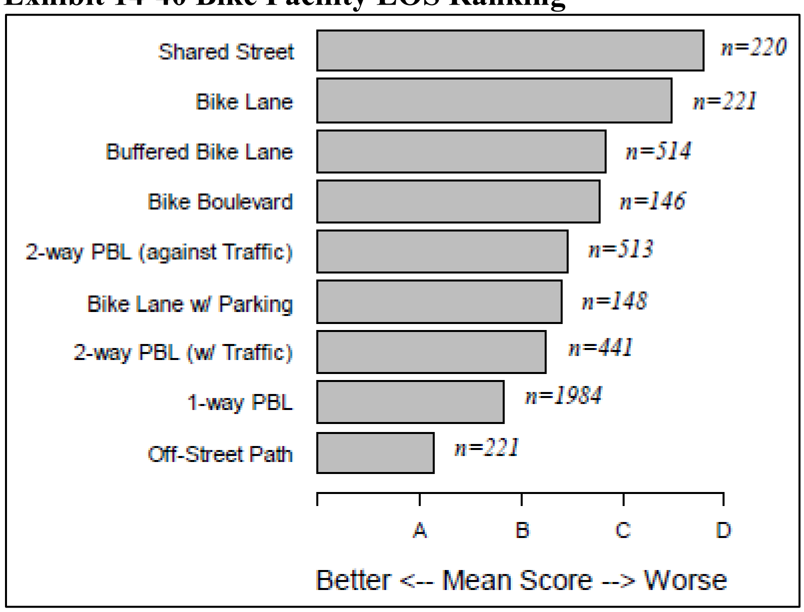
Buffered bike lanes offer additional comfort to the bicyclist by providing separation from the vehicle lanes using a striped and/or hatched buffer. Buffered bike lanes should be used when speeds exceed 25 mph or when volumes are more than 2,500 ADT and should be used up to speeds of 35 mph and/or 5,500 ADT[12]. Beyond these values, separated facilities should be used. 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 number 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 14-40. In the exhibit, the "n" is the observation sample size, and "PBL" is a protected (separated) bike lane. 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 bike lane 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 bike lane 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 bike lane LOS better while the bike lane LOS becomes worse which will generally make the differences balance out between them.

**Exhibit 14-40 Bike Facility LOS Ranking[13]**




[12] Bicycle Facility Tier Identification Matrix, ODOT Blueprint for Urban Design, 2019, p 3-15.
[13] Foster, N., et.al, A Level-of-Service Model for Protected Bike Lanes, Fig.2, p. 7-8.

The standard and separated bike lane 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 and separated bike lanes 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 bike lane 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 14-9 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 14-7) indicated a LOS E-F for the no-build conditions with just standard bike lanes. Example 14-8 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 number of driveways was thought by project staff to potentially create too much interference for good operation of the separated bike lane.

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 bike lane 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 and separated bike lane 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<br>E.N. Gineer | | Protected Bikeway /Buffered Bike Lane MMLOS<br>Segment LOS Output Summary | | | 06/23/16 |
|---|---|---|---|---|---|
| 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 |

---

## 14.13 Shared-use Paths

### 14.13.1 Methodology Summary

This methodology is a full application of the Highway Capacity Manual (HCM) 2010 and later 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 (e.g. soundwall, retaining wall) 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 Sections 800 and 900 of the Highway Design Manual.

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 (future) or signalized roadway crossings, please refer to Sections 14.14 (future) through 14.16.

### 14.13.2 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 14-41 and Exhibit 14-421 below. The LOS criteria are 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 and could increase the probability 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 with no more than 10% extra out-of-direction travel distance 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 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 14-41 Pedestrian and Bicycle LOS Criteria**

| LOS | Pedestrian<br>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 14-42 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 | |

### 14.13.3 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 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 footpath. 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 14-10 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 were 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 | |

## 14.14 Unsignalized Intersections (TBD- In Progress)

## 14.15 Pedestrian Crossing Treatments

Before deciding on specific treatments, project existing conditions and alternatives should be evaluated for adequate spacing of pedestrian crossings. Especially in urban areas, roadway geometry, volumes, and available pedestrian facilities may hinder access to the nearest improved crossing. Pedestrians generally will not walk more than about 10% to go out of their way to and back to use the nearest signalized crossing, but instead may not do a particular trip or risk crossing the roadway mid-block. Land use density and nearby pedestrian generators should be considered when deciding on a specific spacing. When possible, these target ranges should be met.

### 14.15.1 NCHRP 562 Application

One of the main products of the National Cooperative Highway Research Program (NCHRP) Report 562 was creation of a new spreadsheet tool that can be used as a guide to select or screen potential pedestrian crossing treatments for plans and projects. These treatments can range from signs and markings to full mid-block traffic signals. This tool uses relatively little data (i.e. speeds, volumes, widths) which is generally available to the typical TSP planning level all the way to the project development and TIA-level efforts. Selected treatments can also be analyzed with PLTS and MMLOS methods described earlier in this chapter.

*Any crossing treatment should be reviewed by Region Traffic and/or the Traffic, Section for its appropriateness for the given location and plan/project type. These treatments may have additional requirements listed in the Highway Design Manual, the Bicycle Pedestrian Design Guide, the Manual of Uniform Traffic Control Devices, or the Traffic Manual.*

*The need for a crossing treatment should not be based solely on the results of the NCHRP 562 methodology. Other factors such as the distance to the nearest improved crossing, number of vulnerable users, and crash history should also be considered.*

### 14.15.2 Treatment Categories

There are five main categories used in the tool as explained below. Most of these have additional information shown in the solutions section of Chapter 10. For planning level analysis, improvements should be identified using general categories rather than as specific treatments, in order to allow for flexibility in design.

- **No Treatment** – Occurs when the volumes of pedestrians are low (<20 pedestrians per hour at 35 mph or less or <14 pedestrians per hour at greater than 35 mph). Many locations in Oregon will fall into this category. When the tool indicates "no treatment" this means that no traffic control treatments such as signs, markings, or active pedestrian devices such as beacons are recommended. Traffic calming or pedestrian visibility-type measures can still be considered such as illumination, curb extensions, and/or median islands as appropriate. At certain locations such as transit stops and school crossings, it may be appropriate to provide a traffic control treatment even where there are few users in any given hour due to known continuous use throughout the day and presence of particularly vulnerable users. The analyst will need to review these results with the Region Traffic group to determine if the category should remain as "No Treatment" or be upgraded to the "Crosswalk" category.
- **Crosswalk** – Includes typical signing and crosswalk markings. This mainly applies to cases with sufficient pedestrian volume but low traffic volume.
- **Enhanced/Active** – Includes constant presence enhanced and active treatments. Examples of enhanced treatments are in-street signs, raised crosswalks, and curb extensions all of which are known to result in significantly increased stopping compliance. Active treatment examples are rapid-flashing and traditional flashing beacons that are pedestrian activated. This mainly apples to areas with sufficient pedestrians but higher traffic volumes or areas with high pedestrian volumes (>100 pedestrians per hour) and lower traffic volumes.
- **Red (Indication)** – Includes devices that show a "red" indication to vehicles such as pedestrian hybrid beacons (PHB) and mid-block traffic signals. These mainly apply to areas with roadway volumes (both directions) exceeding 1400 vph and peak pedestrian hour volumes less than 100 per hour.
- **Signal** – Includes conventional traffic signals at an intersection. This is a modification of the MUTCD pedestrian warrant. While bi-directional traffic volumes can be low as 400 vph, peak pedestrian volumes need to be at least 100 or more per hour. This category could also be applicable to the red indication devices if in a mid-block location. At certain locations where traffic signals would not be considered an appropriate measure (i.e. rural or an urban access-controlled expressway), this category can be used to indicate a need for a grade-separated pedestrian under or overcrossing.

### 14.15.3 Input Data

- Posted speed limit, 85th percentile speed, or statutory speed (i.e. 25 mph residential or 20 mph downtown)
- Population category of surrounding area (less or greater than 10,000)

> *The NCHRP 562 method does not include an allowance for just "marked crosswalks" when the population in less than 10,000. Treatment options are limited to no treatment, active/enhanced, red indication, and signal, so the method may overestimate the need for active/enhanced options. Adequate illumination, signs and continental crosswalk markings may be the expected outcome especially when volumes, speeds, or crossing distances are low/small.*

- Bi-directional roadway vehicles per hour during the pedestrian peak hour. This can be either an existing condition or future projected volume. If a median/pedestrian refuge island of at least six feet wide is present, then each direction needs to be analyzed separately. When an island is present two spreadsheets will need to be worked up, one for each direction. Vehicle volume in Line 3a will always be the total of both directions, while the volume in Line 4e, will be each approach direction when an island is present or the total when an island is not present. The pedestrian peak hour is typically not the same hour as the vehicular peak hour. Typically it can occur around the lunchtime period (i.e. 12-1 PM) which will likely require longer duration traffic counts at higher pedestrian volume locations in a plan or project.

> *It can be helpful to analyze both the pedestrian peak hour and the vehicle peak hour especially when projecting future conditions. Treatments could be triggered with lower pedestrian volumes and higher vehicle volumes and vice versa.*

- Pedestrian volume in the pedestrian peak hour – Sum existing condition or future projected pedestrian crossings from both directions at a mid-block location. If the analysis site is an intersection, sum both directions on both approaches (i.e. both east-west crosswalks north and south of the intersecting roadway). If separate pedestrian counts are done versus standard intersection classification counts, these should be at least 16-hours to capture multiple potential peaks (e.g. morning, noon, school, afternoon) and taken in good weather (spring/summer/fall) when pedestrians are mostly likely to be at the location. The choice of a weekday or weekend counts should be based on the surrounding land use and pedestrian destinations surrounding the crossing location. Future population growth rates should be considered to estimate future background pedestrian growth. It may be necessary to consider a larger area (approximately a ¼ mile radius) surrounding the crossing to help quantify or qualitatively explain the potential for induced growth above and beyond the background growth. Pedestrian warrant threshold reduction percentage –This parameter is used as part of the analysis for a full traffic signal. If the location experiences high pedestrian volumes (i.e. more than 100 peds/hr), then some consideration of the number of vulnerable pedestrians should be made. Otherwise, this parameter has no effect on the results and the default "no" can be retained.

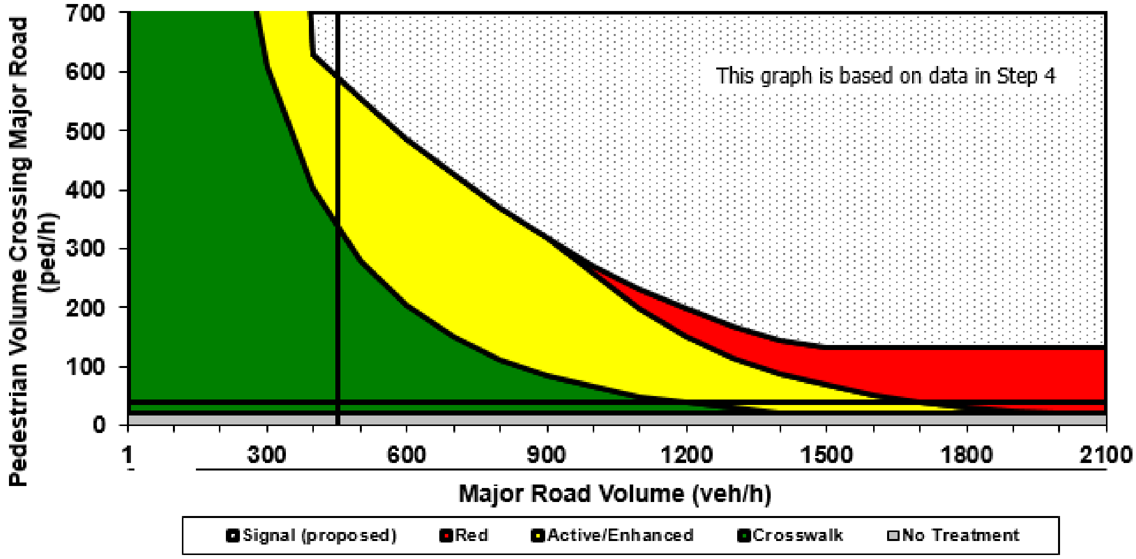
- Pedestrian crossing distance from curb-to-curb (ft). If a median refuge is present, use the curb-to-refuge distance for each approach.
- Pedestrian walking speed – use the default walking speed of 3.5 ft/s unless a significant number of older or younger pedestrians or those with mobility challenges are expected, such as where schools or retirement or similar facilities are nearby, then use 3.0 ft/s. Pedestrian lost time (startup and clearance time) – use the default 3 seconds.
- Pedestrian delay (s) – This value is normally automatically calculated but a field-measured delay value can be entered to override the calculation.
- Expected motorist compliance – Generally, use the "low" value when speeds are 30 mph or higher or when pedestrians are crossing four or more lanes of traffic, due to low compliance rates in Oregon under those conditions.

**Example 14-11 Pedestrian Crossing Treatment Selection**

A state highway in an urban area splits the commercial zone from the residential parts of the city. Residents report that it can be difficult to cross the roadway and it is too far out of direction to reach the nearest traffic signal. The roadway speed is 30 mph. A count was done, and the pedestrian peak hour was determined to be from 12-1 PM and about 40 pedestrians per hour cross at this location. The bi-directional roadway volume was determined to be 450 vph during this time at this location. The assumed pedestrian walking speed is 3.5 ft/s, with a 30 ft curb-to- curb distance. Pedestrian yielding rates remain low at this location regardless of the current pedestrians yielding law which may be due to relatively low visibility of the crossing. The data are entered into the tool which a recommends a marked crosswalk.

Improvements for this location are at least crosswalk signing, continental markings (if not already marked), and illumination.

| Analyst and Site Information | | | | | |
|---|---|---|---|---|---|
| Analyst | E. N. Gineer | Major Street | Main Street | | |
| Analysis Date | March 29, 2018 | Minor Street or Location | Elm Street | | |
| Data Collection Date | March 14, 2018 | Peak Hour | 12-1 PM | | |
| **Step 1: Select worksheet:** | | | | | |
| Posted or statutory speed limit (or 85th percentile speed) on the major street (mph) | | | | *1a* | 30 |
| Is the population of the surrounding area <10,000? (enter ***YES*** or ***NO*** ) | | | | *1b* | No |
| **Step 2: Does the crossing meet minimum pedestrian volumes to be considered for a traffic control devi** | | | | | |
| Peak-hour pedestrian volume (ped/h), $V_p$ | | | | *2a* | 40 |
| **Result: Go to step 3.** | | | | | |
| **Step 3: Does the crossing meet the pedestrian warrant for a traffic signal?** | | | | | |
| Major road volume, total of both approaches during peak hour (veh/h), $V_{maj-s}$ | | | | *3a* | 450 |
| [Calculated automatically] Preliminary (before min. threshold) peak hour pedestrian volume to meet warrant | | | | *3b* | 591 |
| [Calculated automatically] Minimum required peak hour pedestrian volume to meet traffic signal warrant | | | | *3c* | 591 |
| Is 15th percentile crossing speed of pedestrians less than 3.5 ft/s (1.1 m/s)? (enter ***YES*** or ***NO*** ) | | | | *3d* | no |
| If 15th percentile crossing speed of pedestrians is less than 3.5 ft/s (1.1 m/s), then reduce *3c* by up to 50%. | | % rate of reduction for *3c* (up to 50% | | *3e* | |
| | | Reduced value or *3c* | | *3f* | 591 |
| **Result: The signal warrant is not met. Go to step 4.** | | | | | |
| **Step 4: Estimate pedestrian delay.** | | | | | |
| Pedestrian crossing distance, curb to curb (ft), L | | | | *4a* | 30 |
| Pedestrian walking speed (ft/s), $S_p$ (suggested speed = 3.5 ft/s) | | | | *4b* | 3.5 |
| Pedestrian start-up time and end clearance time (s), $t_s$ (suggested start-up time = 3 sec) | | | | *4c* | 3 |
| [Calculated automatically] Critical gap required for crossing pedestrian (s), $t_c$ | | | | *4d* | 12 |
| Major road volume, total both approaches OR approach being crossed if raised median island is present, during peak hour (veh/h), $V_{maj-d}$ | | | | *4e* | 450 |
| Major road flow rate (veh/s), v | | | | *4f* | 0.13 |
| Average pedestrian delay (s/person), $d_p$ | | | | *4g* | 15 |
| Total pedestrian delay (h), $D_p$ The value in 4h is the calculated estimated delay for all pedestrians crossing th | | | | *4h* | 0.2 |
| major roadway without a crossing treatment (assumes 0% compliance). If the actual total pedestrian delay has been measured at the site, that value can be entered in 4i to replace the calculated value in 4h. | | | | *4i* | |
| **Step 5: Select treatment based up on total pedestrian delay and expected motorist compliance.** | | | | | |
| Expected motorist compliance at pedestrian crossings in region: enter ***HIGH for High Compliance*** or ***LOW for Low Compliance*** | | | | *5a* | low |
| **Treatment Category:** | **CROSSWALK** | | | | |




This worksheet provides general recommendations on pedestrian crossing treatments to consider at unsignalized ntersections; in all cases, engineering judgment should be used in selecting a specific treatment for installation. This worksheet does not apply to school crossings. In addition to the results provided by this worksheet, users should consider whether a pedestrian treatment could present an increased safety risk to pedestrians, such as where here is poor sight distance, complex geometrics, or nearby traffic signals.

### 14.15.4 Pedestrian Crossing Safety

The need for a pedestrian crossing treatment is rooted on safety so that the safest crossing can be provided. The NCHRP 562 methods, explained previously, are generally based on volumes of pedestrians or vehicles and the crossing geometry. There can be many locations that fall into the “No Treatment” category for which a pedestrian crossing treatment may be considered because they have a noted crash history, have potential crash risks, or are near vulnerable populations (e.g. schools). Locations should also be screened for safety which can either confirm the NCHRP 562 treatments or suggest other possibilities. The publication, *“FHWA Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations”* contains a countermeasure methodology reproduced in Exhibit 14-43 and Exhibit 14-44. Exhibit 14-43 is a table of pedestrian crash countermeasures by geometry, speed and AADT. Not all the treatments indicated in a particular cell in Exhibit 14-43 should be considered at a single location.

**Exhibit 14-43 Pedestrian Crash Countermeasures**

| Roadway Configuration | Posted Speed Limit and AADT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Vehicle AADT <9,000 | | | Vehicle AADT 9,000–15,000 | | | Vehicle AADT >15,000 | | |
| | ≤30 mph | 35 mph | ≥40 mph | ≤30 mph | 35 mph | ≥40 mph | ≤30 mph | 35 mph | ≥40 mph |
| **2 lanes** (1 lane in each direction) | ❶ 2 4 5 6 | ❶ 5 6 7 9 | ① 5 6 ❼ ❾ | ❶ 4 5 6 | ❶ 5 6 7 9 | ① 5 6 ❼ ❾ | ❶ 4 5 6 7 9 | ① 5 6 7 9 | ① 5 6 ❾ |
| **3 lanes with raised median** (1 lane in each direction) | ❶ 2 3 4 5 | ❶ ❸ 5 7 9 | ① ❸ 5 ❼ ❾ | ① 3 4 5 7 9 | ① ❸ 5 ❼ ❾ | ① ❸ 5 ❼ ❾ | ① ❸ 4 5 7 9 | ① ❸ 5 ❼ ❾ | ① ❸ 5 ❾ |
| **3 lanes w/o raised median** (1 lane in each direction with a two-way left-turn lane) | ❶ 2 3 4 5 6 7 9 | ❶ ❸ 5 6 7 9 | ① ❸ 5 6 ❾ | ① 3 4 5 6 7 9 | ① ❸ 5 6 ❼ ❾ | ① ❸ 5 6 ❾ | ① ❸ 4 5 6 7 9 | ① ❸ 5 6 ❾ | ① ❸ 5 6 ❾ |
| **4+ lanes with raised median** (2 or more lanes in each direction) | ❶ ❸ 5 7 8 9 | ❶ ❸ 5 7 8 9 | ① ❸ 5 8 ❾ | ① ❸ 5 7 8 9 | ① ❸ 5 ❼ 8 ❾ | ① ❸ 5 8 ❾ | ① ❸ 5 ❼ 8 ❾ | ① ❸ 5 8 ❾ | ① ❸ 5 8 ❾ |
| **4+ lanes w/o raised median** (2 or more lanes in each direction) | ❶ ❸ 5 6 7 8 9 | ① ❸ 5 ❻ 7 8 9 | ① ❸ 5 ❻ 8 ❾ | ① ❸ 5 ❻ 7 8 9 | ① ❸ 5 ❻ ❼ 8 ❾ | ① ❸ 5 ❻ 8 ❾ | ① ❸ 5 ❻ ❼ 8 ❾ | ① ❸ 5 ❻ 8 ❾ | ① ❸ 5 ❻ 8 ❾ |

Given the set of conditions in a cell,

- \# Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1 High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2 Raised crosswalk
3 Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4 In-Street Pedestrian Crossing sign
5 Curb extension
6 Pedestrian refuge island
7 Rectangular Rapid-Flashing Beacon (RRFB)**
8 Road Diet
9 Pedestrian Hybrid Beacon (PHB)**

*Refer to Chapter 4, 'Using Table 1 and Table 2 to Select Countermeasures,' for more information about using multiple countermeasures.

**It should be noted that the PHB and RRFB are not both installed at the same crossing location.

This table was developed using information from: Zegeer, C.V., J.R. Stewart, H.H. Huang, P.A. Lagerwey, J. Feaganes, and B.J. Campbell. (2005). Safety effects of marked versus unmarked crosswalks at uncontrolled locations: Final report and recommended guidelines. FHWA, No. FHWA-HRT-04-100, Washington, D.C.; FHWA. Manual on Uniform Traffic Control Devices, 2009 Edition. (revised 2012). Chapter 4F, Pedestrian Hybrid Beacons. FHWA, Washington, D.C.; FHWA. Crash Modification Factors (CMF) Clearinghouse. http://www.cmfclearinghouse.org/; FHWA. Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE). http://www.pedbikesafe.org/PEDSAFE/; Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N.J. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. (2017). NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. Transportation Research Board, Washington, D.C.; Thomas, Thirsk, and Zegeer. (2016). NCHRP Synthesis 498: Application of Pedestrian Crossing Treatments for Streets and Highways. Transportation Research Board, Washington, D.C.; and personal interviews with selected pedestrian safety practitioners.

If a location has an identified crash history or has had recent crash analyses done for a plan or project this may indicate a safety issue. However, most pedestrian crashes are random, and a crash pattern may not be evident. There are a number of pedestrian crash risk factors that are associated with collisions and potential severe injuries:

- Excessive vehicle speed
- Inadequate visibility
- Failing to yield to pedestrians in crosswalks
- Insufficient separation from traffic

Exhibit 14-44 shows these safety risks and the associated countermeasures that address them. These are the same countermeasures shown in Exhibit 14-43 above. The crash reduction factors (CRF) from the original and supplemental ARTS CRF lists should be used as all but the parking restriction countermeasure are available. Appendix B of the FHWA guide does have a 30% CRF applied to a pedestrian crash basis for the parking countermeasure.

**Exhibit 14-44 Safety Issues and Related Countermeasures**

| Pedestrian Crash Countermeasure for Uncontrolled Crossings | Safety Issue Addressed: Conflicts at crossing locations | Excessive vehicle speed | Inadequate conspicuity/ visibility | Drivers not yielding to pedestrians in crosswalks | Insufficient separation from traffic |
|---|---|---|---|---|---|
| Crosswalk visibility enhancement | 🚶 | 🚶 | 🚶 | 🚶 | 🚶 |
| High-visibility crosswalk markings* | 🚶 | | 🚶 | 🚶 | |
| Parking restriction on crosswalk approach* | 🚶 | | 🚶 | 🚶 | |
| Improved nighttime lighting* | 🚶 | | 🚶 | | |
| Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line* | 🚶 | | 🚶 | 🚶 | 🚶 |
| In-Street Pedestrian Crossing sign* | 🚶 | 🚶 | 🚶 | 🚶 | |
| Curb extension* | 🚶 | 🚶 | 🚶 | | 🚶 |
| Raised crosswalk | 🚶 | 🚶 | 🚶 | 🚶 | |
| Pedestrian refuge island | 🚶 | 🚶 | 🚶 | | 🚶 |
| Pedestrian Hybrid Beacon | 🚶 | 🚶 | 🚶 | 🚶 | |
| Road Diet | 🚶 | 🚶 | 🚶 | | 🚶 |
| Rectangular Rapid-Flashing Beacon | 🚶 | | 🚶 | 🚶 | 🚶 |

*These countermeasures make up the STEP countermeasure "crosswalk visibility enhancements." Multiple countermeasures may be implemented at a location as part of crosswalk visibility enhancements.

## Example 14-12 Pedestrian Crossing Safety Countermeasures

This example uses the same basic data as in Example 14-11. This roadway has two lanes, 30 mph speed and has 450 vph (4500 vpd). This data is used in Exhibit 14-37 to determine the potential safety countermeasures. High visibility crosswalk markings, lighting, parking restrictions and warning signs are indicated as the top countermeasure to be considered. This is consistent with the NCHRP 562 results in the previous example. Exhibit 14-43 also indicates that in-street pedestrian crossing signs, curb extensions, and a refuge island also can be considered. Raised crosswalks were also in the exhibit, but these are not installed on state highway mainlines and would be dropped from consideration.

| Roadway Configuration | Posted Speed Limit and AADT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Vehicle AADT <9,000 | | | Vehicle AADT 9,000–15,000 | | | Vehicle AADT >15,000 | | |
| | ≤30 mph | 35 mph | ≥40 mph | ≤30 mph | 35 mph | ≥40 mph | ≤30 mph | 35 mph | ≥40 mph |
| **2 lanes**<br>(1 lane in each direction) | ❶ 2<br>4 5 6 | ❶<br>5 6<br>7 9 | ①<br>5 6<br>❼ ❾ | ❶<br>4 5 6 | ❶<br>5 6<br>7 9 | ①<br>5 6<br>❼ ❾ | ❶<br>4 5 6<br>7 9 | ①<br>5 6<br>7 9 | ①<br>5 6<br>❾ |
| **3 lanes with raised median**<br>(1 lane in each direction) | ❶ 2 3<br>4 5 | ❶ ❸<br>5<br>7 9 | ① ❸<br>5<br>❼ ❾ | ① 3<br>4 5<br>7 9 | ① ❸<br>5<br>❼ ❾ | ① ❸<br>5<br>❼ ❾ | ① ❸<br>4 5<br>7 9 | ① ❸<br>5<br>❼ ❾ | ① ❸<br>5<br>❾ |
| **3 lanes w/o raised median**<br>(1 lane in each direction with a two-way left-turn lane) | ❶ 2 3<br>4 5 6<br>7 9 | ❶ ❸<br>5 6<br>7 9 | ① ❸<br>5 6<br>❾ | ① 3<br>4 5 6<br>7 9 | ① ❸<br>5 6<br>❼ ❾ | ① ❸<br>5 6<br>❾ | ① ❸<br>4 5 6<br>7 9 | ① ❸<br>5 6<br>❾ | ① ❸<br>5 6<br>❾ |
| **4+ lanes with raised median**<br>(2 or more lanes in each direction) | ❶ ❸<br>5<br>7 8 9 | ❶ ❸<br>5<br>7 8 9 | ① ❸<br>5<br>8 ❾ | ① ❸<br>5<br>7 8 9 | ① ❸<br>5<br>❼ 8 ❾ | ① ❸<br>5<br>8 ❾ | ① ❸<br>5<br>❼ 8 ❾ | ① ❸<br>5<br>8 ❾ | ① ❸<br>5<br>8 ❾ |
| **4+ lanes w/o raised median**<br>(2 or more lanes in each direction) | ❶ ❸<br>5 6<br>7 8 9 | ① ❸<br>5 ❻<br>7 8 9 | ① ❸<br>5 ❻<br>8 ❾ | ① ❸<br>5 ❻<br>7 8 9 | ① ❸<br>5 ❻<br>❼ 8 ❾ | ① ❸<br>5 ❻<br>8 ❾ | ① ❸<br>5 ❻<br>❼ 8 ❾ | ① ❸<br>5 ❻<br>8 ❾ | ① ❸<br>5 ❻<br>8 ❾ |

Given the set of conditions in a cell,

- \# Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1. High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2. Raised crosswalk
3. Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4. In-Street Pedestrian Crossing sign
5. Curb extension
6. Pedestrian refuge island
7. Rectangular Rapid-Flashing Beacon (RRFB)**
8. Road Diet
9. Pedestrian Hybrid Beacon (PHB)**

*Refer to Chapter 4, 'Using Table 1 and Table 2 to Select Countermeasures,' for more information about using multiple countermeasures.

**It should be noted that the PHB and RRFB are not both installed at the same crossing location.

*This table was developed using information from: Zegeer, C.V., J.R. Stewart, H.H. Huang, P.A. Lagerwey, J. Feaganes, and B.J. Campbell. (2005). Safety effects of marked versus unmarked crosswalks at uncontrolled locations: Final report and recommended guidelines. FHWA, No. FHWA-HRT-04-100, Washington, D.C.; FHWA. Manual on Uniform Traffic Control Devices, 2009 Edition. (revised 2012). Chapter 4F, Pedestrian Hybrid Beacons. FHWA, Washington, D.C.; FHWA. Crash Modification Factors (CMF) Clearinghouse. http://www.cmfclearinghouse.org/; FHWA. Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE). http://www.pedbikesafe.org/PEDSAFE/; Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N.J. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. (2017). NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. Transportation Research Board, Washington, D.C.; Thomas, Thirsk, and Zegeer. (2016). NCHRP Synthesis 498: Application of Pedestrian Crossing Treatments for Streets and Highways. Transportation Research Board, Washington, D.C.; and personal interviews with selected pedestrian safety practitioners.*

## 14.16 <u>Signalized Intersections Pedestrian and Bicycle Level of Service</u>

This methodology is adapted from the publication, "*Pedestrian and Bicycle Level of Service, Methodology for Crossing at Signalized Intersections*", from the Charlotte, NC Department of Transportation. This intersection methodology is intended to complement the level of service (LOS) segment analysis methods presented in this chapter and should be used in tandem to completely analyze a pedestrian or a bicycle facility. This methodology is intended for project level and detailed planning studies where specific data are plentiful and available.  System planning efforts should use the Level of Traffic Stress methodologies in Sections 14.4 and 14.5. The methodology is based on intersection elements that affect pedestrian and bicyclist safety and comfort using an expert judgment/index basis rather than research based as might be found in the Highway Capacity Manual. These intersection elements mainly include the impacts from reducing traffic conflicts, minimizing crossing distances, slowing down traffic speeds and raising user awareness. This method can be used without modification for signalized mid-block crossings (traffic signals not beacons). Traffic volumes are not explicitly used in this methodology in most areas but are implicitly included by using surrogates such as total crossing distance, number of lanes, speeds, and signal phasing.

*This methodology is intended to be used with other intersection analysis data, tools and methods such as Highway Safety Manual crash analyses, intersection capacity analyses, pedestrian/bicycle volumes, etc. to have a complete picture of the overall operations. In addition, several design and operational-related features are not part of the methodology such as sight distance, illumination, pavement condition, signing, accessibility, and detection but should be considered as part of any project intersection or mid-block crossing design. Please coordinate with traffic engineering and roadway design staff in the appropriate ODOT Region office, the Traffic Section, or local jurisdiction regarding consideration of these features.*

This methodology can be used to assess and improve pedestrian and bicycle user comfort for detailed planning and project development efforts by modifying design and operational features. It can also be used to select intersection features that meet the chosen pedestrian and bicycle LOS. The results can also be compared to traffic operations and other analyses given the objectives and priorities of the plan/project and the local jurisdiction. A companion spreadsheet LOS calculator was also developed and is available on ODOT's Planning and Technical Guidance's Technical Tools webpage.

*It is assumed that any design and operational elements evaluated in this methodology follow applicable ODOT publications (or accepted local/national standards and guidelines for non-state intersections) such as the Highway Design Manual, the Bicycle & Pedestrian Design Guide, Traffic Manual, etc. This means that, for example, appropriate widths, distances, or adequate signal timing should be present as this methodology is primarily concerned with the presence/absence of intersection features.*

This point-based methodology requires a number of design and operational elements that may be obtained from aerial/ground-level photography, field investigation, ODOT Region/Traffic Section/local jurisdiction staff for existing conditions. Project alternative designs/studies along with coordinating with appropriate staff should give the necessary information for future no-build or build conditions. These data elements are:

Pedestrian LOS

- Intersection lane configurations
- Median refuge presence and width
- Corner refuge island presence, number, and type (painted/curbed)
- Channelized right turn lane traffic control and design (high or low speed)
- Curb ramp design/condition
- Effective corner radius
- Total signal cycle length and number of phases
- Left and right turn signal phasing type
- Right/left-turn-on-red presence
- Pedestrian signal types and phasing
- Crosswalk markings

Bicycle LOS

- Intersection lane configurations
- Curb lane width
- Posted speed limit
- Approach and departure leg bicycle facility type
- Right turn lane/bike lane approach configuration
- Right turn lane volume
- Right turn lane length
- Buffer width at intersection
- Stop bar location
- Shared lane markings, conflict area paint, and turn box presence
- Left turn signal phasing
- Right-turn-on-red presence

Pedestrian and Bicycle LOS Criteria

The LOS scores are based on adding or subtracting points for the applicable physical and operational intersection elements on how well they perform based on the safety and comfort objectives for each approach. Higher point scores are equated with a better LOS. Points are summed from each element area: crossing distance, signal phasing and timing, pedestrian delay, corner radius, and crosswalk treatment. The subtotals from each area are summed into grand total for each intersection leg and compared with Exhibit 14-45.

**Exhibit 14-45 Pedestrian and Bicycle LOS Criteria**

| LOS | Pedestrian and Bicycle Total Points | Interpretation |
|---|---|---|
| A | ≥93 | Conditions should be generally acceptable for users. |
| B | 74 - 92 | |
| C | 55 - 73 | Some issues exist that may make users uncomfortable. |
| D | 37 - 54 | |
| E | 19 - 36 | Significant issues exist that will make a majority feel uncomfortable. Likely that this intersection will deter users from using it completely or from certain paths. |
| F | ≤18 | |

The individual intersection legs can be averaged to determine the LOS for the overall intersection. However, in some cases it may be best to report the leg LOS instead as the score for one exceptionally good or poor leg may be obscured in an intersection's average score. Since this methodology results in a reflection of the user's perception of safety and comfort, the LOS results need to be evaluated with other planning considerations (land use context, available funding etc.). The pedestrian and bicycle LOS calculated in this section will need to be weighed and prioritized alongside operational results for motor vehicles (v/c, LOS, etc.) based on the overall study area context, purpose, needs, goals, and objectives.

In some cases, the point assignments may need to be modified to better fit the specific context or allow for the consideration of more detailed elements or items not included in the methodology. Any deviations need to be part of a Methodology and Assumptions memorandum before any analysis work occurs or documented in other correspondence and agreed upon by Region/HQ Traffic and the Transportation Planning Analysis Unit.

### 14.16.1 Pedestrian Signalized Intersection LOS

The major issues for a pedestrian crossing at a signalized intersection are the total crossing distance (exposure to oncoming traffic) and potential conflicts with turning vehicles. Overall vehicle volume and speed also have some influence, but these can be mitigated by the presence of the traffic signal, physical intersection characteristics such as turning radii, and more restrictive signal phasing such as no right-turn-on-red. The factors included in the methodology focus on the physical crossing distances, intersection layout, and motor vehicle turning conflicts with the active pedestrian phase interval. Volumes and speeds are handled implicitly (i.e. assigned points drop more rapidly for a greater number of lanes crossed as wider roadways usually have higher volumes and speeds).

#### Crossing Distance

The roadway crossing distance is the primary component of the pedestrian methodology and receives the highest weight in determining the LOS. The more lanes a pedestrian has to cross, the lower the comfort and safety level are as they are exposed to cross-traffic for a greater distance. For example, two-and three lane signalized crossings are easy to cross and limit exposure as they are more “pedestrian-scaled” so this criterion does not change much at this level and decreases as the number of lanes increase.

Presence of (raised curb) median refuges break up the crossing distance into shorter lengths which can provide a positive LOS improvement especially for four-lane and wider roadways. For two-and three lane roadways, since exposure is limited, the impact of a median refuge is much less. For this criterion, note the presence of the median refuge but ignore pedestrian timing whether a crossing can be made all at once or requires multiple cycles. Extra crossing time is covered in the Pedestrian Delay criteria section.

The crossing distance is based on the number of lanes crossed to reach the other side of the roadway. Include turn, through, and channelized turn lanes in the total number of lanes in Exhibit 14-46. For example, if an intersection leg had a left turn lane, two through lanes, a channelized right turn lane with an island, and two opposing through lanes, this would be coded as a total of six lanes.

If bike lanes, shoulders, or parking are present, then the width of these should be considered as lane equivalents as these increase the overall exposure and motor vehicles could still cross the pedestrian path unexpectedly in these locations. For the purposes of the methodology, add a lane for each pair of bike lanes, shoulders, or parking that exists on a leg.  Add two lanes where the outside lane widths are 20 feet or greater (i.e. which might occur where diagonal parking is present).  Curb extensions shorten the overall crossing distance by removing the pavement width for parking so these will have a positive LOS impact if present (or added in an alternative.)

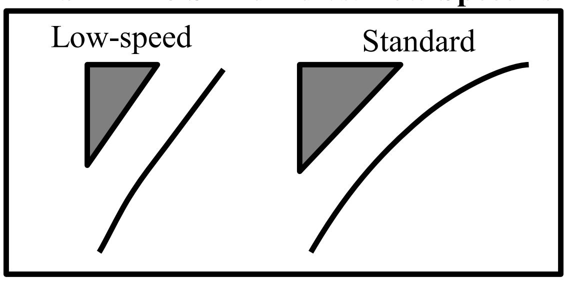
**Exhibit 14-46 Crossing Distance**

| Total Lanes/Lane Equivalents Crossed[1] | Points | | |
|---|---|---|---|
| | Median Refuge None or <4 ft | Median Refuge 4 - <6 ft | Median Refuge ≥6 ft |
| 2 | 78 | 79 | 80 |
| 3 | 76 | 77 | 78 |
| 4 | 65 | 65 | 68 |
| 5 | 50 | 52 | 55 |
| 6 | 37 | 40 | 44 |
| 7 | 24 | 28 | 33 |
| 8 | 8 | 12 | 20 |
| 9 | -5 | 0 | 10 |
| 10 | -15 | -10 | 0 |

[1] Outside lane widths at 20 feet or greater should be considered as two lanes. Parking, shoulders, or bike lanes on both sides of a leg should be considered as an extra lane equivalent.

The addition of corner refuge islands breaks up the overall crossing distance. Corner islands can either be of a standard design which requires more head movement by the driver to check for oncoming pedestrians or a low-speed design which brings the right turns in closer to a right angle as seen in Exhibit 14-47. Low speed islands can be identified as having an approximate 60-degree angle between the refuge lane and the intersecting street. The standard island with 45 or less degree corners is typically not considered a low-speed design unless the turning radius of the refuge lane is very tight (less than 30 feet). The presence of a raised crosswalk will effectively slow vehicles traveling through the channelized right turn lane regardless of island design style which will afford a better likelihood for yielding to pedestrians.

**Exhibit 14-47 Standard vs. Low-Speed Island Shape**




A scoring adjustment is made for each corner refuge island crossed as seen in Exhibit 14-48. For example, if the overall crossing distance traverses a left turn lane, two through lanes in each direction, and a channelized right turn lane separated by an island then the total point would be based on six total lanes crossed (37 points) plus the refuge island (6 points) for a total of 43 points. Adjustments are also made for the traffic control for the channelized right turn lane depending on if there is signal control, yield control or no control (free-flow). Points decrease as the chance of a vehicle not stopping and/or not seeing the pedestrian increase. The point reduction is less if the island is a low-speed design type with a steeper entrance angle that forces vehicles to slow substantially as these offer better driver visibility of oncoming traffic and pedestrians.

**Exhibit 14-48 Channelized Right Turn Refuge Adjustments**

| **Corner Refuge Island Adjustment** | **Points** |
|---|---|
| Each corner refuge island | 6 |
| **Channelized Right Turn Lane Traffic Control Adjustment** | |
| Signalized control | 5 |
| Yield control with low-speed island design and/or raised crosswalk | 2 |
| Yield control | -3 |
| Uncontrolled (free-flow) with low-speed island design and/or raised crosswalk | 0 |
| Uncontrolled (free-flow) | -20 |

### Curb Ramps

When a crossing lacks or has substandard curb ramps, the crossing can prevent use or make it difficult for disabled users potentially even forcing them out into the street and using nearby driveway ramps if available. A ramp built to ADA standards will have a flatter grade, a level landing, and a contrasting detectable surface for visually impaired pedestrians. Older ramps with short and/or steep grades (these almost never have any detectable surfaces) are considered equivalent to no ramp at all. The methodology restricts the total possible points by creating a maximum point threshold for an intersection leg based on the overall ramp quality as seen in Exhibit 14-49. For example, if an intersection leg did not have any curb ramps, then the maximum point value would be 37 (LOS E) regardless of other positive features and would be the controlling factor in this LOS. A good LOS is not possible with poor ramp conditions. The overall quality of the crossing is based on the condition of the curb ramps on either end of the crosswalk. If a curb ramp on one end of the crossing is good and the curb ramp on the other end is poor, the overall quality of the crossing is rated as poor as the crossing is not accessible. Determine the quality of each crossing based on the worst condition of the curb ramp pairs.

**Exhibit 14-49 Maximum Point Thresholds and Curb Ramp Quality**

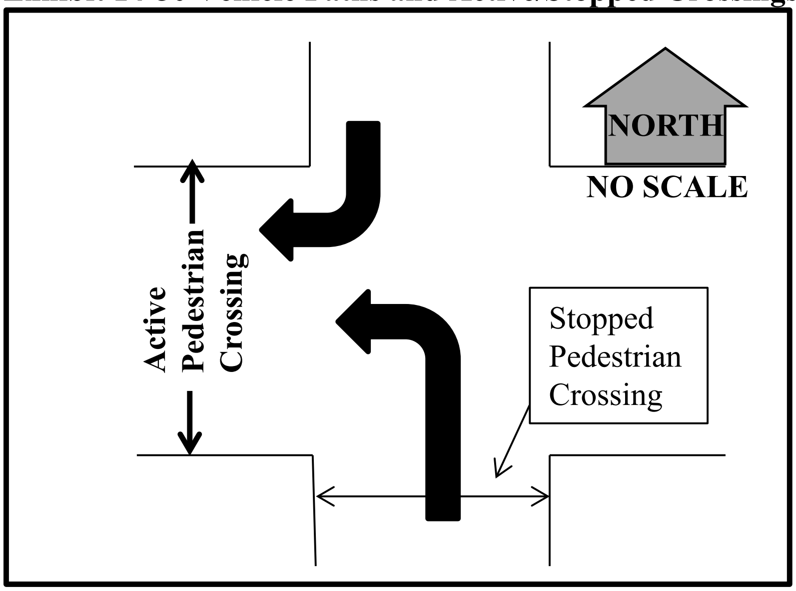
| Rating | Description | Maximum Point Threshold |
|---|---|---|
| Good | ADA-standard; truncated dome insert, level unobstructed landing area, flat grades | None |
| Acceptable | Detectable (cross-hatched) ramp surface, level landing area, shallow grades | 73 |
| Poor | No detectable surface, obstructed/no level landing area, steep grades, or missing ramp | 37 |

### Signal Phasing and Timing

The second-most important element in the methodology is the effect of signal phasing and timing on potential pedestrian-vehicle conflicts. Signal phasing can remove, limit, or create these conflicts. Protected phases are best for minimizing left and right turn conflicts as the pedestrian phase is prohibited from coming up during the green arrow indication for turning vehicles. Permissive phases allow for the conflict to occur as the pedestrian path is crossed by turning vehicles, which are required to yield, but may not do so.

Left and right turn conflicts are based on turns crossing the active pedestrian path on the subject (analysis) leg as shown in Exhibit 14-50. The conflicts are coded for movements that cross the pedestrian path when departing the intersection, not arriving. Note that the pedestrian crossing on the departing side of the intersection is active (going with the through signal phases) while the arriving side is stopped. For example, in Exhibit 14-51, the northbound left turn conflict is coded to the west leg as this movement crosses the west leg crosswalk on green when departing the intersection, directly conflicting with pedestrians. While this movement also crosses the south leg crosswalk upon entering the intersection, this pedestrian movement is stopped. Each leg is analyzed in turn determining the potential conflicts allowed or not by geometry or phasing. Exhibit 14-51 shows the different kinds of left and right turning conflicts. Higher points are awarded for protected phasing than for permissive as shown in Exhibit 14-52 and Exhibit 14-55.

**Exhibit 14-50 Vehicle Paths and Active/Stopped Crossings**




Right turn-on-red is another source of conflicts, so points are increased when this conflict is eliminated (movement is prohibited by signing). In contrast to the right turn conflict, right turn-on-red conflicts are coded to the subject leg that contains the pedestrian path that this movement will cross to enter the intersection. The active pedestrian crossing is on the entering intersection leg instead of the departing leg. For example, in Exhibit 14-51, the eastbound right-turn-on-red movement is coded to the west leg as it directly conflicts with pedestrians.

Left turn-on-red movements are a special case as they only apply for intersections of two one-way streets or a two-way street and a one-way street. Points are assigned if a left turn can be made legally into the proper lane on (typically the curb lane unless otherwise marked) the one-way cross street or is prohibited by signing as shown in Exhibit 14-53. This adjustment does not apply and is skipped for intersections of two two-way streets or for incompatible lane configurations on approach legs.  Left-turn-on-red conflicts are coded (the same way as right-turn-on-red conflicts) to the subject leg that contains the pedestrian path that this movement will cross to enter the intersection.

**Exhibit 14-51 Pedestrian-Vehicle Crossing Conflicts**

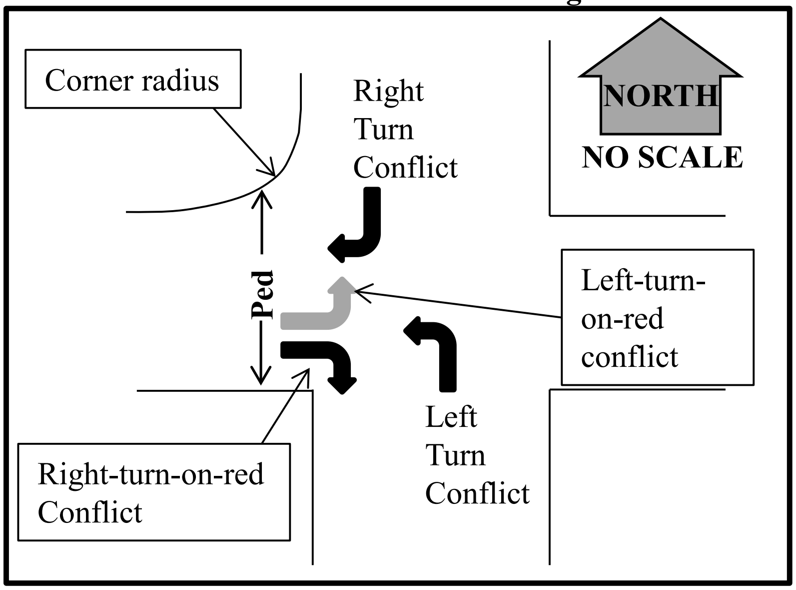



**Exhibit 14-52 Left Turn Conflicts**

| Left Turn Lanes | Left turn phase | Points |
|---|---|---|
| 1 – shared or exclusive | Permissive | -5 |
| | Protected-permissive | 0 |
| 1 or 2 - exclusive | Protected | 10 |
| 2 – shared/ exclusive | Permissive | -10 |
| No turn conflict – "T" intersection, one-way, mid-block crossing, or exclusive pedestrian phase | | 15 |
| Left turn-on-red allowed[1] | | 0 |
| Left turn-on-red prohibited (or no conflict)[1] | | 5 |

[1]Left turn-on-red adjustments are only considered for left turns going onto a one-way street from a one-way or two-way street. This adjustment does not apply in any other configuration.

The points are also adjusted for left turn conflicts coming from a two-way street onto a one-way street (Exhibit 14-53 and Exhibit 14-54) to account for the increased simultaneous exposure from turn conflicts across the entire width of the street. Even though vehicles executing a proper turn would turn into the curb lane, this is frequently ignored (or may be allowed by striping) so a left turning vehicle could end up in any of the receiving lanes. The left turn conflict for a one-way-to-one-way street or from left and right turn conflicts at a two-way to two -way street would only affect one part of the overall pedestrian crossing.

**Exhibit 14-53 Two-Way to One-Way Street Conflicts**

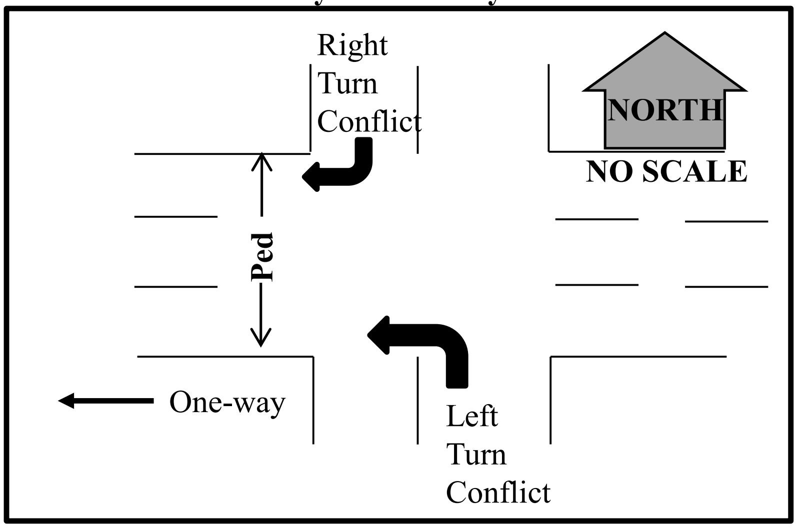



**Exhibit 14-54 One-way Street Adjustment[1]**

| Left Turn Phase Type | Points |
|---|---|
| Permissive or Protected-permissive | -10 |
| Protected | -2 |

[1]Only applies when the turn is made from a two-way to a one-way street.

**Exhibit 14-55 Right Turn Conflicts**

| Right Turn Lanes | Right turn phase | Points |
|---|---|---|
| 1 - shared or exclusive | Permissive | -5 |
| 1 - exclusive | Protected-permissive (Overlap) | 0 |
| 1 or 2 - exclusive | Protected | 5 |
| 2 – shared/ exclusive | Permissive | -12 |
| No turn conflict – “T” intersection, one-way, mid-block crossing or exclusive pedestrian phase | | 15 |
| Right turn-on-red allowed | | 0 |
| Right turn-on-red prohibited (or no conflict) | | 5 |

Points are also given for different kinds of pedestrian signal treatments. Leading pedestrian phases where pedestrians start walking before vehicles get the green, countdown timers, or slower assumed walking speeds will all get higher points as shown in Exhibit 14-56.

**Exhibit 14-56 Pedestrian Signal Displays**

| Display Type | Points |
|---|---|
| Standard (walk/don't walk) | 0 |
| Leading pedestrian phase | 4 |
| Countdown timer | 5 |
| Countdown timer and walking speed basis <3.5ft/s | 8 |
| Leading pedestrian phase & countdown timer | 8 |
| Leading pedestrian phase, countdown timer and walking speed basis <3.5ft/s | 12 |

**Pedestrian Delay**

Pedestrians all expect to wait to cross for some period at a signalized intersection. However, an "excessive" amount of pedestrian delay can be incurred waiting to cross a busy intersection if multiple signal cycles are spanned and if a crossing cannot be done all at once. Long wait times, especially when experienced on a median island, can diminish the walking experience. Some complex intersections may require two or three separate crossings between islands where, if not carefully managed, the cumulative wait time could equal the walking time for a short trip. Too much delay may increase the likelihood of someone crossing at an unprotected midblock location or not obeying the signal indications which is a safety concern.

The pedestrian delay criteria are based on the tolerance for waiting which the maximum would be about 45 seconds (for the typical three-phase signal). Shorter cycle lengths for two-phase signals get increased points as potential violations would be substantially reduced while longer lengths for four-phase signals, signals with long cycle times over 120 seconds, or intersections/mid-block crossings that require more than one cycle length (cannot be crossed completely in one pedestrian phase) get negative points as shown in Exhibit 14-57. Signals that have pedestrian phases that end more than five seconds before the start of the yellow phase are regarded as being too short as the walk/don't walk phase could be a few seconds longer. These may incur additional delay for the pedestrian as they would have to wait for the next cycle. Use the cycle length corresponding to the analysis period used for other methodologies if cycle lengths vary over the day. Intersections with longer cycles than what is shown in the table for the number of phases should use the next higher value. For example, a three-phase signal that has a 110-second cycle should use the point value for the four-phase signal.

**Exhibit 14-57 Pedestrian Delay**

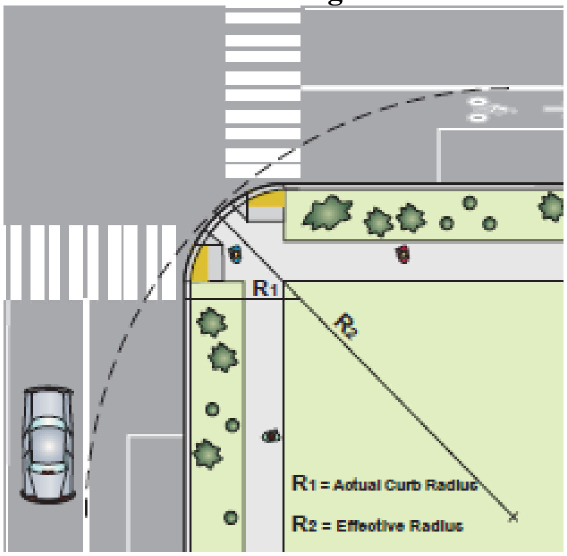
| Signal Phases/Cycle length | Points |
|---|---|
| Two-phase (maximum 60 s) | 5 |
| Three-phase (maximum 90 s) | 0 |
| Four-phase (maximum 120 s) | -5 |
| Any intersection with cycle length >120 s | -8 |
| Adjustment for each extra cycle required for crossing | -5 |
| Adjustment for pedestrian phase ending more than 5 seconds before start of yellow | -5 |

**Corner Radius**

Corner radius primarily impacts pedestrian safety and comfort by being a significant determinant of the speed at which vehicles are likely to cross the pedestrian path. At large values, it can also add to the crossing distance. The effect of wide lanes, bike lanes, & parking lanes on vehicle speed can be captured by considering the effective corner radius rather than simply the curb radius. Tighter corners with effective radii of 30 feet or less are rated best while wider effective radii of 50 feet or more impact the pedestrian enough to obtain negative values. The effective radius should be measured from edge of the bicycle lane around the corner to the edge of the bicycle lane on the cross-street as shown in Exhibit 14-58. Measurements can also be made from the edge of the travel lane if a bicycle lane does not exist, but parking does, or even from the curb is bicycle lanes and parking do not exist. The effective corner radius is assigned to the analysis leg corresponding to the right-turning movement departing the intersection (the same as a right turning conflict) as shown on Exhibit 14-58.

Exact measurements are not necessary as it only matters to be close enough to determine what radius category the corner falls into. Residential or central business district street intersections are likely 30 feet or less. Arterial street intersections will be likely in the 50-60 feet range especially if compound curves (more than one radius) are evident for accommodating larger vehicles. Collector –level intersections are likely in between. Effective radii in future alternatives should be measured from design plans, if available, for alternatives in active projects. Otherwise, coordinate with the appropriate ODOT Region, Traffic and/or-Roadway Section, or local jurisdiction design staff on assuming a typical radius to use for future improvements for a planning or design project. Exhibit 14-59 shows the point values assumed for each radius category.

**Exhibit 14-58 Measuring Effective Corner Radii**




Source: Oregon Bicycle & Pedestrian Design Guide, 2011, Fig 6-10, p.6-6.

**Exhibit 14-59 Effective Corner Radius**

| Radius (ft) | Points |
|---|---|
| ≤ 30 | 10 |
| >30 and ≤ 40 | 5 |
| >40 and ≤ 50 | 0 |
| >50 and ≤ 60[1] | -10 |
| >60[1] | -15 |

[1]May have compound curves present. Use approximate average radius between them when measuring.

If corner refuge islands are present instead of a regular corner radius, their effect on the score is based on the type of island (painted/raised), type of traffic control present for the channelized lane and whether the design forces vehicles to slow substantially as shown in Exhibit 14-60. This element, in contrast to the refuge island adjustments in Exhibit 14-48, considers the impact of the island on the departing leg crossing. Designs with lower speed channelized approaches have better visibility for oncoming traffic and pedestrians as less head movement is required. Higher speed approaches typically require the driver to look back over their shoulder to some degree and it is difficult to see pedestrians in this configuration.

**Exhibit 14-60 Corner Refuge Island (in lieu of Corner Radius)**

| Island Type | Traffic Control | Right Turn Phasing Type | Points |
|---|---|---|---|
| Painted | Uncontrolled (free-flow) | | -20 |
| | Yield or signalized | All | -10 |
| Curbed | Uncontrolled (free-flow) | | -20 |
| | Yield or signalized | Permissive or Permissive/Protected | 0 |
| | Signalized | Protected | 5 |
| Curbed – Low Speed | Yield or signalized | Permissive or Permissive/Protected | 5 |
| | Signalized | Protected | 10 |

**Crosswalk Treatment**

The more visible a crosswalk is, the more awareness that a driver will have to the potential of pedestrians crossing the street. An unmarked crosswalk at a signalized intersection gets negative points on account of additional exposure required or more risk for the pedestrian. Crosswalk treatments beyond just the standard transverse or ladder striping garner positive points as shown in Exhibit 14-61.

**Exhibit 14-61 Crosswalk Treatment**

| Crosswalk Treatment | Points |
|---|---|
| Unmarked | -5 |
| Marked with transverse or ladder striping | 0 |
| Raised[1] and marked across entire approach | 5 |
| Raised[1] and marked across channelized right turn lane | 5 |

[1]Raised crosswalks may not be appropriate on some state highway approaches or right turn lanes

**Example 14-13 Signalized Intersection Pedestrian Level of Service**

An urban intersection needs to be assessed for Signalized Pedestrian LOS as part of an analysis project. The intersection is at the junction of a north-south four-lane two-way street and a westbound two/three lane one-way street. Railroad tracks are adjacent to the intersection across the east leg and the pedestrian stop-bar is 25’ from the edge of the curb. There are no medians or refuges on any of the legs. Corner radius was measured at 15’ for all corners. All crosswalks are open and marked with standard transverse stripes. All curb ramps are of modern ADA design. A site inventory revealed the following additional signal phasing data:

- Three-phase (protected-permissive in the northbound direction with permissive turns on all other legs) signal operation running at a 65 second cycle length
- Countdown timers present on all legs

- Leading pedestrian phase on north and south legs
- Right-turn-on-red prohibited on east leg

Source: Google Earth, 2017.

The individual criteria scores were determined from the methodology for each leg and are shown below with the general reason behind the score. Since all curb ramps are of modern ADA design and are in good condition, there is no limitation on the maximum number of points that a leg can have.

| Criteria | Score | | | |
|---|---|---|---|---|
| | North Leg | East Leg | South Leg | West Leg |
| Crossing Distance | 5 lane equivalents = 50 pts[1] | 2 lanes = 78 pts | 5 lane equivalents = 50 pts[1] | 3 lanes = 76 pts |
| Left turn conflicts | No conflict = 15 pts | No conflict = 15 pts | Yes (WB permissive turn) = -5 pts | Yes (NB protected-permissive turn) = 0 pts |
| Left turn-on-red | Does not apply | | Allowed = 0 pts | Does not apply |
| One-way street adjustment | Does not apply | | | Yes = -10 pts |
| Right turn conflicts | Yes (WB permissive turn) = -5 pts | No conflict = 15 pts | No conflict = 15 pts | Yes (SB permissive turn) = -5 pts |
| Right turn-on-red | Allowed = 0 pts | WB prohibited = 5 pts | No conflict = 5 pts | No conflict = 5 pts |
| Pedestrian signal displays | Leading pedestrian phase & countdown timers = 8 pts | Countdown timers = 5 pts | Leading pedestrian phase & countdown timers = 8 pts | Countdown timers = 5 pts |
| Pedestrian delay | Three phase signal with >90 seconds cycle = 0 pts | | | |
| Corner radius | 15' effective radius = 10 pts | | | |
| Crosswalk treatments | Transverse striping = 0 pts | | | |
| Leg Totals | 78 | 128 | 83 | 81 |
| Leg LOS | B | A | B | B |
| Intersection LOS | = (78 + 128 + 83 + 81) / 4 = 92 | | B | |

[1]Note that the placement of the railroad tracks lengthens the overall crossing distance as there so safe place to wait between the tracks and the street for westbound pedestrians. The "official" waiting area also makes it more difficult for drivers to notice the pedestrians as they are more focused on the corner. Eastbound pedestrians are easier to see. The extra distance is approximately 24 feet but affects westbound more than eastbound, so one extra lane equivalent was added to the total crossing width of this leg

### 14.16.2 Bicycle Signalized Intersection LOS

The major issues for a bicyclist crossing at a signalized intersection are the amount of separation from motor vehicles and the overall traffic speed. Most people desire the greatest separation as possible from faster moving vehicles to achieve the desired comfort (stress) level. Features that maximize separation between vehicles and bicyclists are awarded the most points while ones that have minimal or no separation are penalized.

Turning conflicts, crossing distance (exposure), and traffic signal features are somewhat less important, but still prominent for overall safety needs. The factors included in the methodology affecting the bicyclist focus on separation, speed, signal phasing, physical distances, intersection layout and turning conflicts, while volumes are handled implicitly.

**Bicycle Facility & Adjacent Traffic Speed**

The space dedicated to bicyclists including any separation from the motor vehicle traffic stream and the speed of that stream are the largest factors in determining the quality of the intersection crossing. Higher speeds (and related volumes) add difficulty for the bicyclist on intersection approaches, especially in the conflict areas around right turn lanes. Bicycle facilities that greater separate the bicyclist from adjacent traffic rate the best while conditions that force the bicyclist to share the lane rate the worst. Points decrease as roadway speed increases and/or separation decreases. Sharing roadway space works best when the speeds are low (20-25 mph) as the bicyclist can generally keep pace with traffic. Higher speeds at 30 mph or more require some sort of separation such as standard, buffered or separated bike lanes. Exhibit 14-62 illustrates the arriving and departing legs on an approach as to be used in Exhibit 14-63. Exhibits 14-63 through 14-67 show the point values for a given bike facility type on an arrival leg bike facility combined with different departing facility types and roadway speeds.

**Exhibit 14-62 Arriving & Departing Legs for Approach Bike Facilities**

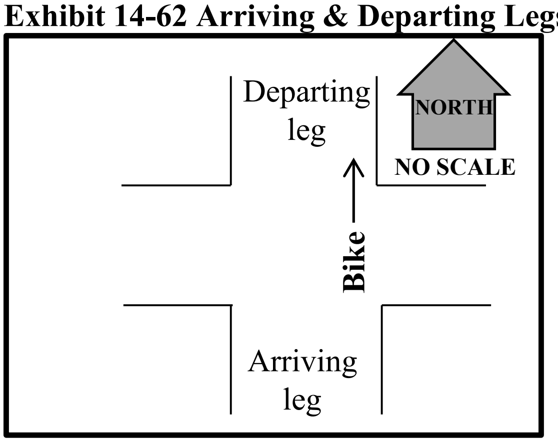


**Exhibit 14-63 Arriving Leg - Shared Lanes**

| Shared Lane to Departing Leg Facility Type | Speed Limit (mph) | Points |
|---|---|---|
| To Shared Lane | ≥ 40 | -15 |
| | 30 - 35 | 10 |
| | ≤ 25 | 30 |
| To Wide Outside Lane | ≥ 40 | 0 |
| | 30 - 35 | 20 |
| | ≤ 25 | 35 |
| To Bike Lane | ≥ 40 | 15 |
| | 30 - 35 | 30 |
| | ≤ 25 | 40 |
| To Buffered Bike Lane | ≥ 40 | 30 |
| | 30 - 35 | 40 |
| | ≤ 25 | 45 |
| To Separated Bike Lane | ≥ 40 | 45 |
| | 30 - 35 | 50 |
| | ≤ 25 | 55 |

**Exhibit 14-64 Arriving Leg - Wide Outside (Curb) Lanes**

| Wide Outside Lane to Departing Leg Facility Type | Speed Limit (mph) | Points |
|---|---|---|
| To Shared Lane | ≥ 40 | -5 |
| | 30 - 35 | 15 |
| | ≤ 25 | 30 |
| To Wide Outside Lane | ≥ 40 | 10 |
| | 30 - 35 | 30 |
| | ≤ 25 | 40 |
| To Bike Lane | ≥ 40 | 25 |
| | 30 - 35 | 40 |
| | ≤ 25 | 50 |
| To Buffered Bike Lane | ≥ 40 | 40 |
| | 30 - 35 | 50 |
| | ≤ 25 | 60 |
| To Separated Bike Lane | ≥ 40 | 55 |
| | 30 - 35 | 65 |
| | ≤ 25 | 70 |

**Exhibit 14-65 Arriving Leg - Bike Lanes**

| Bike Lane to Departing Leg Facility Type | Speed Limit (mph) | Points |
|---|---|---|
| To Shared Lane | ≥ 40 | 10 |
| | 30 - 35 | 25 |
| | ≤ 25 | 35 |
| To Wide Outside Lane | ≥ 40 | 20 |
| | 30 - 35 | 35 |
| | ≤ 25 | 45 |
| To Bike Lane | ≥ 40 | 40 |
| | 30 - 35 | 50 |
| | ≤ 25 | 60 |
| To Buffered Bike Lane | ≥ 40 | 50 |
| | 30 - 35 | 55 |
| | ≤ 25 | 70 |
| To Separated Bike Lane | ≥ 40 | 65 |
| | 30 - 35 | 70 |
| | ≤ 25 | 75 |

**Exhibit 14-66 Arriving Leg - Buffered Bicycle Lanes**

| Buffered Bike Lane to Departing Leg Facility Type | Speed Limit (mph) | Points |
|---|---|---|
| To Shared Lane | ≥ 40 | 20 |
| | 30 - 35 | 30 |
| | ≤ 25 | 40 |
| To Wide Outside Lane | ≥ 40 | 30 |
| | 30 - 35 | 40 |
| | ≤ 25 | 50 |
| To Bike Lane | ≥ 40 | 50 |
| | 30 - 35 | 55 |
| | ≤ 25 | 65 |
| To Buffered Bike Lane | ≥ 40 | 60 |
| | 30 - 35 | 65 |
| | ≤ 25 | 75 |
| To Separated Bike Lane | ≥ 40 | 70 |
| | 30 - 35 | 75 |
| | ≤ 25 | 80 |

Protected intersections are a new intersection treatment that has a wide appeal by separating the bicyclist from vehicles and pedestrians on all approaches. These allow for better visibility for drivers when turning right. These can be analyzed by using Exhibit 14-67 with a separated bike lane as the departing leg. If exclusive bicycle signal phasing exists, then no left or right vehicle turn conflicts can be additionally assumed.

**Exhibit 14-67 Arriving Leg - Separated Bicycle Lanes**

| Separated Bikeway to Departing Leg Facility Type | Speed Limit (mph) | Points |
|---|---|---|
| To Shared Lane | ≥ 40 | 35 |
| | 30 - 35 | 40 |
| | ≤ 25 | 45 |
| To Wide Outside Lane | ≥ 40 | 40 |
| | 30 - 35 | 45 |
| | ≤ 25 | 55 |
| To Bike Lane | ≥ 40 | 60 |
| | 30 - 35 | 70 |
| | ≤ 25 | 75 |
| To Buffered Bike Lane | ≥ 40 | 70 |
| | 30 - 35 | 75 |
| | ≤ 25 | 80 |
| To Separated Bike Lane | ≥ 40 | 80 |
| | 30 - 35 | 85 |
| | ≤ 25 | 90 |

**Left Turn Conflicts**

Left turn conflicts can be problematic for bicyclists as turning vehicles are typically travelling at higher speeds than right turns. Drivers may not see a bicyclist if they are concentrating on getting through a gap in traffic. The greatest chance of conflict is when the left-turn is permissive rather than purely protected.  Intersection and signalization features that reduce or eliminate conflicts are rated the best and are the second contributing highest factor in the methodology. Exhibit 14-68 shows the bicycle-vehicle crossing conflicts and Exhibit 14-69 shows the point values for the opposing left turn conflicts. Left turn conflicts for bicyclists (note this is different from the facility types noted above) are coded to the approaching (arriving) leg for vehicles, so the southbound left turn conflicts with the northbound bicyclist in Exhibit 14-68 are coded to the north leg.

**Exhibit 14-68 Bicycle-Vehicle Crossing Conflicts**

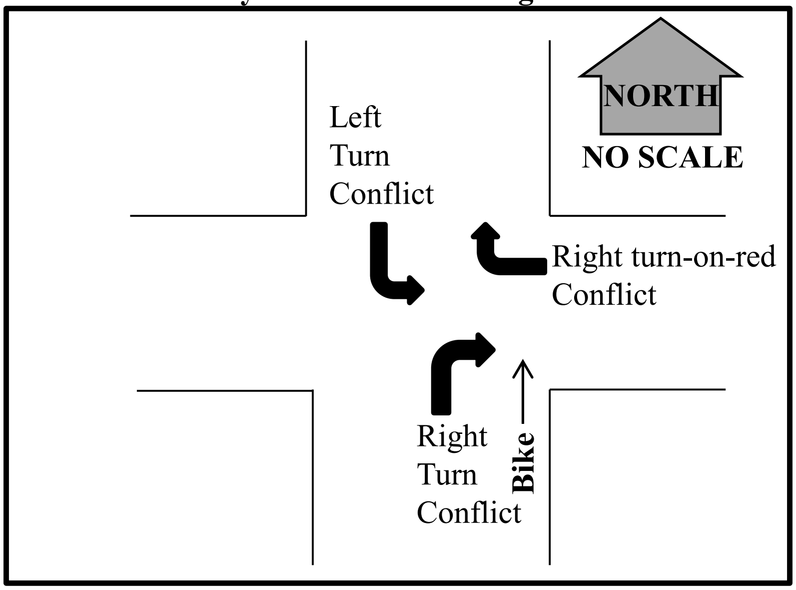



**Exhibit 14-69 Left Turn Conflicts**

| Left Turn Phase Type[1] | Points |
|---|---|
| Permissive | 0 |
| Protected-permissive | 5 |
| Protected | 15 |
| No turn conflict – "T" intersection or one-way streets | 15 |
| **Left Turn Adjustments** | |
| Green "conflict area" paint | 5 |
| Two-stage turn box | 10 |
| **Stop Bar Location** | |
| Shared stop bar – vehicles and bikes stop at common point | 0 |
| Advance stop bar/bike box – bikes stop closer to intersection | 10 |

[1]Left turn type that is opposing to the oncoming bicyclist.

Right Turn Conflicts

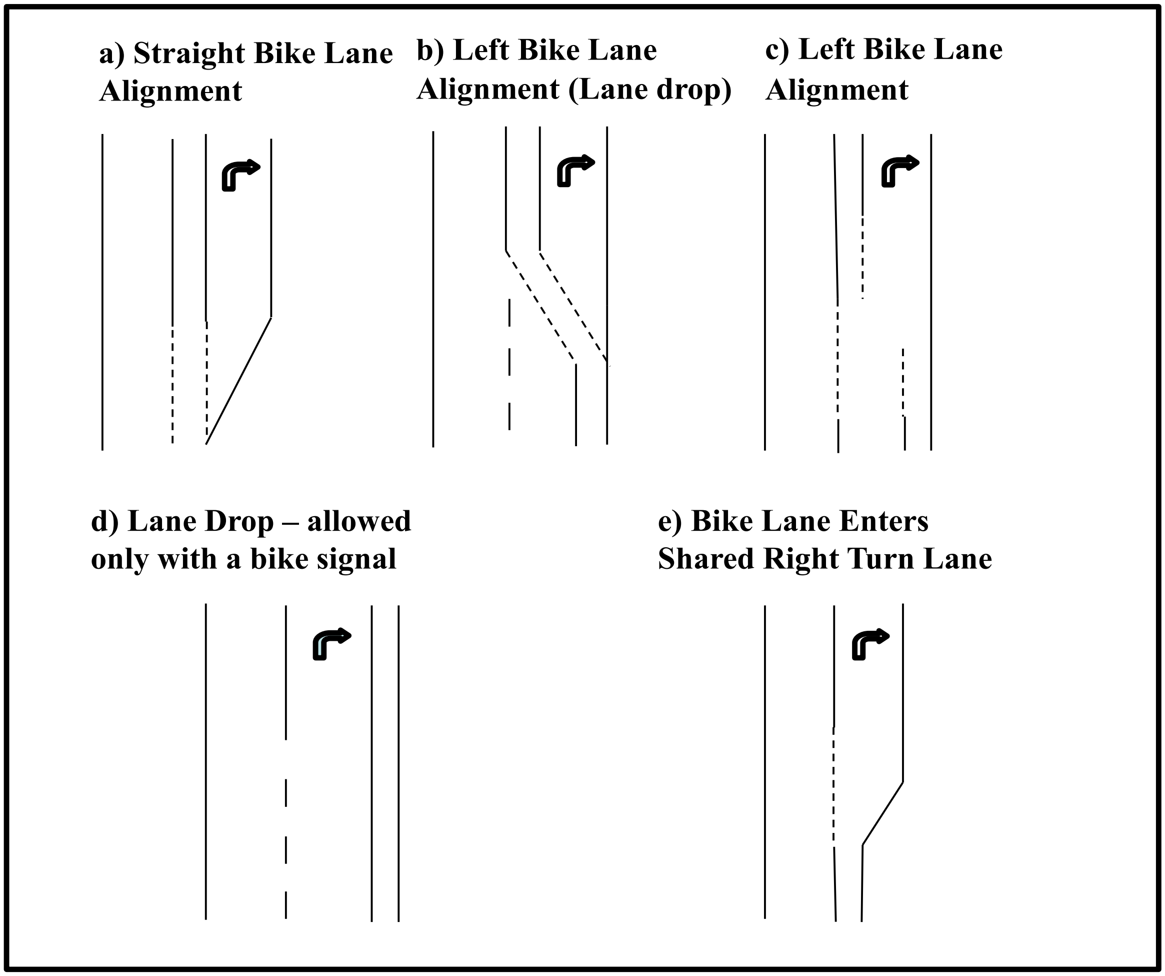
The most common right turn conflict involves a vehicle turning right and a bicycle heading straight ("right-hook"). The right turn conflict depends on the approach treatment at the intersection between the positioning of the right turn lane and the bicycle facility. Right turn conflicts are coded to the arriving approach leg for both vehicles and bicyclists, so as shown in Exhibit 14-68, so the right turn conflict on the northbound approach is coded to the south leg. The most desirable combination is to have the bicyclist traveling straight while the vehicle yields and merges to the right (bicycle lane is to the left of the right turn lane) as shown in Exhibit 14-70(a). Higher speeds and/or volumes may give bicyclists pause especially if there is a lack of yielding to bicyclists as vehicles cross over the bike lane to access the right turn lane. Longer right turn lanes, especially under higher volume conditions can create "sandwich" feeling for the bicyclist which can limit the actual use of the bike lane on the approach. It is recommended that coordination with either Region Traffic or Traffic-Roadway Section staff be done if higher speeds and volumes are prevalent in the study area as the point assignment may need to be modified.

Configurations that require the bicyclist to shift left (Exhibit 14-70(b) or Exhibit 14-70(c)) are awarded little or no points as the vehicle yielding behavior is less as there is too much of a straight shot into the right turn lane without a conscious need to move to the right. Exhibit 14-70(b) shows an older marking style while Exhibit 14-70(c) shows the current style. Both require bicyclists to shift to the left and are progressively more difficult to make as right turning volumes increase. Intersection approaches that do not have a bike facility require the bicyclist to share the vehicle lanes and shift left should also use Exhibit 14-70(e). Sharrow markings are optional for shared right turn lanes as shown in Exhibit 14-70(e).

The least desirable configuration is Exhibit 14-70(d) where the bike lane is to the right of the right turn lane. This configuration limits the ability of the driver to see any oncoming bicyclists as many drivers fail to check the right-hand mirror and blind spot which could result in a “right-hook” crash. This conflict can be removed with a presence of a bicycle signal by prohibiting right turning traffic while bicyclists have a green (and vice versa when vehicular traffic has a green). A bicycle signal can make this configuration significantly better than the standard design in Exhibit 14-70(a) by eliminating the turn conflict. However, this configuration should only be allowed with a bicycle signal. Adding bicycle signals will either require a significant bicycle volume, a high right turn volume or both. The presence of green paint in the conflict areas shows both drivers and bicyclist to be aware of potential conflicts and thus gets a positive point adjustment.

*Adding bicycle signal phases will impact operation of the entire intersection as there will be less time for the other motor vehicle phases. Bicycle signal phases may also result in more delay for bicyclists as they would be prohibited from traveling with the vehicular phases. This tradeoff will need to be evaluated in context of all users, the local environment and the community.*

**Exhibit 14-70 Bike Lane Alignments**




Right-turn on-red movements also create a safety issue as drivers are looking for approaching vehicles and may not see an oncoming bicyclist. Adjustments for right turn and right-turn-on-red conflicts are shown in Exhibit 14-71.

**Exhibit 14-71 Right Turn Conflicts**

<table>
<tr><th colspan="2">Right Turn Conflict Type</th><th>Points</th></tr>
<tr><td colspan="2">No exclusive right turn lane</td><td>5</td></tr>
<tr><td rowspan="9">Exclusive right turn lane</td><td>Right turn lane <500’ develops to the right of bike lane. Bike lane is left of right turn lane.<br>(Exhibit 14.70a)</td><td>0</td></tr>
<tr><td>Right turn lane ≥500’ develops to the right of bike lane. Bike lane is left of right turn lane.<br>(Exhibit 14.70a)</td><td>-15</td></tr>
<tr><td>Right turn lane drop, bike lane shifts left<br>(Exhibit 14.70b or c)</td><td>-10</td></tr>
<tr><td>Bike lane enters <100’ (including taper) shared right turn lane. Right turn lane volume <75 vph and at <25 mph (Exhibit 14.70e)</td><td>0</td></tr>
<tr><td>Bike lane enters <100’ (including taper) shared right turn lane. Right turn lane volume <150 vph and at <25 mph (Exhibit 14.70e)</td><td>-5</td></tr>
<tr><td>Bike lane enters >100’ (including taper) shared right turn lane or right turn lane volume >150 vph or >25 mph (Exhibit 14.70e)</td><td>-10</td></tr>
<tr><td>No bike lane</td><td>0</td></tr>
<tr><td>Bike lane right of right turn lane<br>(Exhibit 14-70d)</td><td>-20</td></tr>
<tr><td>Bike lane right of right turn lane with bike signal</td><td>15</td></tr>
<tr><td colspan="2">No right turn conflict<br>(“T” intersection, one-way street)</td><td>15</td></tr>
<tr><th colspan="2">Right Turn Adjustments</th><th></th></tr>
<tr><td colspan="2">Green “conflict area” paint</td><td>5</td></tr>
<tr><td colspan="2">Shared lane use marking in shared lane</td><td>5</td></tr>
<tr><th colspan="2">Right Turn-on-red Conflict</th><th></th></tr>
<tr><td colspan="2">Allowed</td><td>0</td></tr>
<tr><td colspan="2">Prohibited or no conflict</td><td>5</td></tr>
</table>

### Crossing Distance

The wider the intersection, the greater exposure a bicyclist has to the cross-street traffic. Signal timing is often set for motor vehicle speeds and clearances, so wider intersections have a greater risk of having the bicyclist in the intersection in the phase change intervals. Exhibit 14-72 shows the adjustments for crossing distance based on total lanes (through and turn) crossed. If exclusive bicycle signal phasing exists on an approach, then this criteria does not apply.

**Exhibit 14-72 Intersection Crossing Distance**

| Total Lanes Crossed | Points |
|---|---|
| ≤ 3 | 0 |
| 4 – 5 | -5 |
| ≥ 6 | -10 |

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**Example 14-14 Signalized Intersection Bicycle Level of Service**

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An urban intersection was assessed for Signalized Bicycle LOS as part of an analysis project. The intersection is at the junction of an east-west two-lane street and a north-south three lane street. Bike lanes are present on the north, south and east legs while the bike share the lanes with vehicles on the west leg. The speed is 30 mph on both streets. The signalized intersection has protected left-turn phasing on all legs and the exclusive right turn lane on the north leg is controlled by a protected-permissive signal head.

Source: Google Earth, 2017.

The individual criteria scores were determined from the methodology for each leg and are shown below with the general reason behind the score.

| Criteria | Score | | | |
|---|---|---|---|---|
| | North Leg | East Leg | South Leg | West Leg |
| Bicycle Facility and Traffic Speed | Bike lane to bike lane; 30 mph = 50 pts | Bike lane to shared lane; 30 mph = 25 pts | Bike lane to bike lane; 30 mph = 50 pts | Shared lane to bike lane; 30 mph = 30 pts |
| Left turn conflicts | Protected phasing = 15 pts | Protected phasing = 15 pts | Protected phasing = 15 pts | Protected phasing = 15 pts |
| Stop Bar Location | Shared stop bar = 0 pts | Shared stop bar = 0 pts | Shared stop bar = 0 pts | Shared stop bar = 0 pts |
| Right turn conflicts | Exclusive right lane; bike lane shifts left = -10 pts | No exclusive right turn lane = 5 pts | No exclusive right turn lane = 5 pts | No exclusive right turn lane = 5 pts |
| Right turn-on-red | Allowed = 0 pts | Allowed = 0 pts | Allowed = 0 pts | Allowed = 0 pts |
| Intersection Crossing Distance | 3 lanes crossed = 0 pts | 4 lanes crossed = -5 pts | 3 lanes crossed = 0 pts | 3 lanes crossed = 0 pts |
| Leg Totals | 55 | 40 | 70 | 50 |
| Leg LOS | C | D | C | D |
| Intersection LOS | = (55 + 40 + 70 + 50) / 4 = 54 | | D | |

## 14.17 <u>Transit LOS</u>

### 14.17.1 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 14.9) 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*.

### 14.17.2 Transit LOS Criteria

LOS scoring threshold criteria for the transit mode is shown below in Exhibit 14-73. These are based on updated values of HCM Exhibit 18-2 and 18-3. The pedestrian LOS input has been converted from a range into an averaged single value for input into the final transit LOS equation.

**Exhibit 14-73 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 |

[1]The average score for LOS A is based on the minimum value of 0.00 and the highest score of 1.5.
[2]The average score for LOS F is based on the maximum value of 6.0 in HCM Equation 18-63 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 considered 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 18-56:

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

All of the following inputs are defaults with the exception of needing the Pedestrian LOS data in Section 14.9.

**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 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 14-74. 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 18-59 for computing the appropriate passenger loading factor.

**Exhibit 14-74 Passenger Load Factors[1]**

| Passenger to Seat Ratio | Passenger Load Factor($a_1$) |
|---|---|
| <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 18-59 |

[1]Derived from *Highway Capacity Manual 6th Edition* Equation 18-59

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 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 18-61, 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 sensitive[14] to the results and is ignored in this simplified method. The perceived travel time rate (HCM Equation 18-58) equation can be simplified with the above defaults and simplifications to:

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

Use the equation form $T_{ptt}$ (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.

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 18-57, 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 18-63. 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 14.9. Since the Pedestrian LOS from Section 14.9 is based on a probability of the entire range, the average LOS score is used for $I_p$ in Exhibit 14-67, which is based on HCM Exhibit 18-3. If the Pedestrian LOS results in a range of levels, then the appropriate Pedestrian LOS scores in the second column in Exhibit 14-67 should be averaged together. The Transit LOS score ($I_t$) is then compared to the transit score range in the third column in Exhibit 14-73 to determine the final LOS for the directional segment.

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

**Example 14-14 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:

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

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

$S_{t30}$ = (segment length in feet / 5280 feet per mile) / (travel time in minutes / 60 minutes per hour)
= (6150 ft / 5280 ft/mi) / (4 min / 60 min/hr)
= 1.165 mi / 0.067 hr
= 17.48 mph

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.

$S_t$ = 8.75(0.67) + 17.48(0.33)
= 11.63 mph

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

$F_h = 4.00e^{-1.434/(v_s+0.001)}$
$= 4.00e^{-1.434/(6+0.001)}$
= 3.15

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

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

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

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

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 14-67 of 3.00.

$$I_t = 6.0 – 1.5 (F_h * F_{tt}) + 0.15I_p$$
$$= 6.0 – 1.5 (3.15 * 0.85) + 0.15(3.00)$$
$$= 6.0 – 4.02 + 0.47$$
$$= 2.43$$

Comparing the final LOS score with Exhibit 14-67 shows this segment to have a Transit LOS B (both directions the same).

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

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

## 14.18 Transit Capacity and Quality of Service Manual

### 14.18.1 Overview

The *Transit Capacity and Quality of Service Manual* (TCQSM), 3rd edition (TCRP Report 165), is a comprehensive reference manual used to assist with public transit analysis and methods and is a companion document to the HCM. The purpose of this section is to give a high-level synopsis of the manual as generally it is not as well-known as the HCM.

Generally, the TCQSM is used when trying to determine the capacity and performance of transit services (i.e. bus, light and heavy rail, ferry etc.) rather than just the impact of the vehicles on the roadway system. Transit outside of the roadway right-of-way (i.e. bus rapid transit busways, heavy rail commuter service etc.) would need to be analyzed using TCQSM methodologies. While quality of service methods is still in the TCQSM, most of this analysis is covered already in other portions of Chapter 14, so there is more coverage of advanced transit topics.

Previous editions contributed service frameworks and filled in gaps in transit capacity and quality of service knowledge. This edition focuses on providing tools and techniques to evaluate critical aspects of transit operations which include analyzing capacity, speed, reliability, and quality of service for all transit needs on a consistent basis. These methodologies can be applied across different transit modes, such as buses and trains, and are important for decision-making in transit planning, infrastructure investment, and policy development. TCRP Project A-47, in progress as of 2025, was developing the TCQSM 4th edition, with publication expected in 2026.

### 14.18.2 Key Concepts

The key concepts in the TCQSM are quality of service, capacity, and speed/reliability. These key concepts are central to understanding and applying the manual's methodologies.

Quality of service refers to the overall experience of transit service as measured or perceived by the passenger. It involves factors like comfort, frequency, reliability, and convenience. While passengers typically seek high levels of service, the transit agency must balance this desire with practical constraints, such as budget limitations and demand. The quality of service is also influenced by the operational decisions of a transit agency, such as where and how often service is provided, and the level of service that is affordable or reasonable for the agency to deliver. Furthermore, these decisions are generally shaped by the agency's goals and objectives, like providing equitable access, reducing congestion, or improving sustainability.

Capacity is the maximum number of passengers, transit vehicles, or both, that can pass a given point in a specified time and under specific conditions. In the TCQSM, different types of capacity are discussed, focusing on both vehicles and passengers, depending on the type of transit system. In general, transit service should be designed for a practical ("design") capacity that reflects normal operating conditions and allows for some operational irregularity, rather than a maximum capacity achievable only under ideal conditions. Capacity is critical for understanding how much demand a system can handle, influencing decisions about route design, vehicle frequency, and infrastructure investment. Capacity limits are essential for planning purposes, helping agencies assess whether their systems will operate at or beyond their capacity.

Speed (or travel time) and reliability are vital for passenger satisfaction and influence overall ridership. Speed refers to how quickly a transit vehicle travels between locations, whereas reliability concerns how consistently the service adheres to its schedule. Both speed and reliability directly impact operating costs. For example, longer travel times or less reliable service require more vehicles and larger budgets to maintain service levels. These factors also influence the transit agency's ability to meet passenger demand efficiently. The manual highlights that factors impacting capacity also influence speed and reliability. For example, if the number of vehicles on a street approaches its capacity, it may lead to delays or slower travel times, reducing overall service quality.

These three concepts are fundamental to understanding how transit systems operate and how they can be evaluated. The TCQSM emphasizes that these concepts are interconnected and affect each other in various ways. For instance, decisions about capacity (such as increasing the number of vehicles on a route) can influence both speed (reducing delays) and reliability (increasing on-time performance). Similarly, increasing quality of service often requires adjustments in capacity, speed, and reliability to meet passenger needs effectively.

### 14.18.3 Manual Organization

The TCQSM is arranged into concepts and methods chapters, similar to the HCM. These chapters work together to provide both foundational knowledge and practical methodologies for evaluating transit systems' capacity, quality of service, and related performance measures.

Chapter 1 is a user's guide to the rest of the manual serving as an introduction to the chapters and concepts. This APM section is a summary of that chapter.

Concept Chapters 2 – 4 lay the groundwork by defining essential terms and presenting key ideas that are fundamental to understanding transit capacity, speed, reliability, and quality of service. Method Chapters 5 – 10 focus on providing computational methods for evaluating quality of service, transit capacity, and other performance metrics.

**Mode and Service Concepts (Chapter 2):** This chapter introduces the major types of transit modes addressed by the TCQSM—fixed route bus transit, demand-responsive transit (DRT) such as paratransit (“dial a ride”), and rail transit - along with their sub-modes (e.g., light rail, heavy rail, commuter rail). It also covers vehicle types and the general characteristics of fixed route and DRT services.

**Operations Concepts (Chapter 3):** This chapter explores how transit speed, capacity, and reliability are influenced by factors within and outside a transit agency's control. It covers topics like passenger demand patterns, dwell times, operating environments, and stop/station characteristics. Graphs are provided to show the relative impacts of these factors.

**Quality of Service Concepts (Chapter 4):** This chapter focuses on the role of transit in a community and the different perspectives of stakeholders regarding service performance. It emphasizes the passenger’s point of view on quality of service, introducing key factors that influence satisfaction, such as availability, comfort, and convenience. The chapter also introduces the quality-of-service framework that will be expanded upon in Chapter 5.

**Quality of Service Methods (Chapter 5):** This chapter provides methods for evaluating fixed-route and demand-responsive transit availability, comfort, and convenience from the passenger's perspective. It also introduces a method for evaluating the transit level of service in a multimodal context.

**Bus Transit Capacity (Chapter 6):** This chapter discusses factors that affect bus capacity, speed, and reliability, including infrastructure and operational measures that can improve bus performance. It includes methods for evaluating bus capacity and speed and offers general information on the causes of bus unreliability, though no detailed forecasting methods are provided.

**Demand-Responsive Transit (Chapter 7):** This chapter covers the factors influencing DRT capacity and presents approaches and resources for estimating the number of vehicles and service hours required to meet DRT demand.

**Rail Transit Capacity (Chapter 8):** This chapter focuses on rail-specific capacity concepts, including train control, signaling, and operations. The chapter provides computational methods for estimating rail transit system capacity, with detailed guidance on measuring input values for calculations.

**Ferry Transit Capacity (Chapter 9):** This chapter describes ferry service-specific aspects like service planning, infrastructure, and scheduling. It includes methods for estimating ferry vessel capacity, including passenger and vehicle accommodation.

**Station Capacity (Chapter 10):** This chapter covers the design and capacity of transit stations, including access for people with disabilities, emergency evacuation, and security. The chapter discusses different types of stations and stops, and it provides methods for evaluating station features such as passenger circulation, vehicle circulation, and bike storage.

### 14.18.4 Applications

The TCQSM supports a comprehensive range of transit agency activities—from high-level policy and planning decisions to detailed operational and design analyses. One of the manual's most powerful contributions is its support for passenger-focused quality of service standards, evaluation, planning, and design. This allows strategic thinking around service quality from the passenger's perspective, enabling data-informed, rider-centered decisions.

Potential applications of the TCQSM methodologies include:

- **Transit mode guidance:** This includes transit mode concepts, operations, terms, and effects of transit treatments (i.e. transit signal priority).
- **Evaluation**: The methodology can be used to analyze and diagnose operational issues.
- **Comparisons**: Different transit modes (i.e. bus vs. light rail), alignments, frequencies, or fare collection types among others can be compared to answer "what-if" kinds of questions on the overall operations and quality of service.
- **Planning**: Either sketch-level or detailed operational methodologies can be applied to analyze a particular mode or alternative.
- **Design:** The manual can be used for supporting a wide range of sizing and capacity applications such as numbers of bus bays needed, platform lengths, passenger circulation areas, stop spacing, or line capacities.