Appendix A: LTS Methodology

Technical Memorandum

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Subject	Level of Traffic Stress Results	**Project no.**	12575135

1. Introduction

Level of traffic stress (LTS) is a suitability rating system from the perspective of different subsets of the population, which measures the perceived comfort, safety and convenience associated with bicycling or walking in or adjacent to vehicle traffic. Studies have shown that 60 percent of the population will be deterred from bicycling or walking if an active transportation facility features high levels of traffic stress and they will only choose the routes with the highest levels of perceived safety.[1] The less stressful the experience, and the lower the LTS score, the more likely bicycling or walking is to appeal to a broader segment of the population.

A bicycle and pedestrian network will attract greater numbers of residents, employees and visitors of all ages and abilities if it is designed to reduce the level of stress associated with potential conflicts with motor vehicles and safely connect people to their destinations. Facilities that provide greater separation between vehicle traffic and people walking and bicycling, as well as minimize the potential for stressful conflicts between these road user groups, will result in the lowest levels of traffic stress and highest comfort using the facility.

The level of traffic stress (LTS) analysis for the City of Chico Active Transportation Plan analyzes the traffic stress associated with bicycling in the City of Chico. Bicycle LTS analysis employs the level of traffic stress methodology described in the Oregon Department of Transportation (ODOT) "Analysis Procedures Manual Version 2, Chapter 14, Multimodal Analysis," (October 2020). The methodology presented there is based on the paper, *Low Stress Bicycling and Network Connectivity,* Report 11-19, published by the Mineta Transportation Institute (MTI) (May 2012). The LTS methodology as reported by ODOT's latest Multimodal Analysis Procedure Manual includes updates to the methodology that was originally published by MTI. The updated methodology includes analysis criteria for new bicycle facility types that have become more popularly used since the original report was published and considers additional infrastructure types not analyzed under the MTI methodological approach.

This memorandum describes the LTS methodology and analysis criteria in additional detail. For internal review of the results of the analysis, an internally accessible Atlas web map can be accessed **here**.

[1] "Four Types of Transportation Cyclists in Portland," Geller, 2006

2. Methodology

The bicycle level of traffic stress methodology considers a variety of roadway infrastructure characteristics to determine the LTS score of a roadway or intersection, including:

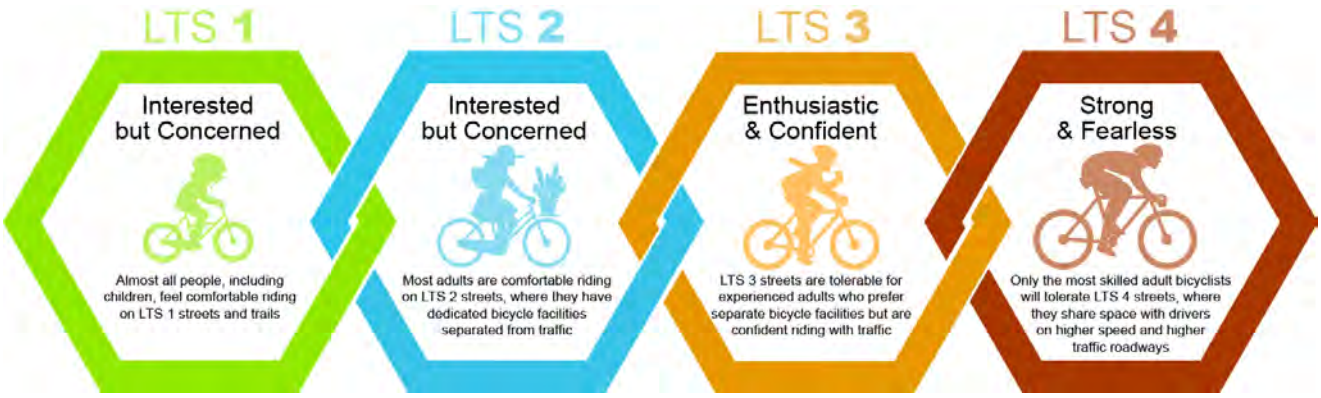
- level of separation from vehicular traffic
- street width (number of lanes), daily traffic volumes and/or functional classification
- presence and width of bike lanes, parking lanes, medians and turn lanes
- frequency of bike lane blockage
- speed limit or prevailing speed of adjacent street or streets being travelled along or crossed
- intersection control type

Level of traffic stress scores are governed by the worst-case principle, meaning that the highest stress score associated with analyzed criteria will determine the LTS score of the overall segment, with LTS 1 being the lowest stress and LTS 4 being the highest stress. The application of these criteria specific bicycle level of traffic stress analysis of the City of Chico's streets and bikeways is described below.

1.1 Bicycle Level of Traffic Stress

Figure 1 describes each LTS score by bicycle user type or category. 60 percent of the population falls within the interested but concerned LTS 1 or LTS 2 categories. Bicycle level of traffic stress analyzes roadway segments, intersection approaches and intersection crossings, and the worst score among the three analysis categories determine the overall LTS score of the overall segment.

Figure 1: Level of Traffic Stress by User Category



Segments

The criteria for analyzing Bicycle LTS is broken into three categories:

- physically separated paths or lanes, such as Class I shared-use paths or Class IV cycle tracks
- streets with standard bicycle lanes, such as Class II or Class II buffered bicycle lanes
- streets without bicycle lanes, also referred to as mixed traffic

Physically separated paths or lanes are generally assigned LTS scores of one due to the greater separation from vehicular traffic, while the LTS scores associated with the other two categories vary based on a variety of factors.

The criteria for analyzing the segment LTS of streets with Class II bicycle lanes are presented in Table 1 and

Table 2, which are separated by segments that feature an adjacent parking lane, and those that do not. As shown, the segment BLTS score considers bicycle lane width, presence and parking lane width, speed and lanes per direction.

Table 1: 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).

Table 2: BLTS Criteria for Segment with Bike Lane, no Adjacent Parking Lane

Prevailing or Posted Speed	1 Lane per direction				≥2 lanes per direction	
	≥ 7' bike lane (buffered bike lane)	5.5' – 7' bike lane	≤ 5.5' bike lane	Frequent bike lane blockage[1]	≥ 7' bike lane (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).

Table 3 and Table 4 presents the criteria for analyzing segments without bicycle lanes that require a bicyclist to ride with mixed traffic. If daily traffic volume is available, then that data should be considered in the analysis. If daily volume data is not available, functional classification should be analyzed in place of daily traffic volumes. As shown, lower speed roadways and higher speed roadways are analyzed differently, but both categories consider presence of a marked centerline, number of through lanes per direction, daily traffic volume or functional classification, and speed. While daily traffic counts from 2017/2018 and forecast year 2035 are available for some locations in Chico, this is not the case for many locations in the city[2]. To remain consistent in the analysis criteria, functional class was considered rather than ADT for this analysis. In some cases, traffic counts, where available, were considered to assess if arterial roadways with two through lanes per direction should be analyzed above or below the 8,000 ADT threshold referenced in Table 3 and Table 4.

[2] City of Chico Traffic Counts, https://chico.ca.us/post/traffic-counts-0

Table 3: BLTS Criteria for Segments in Mixed Traffic - 30 mph or less

Number of Lanes	ADT (Average Daily Traffic)	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+ through lanes per direction	Any ADT	Arterial	BLTS 3	BLTS 3	BLTS 4

Table 4: BLTS Criteria for Segments in Mixed Traffic - 35 mph or more

Number of Lanes	ADT (Average Daily Traffic)	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+ through lanes per direction	Any ADT	Arterial	BLTS 4	BLTS 4	BLTS 4

Intersection Approaches

Right-Turns

The Bicycle LTS criteria for analyzing intersection approaches in Chico corridor considers locations with right-turn lanes at the intersection approach, as well as the configuration, lane length, alignment, vehicle turning speed or curb radius at the intersection corner. Only locations with a dedicated right-turn lane are analyzed herein. If there are locations known to be high stress based on local data that are not identified as such using this approach, those locations should be adjusted to reflect actual conditions. To identify right-turn approaches in Chico, the approach locations identified in the 2019 Chico Bicycle Plan LTS analysis were examined and additional locations not identified in the 2019 dataset were added where applicable.

Figure 2 presents the types of right-turn lane configurations analyzed to assess the BLTS of intersection approaches where bike lanes are present. Approaches with right-turn lanes where no bike lanes are present

are considered high stress unless the right-turn lane is less than 100 feet including the lane taper or is rarely used. Additional high stress scenarios include approaches with turn lanes longer then 300 feet, and locations with dual turn lanes. The criteria for analyzing intersection approach BLTS at locations with right-turn lanes with bike lanes is shown in Table 5.

Figure 2: Right Turn Lane Configuration Types[3]

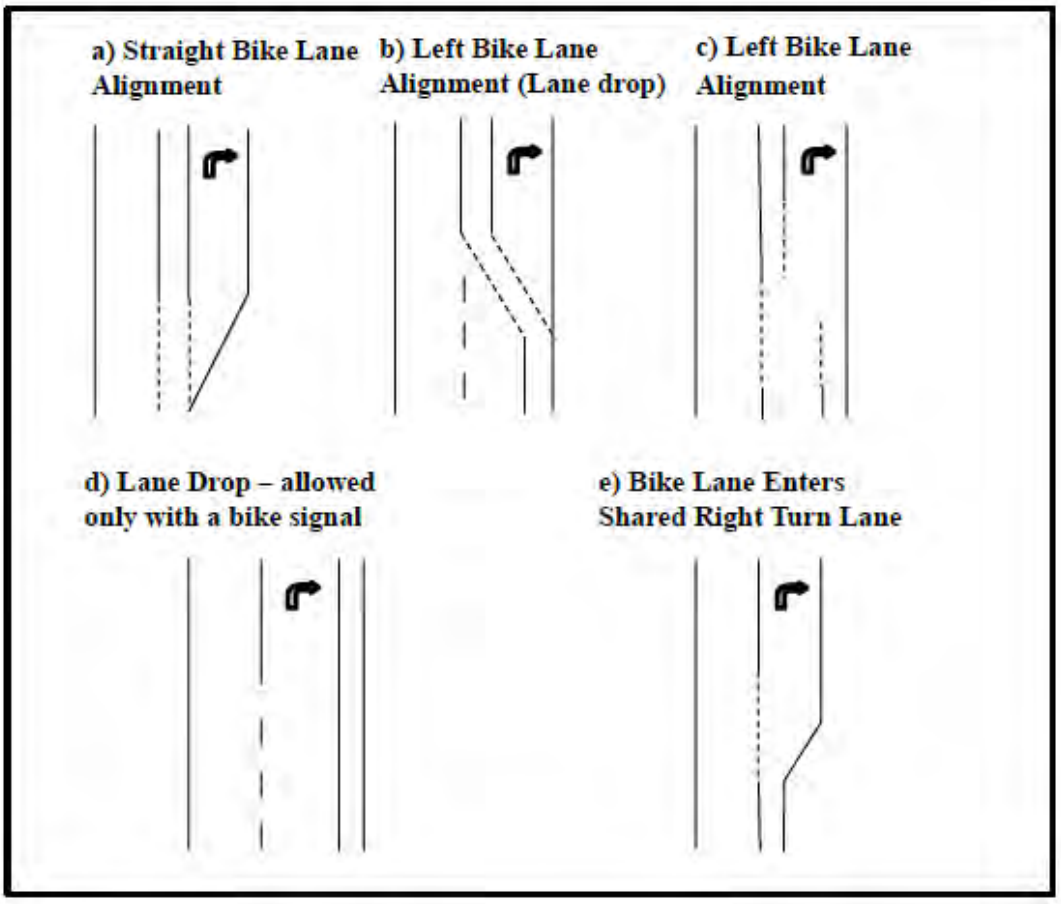


Table 5: BLTS Criteria for Intersection Approaches with Right-Turn Lanes[1]

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

[3] Oregon Department of Transportation (ODOT), "Analysis Procedures Manual Version 2, Chapter 14, Multimodal Analysis," (October 2020).

1 Assign BLTS 4 for any lengths, speeds, or configurations (e.g. dual right turns or Exhibit d if bike signal is not present) not shown in the table.
2 For the purposes of this methodology, the right turn lane length include 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.

Left-Turns

The original LTS methodology published by MTI did not consider the effect of left-turns on an intersection approach. However, the ODOT methodology suggests an approach for considering left-turn lanes in locations where a route requires a left-turn and typically uses the vehicle lane rather than a two-stage movement for facilitating the left-turn. To identify left-turn locations required by a bicycling route and analyzed in this analysis, the key corridor routes proposed in the 2019 Chico Bicycle Plan were examined[4]. Left turn lanes at locations where a bicyclist would initiate a left turn to a key corridor route and from a key corridor route were considered.

Table 6 presents the criteria for analyzing the left turns considered in this analysis. For locations where bicyclists use a lower-stress two-stage movement such as with a bike box or left-turn queue box markings at a low-speed signalized intersection, then the left-turn approach LTS is scored as LTS 1 and the crossing LTS score will determine the stress of the movement. High-speed intersections should include additional treatments to provide the lowest-stress bicycling experience.

Table 6: BLTS Criteria for Intersection Approaches with Left-Turn Lanes [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)

Intersection Crossings

The Bicycle LTS criteria for analyzing intersection crossings considers only unsignalized intersections, because signalized intersections usually do not create a barrier as the signal generally provides adequate protections. BLTS 1 is assumed for the crossing movements at signalized intersections unless the location is known to create a barrier for the user. All signalized intersections analyzed herein were assigned a BLTS score of 1 due to no available data to suggest otherwise. If there are locations known to feature issues causing a barrier, the LTS score of the locations should be adjusted to reflect this information. Barriers could result from difficulty in triggering signal detection, or an intersection may not have the proper markings, ramps, and/or push-button accommodations for bicyclists. In locations such as these, the bicyclist is often forced to use the crosswalk like a pedestrian and should be assigned BLTS 2. Engineering judgement should be used for assigning stress levels higher than BLTS 1 at signalized intersections.

Table 7 and Table 8 present the BLTS criteria for analyzing unsignalized crossing locations, which considers the total number of through lanes, daily traffic volume or functional classification and speed. Locations with a median refuge can lower traffic stress by providing space for bicyclists if they are unable to cross before oncoming traffic is approaching. Thus, they are analyzed differently, as shown in Table 7 and Table 8.

[4] https://www.csuchico.edu/sustainability/_assets/documents/2019-city-of-chico-bike-plan.pdf

Table 7: 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 (daily traffic volume)					
	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

Table 8: 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 [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.