Proposed Methodology for Calculating & Mapping Bicycle and Pedestrian Levels of Traffic Stress (LTS) in the Greater Humboldt Bay Area

for the

Humboldt County Association of Governments
Humboldt Multimodal and Vibrant Neighborhoods Project

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Introduction & General Approach to Level of Traffic Stress

The Humboldt Multimodal and Vibrant Communities Project ("project") is a planning, assessment and outreach project funded by a Caltrans Sustainable Transportation Planning Grant and led by the Humboldt County Association of Governments (HCAOG). A major component of the project is to develop a level of traffic stress (LTS) methodology, and apply that methodology to the streets and roads of the Greater Humboldt Bay/Wigi Area. The Greater Humboldt Bay/Wigi Area, as defined in the grant Scope of Work (SOW), includes Eureka (Jaroujiji), Arcata (Goudi'ni), Bayside, McKinleyville, Fortuna, Manila, Samoa, Fairhaven, Cutten, King Salmon, and Loleta including the Wiyot Tribe Table Bluff Reservation.

LTS is a metric for assessing the user experience of bicyclists and/or pedestrians on various transportation facilities, and placing those experiences in context of the level of discomfort or stress different kinds of users will tolerate. Specifically, LTS methodologies today most often use numerical scoring on a scale of 1 to 4, where LTS 1 "is meant to be a level that most children can tolerate," LTS 2 can be "tolerated by the mainstream adult population," and LTS 3 and 4 "represent greater levels of stress."[1]

In order to support the goals of the grant, as well as HCAOG's broader goals as represented by the adopted Regional Transportation Plan (RTP, also known as "Variety in Rural Option of Mobility: 2022-2042," or "VROOM"), the LTS methodology must meet a number of key criteria, including:

- **Simple and easy to replicate.** The methodology is initially intended to be applied to the Greater Humboldt Bay Area. Later, the methodology will be applied to the rest of Humboldt County in order to meet the RTP target of completing a countywide "Low-Traffic-Stress and connectivity analysis" by 2026. The SOW states that the methodology will be a "standardized LTS analysis that can be repeated inexpensively." Therefore, the methodology should be simple and easy to replicate. The level of complexity and cost of applying any given LTS methodology depends largely—although not entirely—on the amount of data collection required. If methodologies

[1] Mekuria, Maaza C., Peter G. Furth and Hilary Nixon. 2012. Low-Stress Bicycling and Network Connectivity: p.1. Mineta Transportation Institute. https://transweb.sjsu.edu/sites/default/files/1005-low-stress-bicycling-network-connectivity.pdf

demand large amounts of data which are not readily available, it may be necessary to make certain assumptions rather than mount extensive data collection efforts.

- **Supported by high-quality evidence.** Initial LTS measures were developed to assess how many bicyclists and potential bicyclists will tolerate various conditions—or, put another way, how many bicyclists will tend to avoid certain facilities based on "a combination of perceived danger and other stressors."[2] Pedestrian LTS measures developed later have the same purpose. In order to produce useful results, the LTS methodology must use high-quality evidence correlating the calculated LTS with actual user experience.
- **Supportive of equity goals.** Transportation equity is a central concern of HCAOG (and CRTP). The RTP, *VROOM 2022-2042*, has a "Safety and Health" objective to, in part: "Increase safety especially for the most vulnerable users (elderly, youth, pedestrians, bicyclists, people with disabilities)." VROOM Policy Streets-10: Safe Routes to School and Transit, among others, also strives for equitable transportation safety. The LTS methodology is intended to reflect not only the traffic stress that children can tolerate, but also that older people, people with disabilities, and other potentially vulnerable or sensitive populations can tolerate.
- **Supportive of other adopted goals.** This LTS analysis is being pursued to support broader adopted Safe and Sustainable Transportation Targets in the RTP, including reducing greenhouse gas emissions and fossil fuel consumption, dramatically increasing the active transportation mode share (which includes transit), and correspondingly decreasing car-based vehicle miles traveled (VMT). The RTP goal of mapping LTS in Humboldt County corresponds to the "percent mode shift" performance measure. The idea is that to encourage more bicycling (or walking or rolling), conditions must provide an experience that more people find "low-stress." Therefore, to meet the needs of HCAOG and local jurisdictions, the LTS methodology aims to provide real insights as to where and what improvements will help induce mode shift and reduce VMT.

Considering these criteria for a successful LTS methodology, we propose an approach that starts with two general principles:

1. **Utilize existing, well established and validated methodologies for bicycle and pedestrian LTS.** Using validated methodologies will help ensure that the resulting LTS calculations reflect actual user experience and therefore support related goals for increasing mode shift, and reducing VMT and emissions. However, it should be noted that no single methodology is supported by all validation studies, and there is no established consensus on a pedestrian LTS methodology. Additionally, we propose some simplifications and assumptions to reduce data collection required.
2. **Define high traffic stress as level of traffic stress 3 and 4 (LTS 3 and LTS 4) for the purposes of the RTP's "Low-Traffic-Stress and connectivity analysis."** The RTP calls for calculating the "percent of all road miles that are connection nodes at Low Traffic Stress Levels 1 or 2." HCAOG's goal of ensuring safety and utility for all users, including children and vulnerable adult populations, supports mapping LTS 1 and LTS 2 separately. However, LTS 3 and LTS 4 are tolerated by a relatively small proportion of the overall population, so we believe the benefits of differentiating between them are outweighed by the data collection and analysis costs. Lumping LTS 3 and LTS 4 together as "high traffic stress" facilities will make the methodology simpler, less expensive, and more easily replicable.

The following sections add detail about the proposed bicycle and pedestrian LTS methodologies. The accuracy and representativeness of the results of this methodology will rely in large part on the choices

[2] Mekuria et al. 2012, p.1

to either make simplifying assumptions or collect actual data on a variety of LTS criteria. Further discussion with HCAOG, Caltrans, local agencies, and other project partners is needed before deciding which assumptions are reasonable and where data collection efforts should be focused.

Bicycle Level of Traffic Stress

The bicycle LTS concept was first developed by Mekuria, Furth and Nixon in 2012.[3] Furth has further refined the bicycle LTS criteria for road segments several times in the intervening years; he published the most recent version in 2022.[4] The criteria for intersections have not been updated since 2012, with the exception of a proposed set of criteria for roundabouts in 2014 (not included in the original 2012 publication).[5]

Despite mixed validation results, Furth's criteria are the most widely used, best studied, and most well validated measure of bicycle LTS. They were used by Caltrans for the development of district Active Transportation Plans,[6] including the local District 1 plan. Therefore, we propose to use them here as well.

Furth and his colleagues developed the bicycle LTS criteria based on studies of public attitudes toward bicycling that show that the majority of Americans are "interested but concerned," meaning they might bicycle more if they were more comfortable doing so.[7] Furth's LTS criteria represent the original, most widely used approach to assessing traffic stress for bicyclists.

The Furth et al approach is also the most well researched. A number of studies have tested the criteria against real world bicyclist behavior. For example, studies in Oregon[8] and Ohio[9] both found that this LTS scheme partly predicted bicyclist travel behavior, but not in all analyses. Another study found that Furth's LTS 4 was correlated with bicycle crashes with more serious injuries.[10]

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[3] Mekuria et al. 2012

[4] See https://bpb-us-w2.wpmucdn.com/sites.northeastern.edu/dist/e/618/files/2014/05/LTS-Tables-v2.2.pdf

[5] See https://bpb-us-w2.wpmucdn.com/sites.northeastern.edu/dist/e/618/files/2014/05/LTS-Criteria-for-Modern-Roundabouts.pdf

[6] Caltrans, Toole Design, Cambridge Systematics and WSP. 2019. California Active Transportation Plans Data Framework and Applications.

[7] The classification of people according to their attitudes toward bicycling was first proposed around 2006 by Roger Geller at the Portland Bureau of Transportation. It has since been validated in nationwide surveys; see for example: Dill, Jennifer and Nathan McNeil. 2016. Revisiting the four types of cyclists: findings from a national survey. Transportation Research Record: Journal of the Transportation Research Board 2587(1). https://journals.sagepub.com/doi/abs/10.3141/2587-11

[8] Wang, Haizhong, Matthew Palm, Chen Chen, Rachel Vogt and Yiyi Wang. 2016. Does bicycle network level of traffic stress (LTS) explain bicycle travel behavior? Mixed results from an Oregon case study. Journal of Transport Geography 57. https://www.researchgate.net/profile/Haizhong-Wang/publication/308736761_Does_bicycle_network_level_of_traffic_stress_LTS_explain_bicycle_travel_behavior_Mixed_results_from_an_Oregon_case_study/links/5a090f57aca272ed279ffa1d/Does-bicycle-network-level-of-traffic-stress-LTS-explain-bicycle-travel-behavior-Mixed-results-from-an-Oregon-case-study.pdf

[9] Wang, Kailai, Gulsah Akar, Kevin Lee and Meredyth Sanders. 2020. Commuting patterns and bicycle level of traffic stress (LTS): Insights from spatially aggregated data in Franklin County, Ohio. Journal of Transport Geography (86). https://www.sciencedirect.com/science/article/abs/pii/S0966692319309081

[10] Chen, Chen, Jason C. Anderson, Haizhong Wang, Yinhai Wang, Rachel Vogt and Salvador Hernandez. 2017. Accident Analysis and Prevention (108). https://research.engr.oregonstate.edu/hernandez/sites/research.engr.oregonstate.edu.hernandez/files/how_bicycle_level_of_traffic_stress_correlate_with_reported_cyclist_accidents_injury_severities_a_geospatial_and_mixed_logit_analysis.pdf

Of interest for equity considerations, recent studies have focused specifically on validating Furth's LTS 1 as an accurate representation of comfort for children (and their parents). A Denver, Colorado study largely validated LTS 1, finding that parents were mostly willing to allow their children to use LTS 1 facilities, and even allowed them to use some Level 2 facilities.[11] However, a New Jersey study found that many parents were unwilling to let their children use many LTS 1 facilities. The New Jersey study noted that how parents assessed traffic stress for their children correlated with their own attitudes toward bicycling.[12]

Street and Road Segments

We propose to use Furth's most recent (2022) criteria for assessing segments. [13] The tables are modified with minor changes to formatting or wording. As discussed above, per our general principle #2, we define LTS 3 and LTS 4 as "high stress." Note that per Mekuria et al., separated (Class I) trails and protected (Class IV) bikeways are considered to have LTS 1.

Table 1: Bicycling in mixed traffic (i.e., no bike-only facility)								
		Prevailing speed (mph)						
Number of lanes	*Average daily traffic*	*0-23.5*	*23.5-28.5*	*28.5-33.5*	*33.5-38.5*	*38.5-43.5*	*43.5-48.5*	*48.5+*
Unlaned 2-way street (no centerline)	0-750	LTS 1	LTS 1	LTS 2	LTS 2	High	High	High
	751-1500	LTS 1	LTS 1	LTS 2	High	High	High	High
	1501-3000	LTS 2	LTS 2	LTS 2	High	High	High	High
	3001+	LTS 2	LTS 2	High	High	High	High	High
2-way with 1 lane per direction and centerline, or wide* 1-way, 1-lane	0-1000	LTS 1	LTS 1	LTS 2	LTS 2	High	High	High
	1001-1500	LTS 2	LTS 2	LTS 2	High	High	High	High
	1501+	LTS 2	High	High	High	High	High	High
Narrow* 1-way, 1-lane	0-600	LTS 1	LTS 1	LTS 2	LTS 2	High	High	High
	601-1000	LTS 2	LTS 2	LTS 2	High	High	High	High
	1001+	LTS 2	High	High	High	High	High	High
2 thru-lanes per direction	0-8000	High	High	High	High	High	High	High
	8001+	High	High	High	High	High	High	High
3+ thru-lanes per direction	Any ADT	High	High	High	High	High	High	High
Note: *A one-way street is "narrow" if it is less than 30-ft wide with parking on both sides, less than 22-ft wide with parking on one side, or less than 15-ft wide with no parking. Otherwise, it is "wide."								

Note: For HCAOG and CRTP's purposes, LTS 3 and LTS 4 are identified as "high" stress.

[11] Ferenchak, Nicholas N. and Wesley E. Marshall. 2020. Validation of bicycle level of traffic stress and perceived safety for children. Transportation Research Record 1-10.

[12] Ralph, Kelcie and Leigh Ann Von Hagen. 2019. Will parents let their children bike on "low stress" streets? Validating level of traffic stress for biking. Transportation Research Part F: Psychology and Behavior (65). https://www.sciencedirect.com/science/article/abs/pii/S136984781830740X

[13] See https://bpb-us-w2.wpmucdn.com/sites.northeastern.edu/dist/e/618/files/2014/05/LTS-Tables-v2.2.pdf

Table 2: Bicycling in conventional bike lanes, advisory bike lanes, and shoulders not adjacent to a parking lane							
		Prevailing speed (mph)					
Number of lanes	*Bike lane width*	*0-28.5*	*28.5-33.5*	*33.5-38.5*	*38.5-43.5*	*43.5-48.5*	*48.5+*
One thru-lane per direction or contraflow lane	6+ ft	LTS 1	LTS 1	LTS 2	High	High	High
	Less than 6 ft	LTS 2	LTS 2	LTS 2	High	High	High
2 thru lanes per direction	6+ ft	LTS 2	LTS 2	LTS 2	High	High	High
	Less than 6 ft	LTS 2	LTS 2	LTS 2	High	High	High
3+ lanes per direction	Any width	High	High	High	High	High	High

Notes:

1. If bike lane is frequently blocked (as may be the case in commercial areas), or if parking is allowed in an advisory lane, use mixed traffic criteria.
2. Minimum bike lane width is 4 ft next to a curb and 3.5 ft next to a road edge or discontinuous gutter seam. For narrower bike lanes, use mixed traffic criteria.
3. Bike lane width includes any marked buffer next to the bike lane; also, add 2 ft if road has 1 thru-lane per direction and a central 2-way turn lane.
4. Use mixed traffic criteria if it would result in lower LTS.

Note: For HCAOG and CRTP's purposes, LTS 3 and LTS 4 are identified as "high" stress.

Table 3: Conventional bike lanes and advisory bike lanes alongside a parking lane					
		Prevailing speed (mph)			
Number of lanes	*Bike lane reach = bike + parking lane width*	*0-28.5*	*28.5-33.5*	*33.5-38.5*	*38+*
One thru-lane per direction or contraflow lane	15+ ft	LTS 1	LTS 2	LTS 2	High
	<15 ft	LTS 2	LTS 2	High	High
1-way multi-lane	15+ ft	LTS 2	High	High	High
	<15 ft	High	High	High	High
2-way, 2 lanes per direction	15+ ft	LTS 2	High	High	High
	<15 ft	High	High	High	High
Other 2-way multi-lane	Any	High	High	High	High

Notes:

1. If bike lane is frequently blocked (as may be the case in commercial areas), use mixed traffic criteria.
2. Minimum bike lane reach is 12 ft; for narrower reach, use mixed traffic criteria.
3. Bike lane reach includes any marked buffer next to the bike lane; also, add 2 ft if road has 1 thru lane per direction and a central 2-way turn lane.
4. Use mixed traffic criteria if it would result in lower LTS.

Note: For HCAOG and CRTP's purposes, LTS 3 and LTS 4 are identified as "high" stress.

Intersections and Crossings

A high-stress intersection can change the character of what would otherwise be a low-stress route, so characterizing intersection LTS is important. The adopted RTP also calls for calculating the "number of barriers to low-stress bike/ped transportation." A high-stress road or street crossing is one type of barrier to low-stress transportation; thus, the RTP provides another reason to assess intersection LTS. We propose, for the purposes of this project, using the unsignalized crossing LTS of the segment being crossed to assess bicycle crossing LTS of a segment outside of an intersection is (see Table 4).

Mekuria et al. (2012) assume that signalized intersections "pose no traffic stress to cyclists." We disagree. As the National Association of City Transportation Officials (NACTO) points out, most bike-vehicle conflicts occur at intersections, and NACTO therefore acknowledges the need to implement safer intersection design strategies for bikes.[14] In the absence of established LTS criteria for signalized intersections, we propose focusing on what is generally the highest stress intersection maneuver: the left turn. Specifically, we propose classifying any signalized intersection with a bicycle left-turn improvement (e.g., protected intersection, bike box, or bike priority signal) as LTS 1, while classifying signalized intersections lacking any such improvements as "high stress."

We propose to use the original Mekuria et al. (2012) criteria for unsignalized intersections. The following table is from Furth[15] (summarizing Mekuria et al.), with lightly modified formatting.

Table 4: Bicycling at unsignalized crossings			
a. No Crossing Island	*Width of Street Being Crossed*		
Speed Limit or Prevailing Speed	*Up to 3 lanes*	*4-5 lanes*	*6+ lanes*
Up to 25 mph	LTS 1	LTS 2	High
30 mph	LTS 1	LTS 2	High
35 mph	LTS 2	High	High
40+ mph	High	High	High
b. With Crossing Island	*Width of Street Being Crossed*		
Speed Limit or Prevailing Speed	*Up to 3 lanes*	*4-5 lanes*	*6+ lanes*
Up to 25 mph	LTS 1	LTS 1	LTS 2
30 mph	LTS 1	LTS 2	High
35 mph	LTS 2	High	High
40+ mph	High	High	High

Note: LTS 3 and LTS 4 are identified as "high" stress.

For roundabouts, we propose to use Furth's 2014 criteria. Using these criteria, when there is a "practical" bicycle sidepath around a roundabout, LTS is determined by the street crossings. (A practical sidepath by Furth's definition must be paved, be at least 6 ft wide, be offset no more than 30 feet from the roundabout edge, have no turns sharper than 90 degrees, allow a bicyclist to see within 10 feet of each crossing whether it is safe to cross without looking over their shoulder, and have direct ingress and egress from adjoining bicycle facilities.) Where there is no practical sidepath, LTS is determined by the criteria of riding in mixed traffic (Table 1).

The following tables are from Furth[16] lightly modified with "high" stress and wording.

[14] See https://nacto.org/publication/dont-give-up-at-the-intersection/
[15] See https://peterfurth.sites.northeastern.edu/level-of-traffic-stress/
[16] See https://bpb-us-w2.wpmucdn.com/sites.northeastern.edu/dist/e/618/files/2014/05/LTS-Criteria-for-Modern-Roundabouts.pdf

Table 5: Bicycling using a sidepath at a roundabout		
Type of entry/exit bicyclist crosses‡	*Non-tangential* entry or exit lane*	*Tangential* entry or exit lane*
Single entry lane into roundabout	LTS 1	LTS 2
Single exit lane from roundabout	LTS 1	LTS 2
Dual entry lane, non-tangential	LTS 1	High
Dual exit lane, non-tangential	High	High
Notes: *An entry or exit lane is tangential if a driver does not have to steer to the right to enter or exit the roundabout. If a driver has to steer to the right to enter the roundabout, the entry lane is non-tangential, and if a driver must steer to the right to exit the roundabout, the exit lane is non-tangential. ‡The crossing with the worst LTS determines the score for the roundabout.		

Note: LTS 3 and LTS 4 are identified as "high" stress.

Table 6: Bicycling in mixed traffic in a roundabout		
Number of circulating lanes in roundabout	*Average daily traffic (sum over all entry legs)*	*LTS*
1	4000 or less	LTS 1
1	4001 – 6000	LTS 2
1	>6000	High
2	Any	High

Note: LTS 3 and LTS 4 are identified as "high" stress.

Data Availability, Collection, and Assumptions

Applying the criteria listed above to this project will require accurate data about every street, road and highway segment in the Greater Humboldt Bay. Specifically, we will need data on:

- number of lanes,
- presence or absence of a centerline,
- overall street width,
- average daily traffic,
- prevailing speed,
- presence or absence of bike lanes and bike lane buffers,
- width of bike lanes and bike lane buffers,
- presence or absence of parking lanes, width of parking lanes,
- presence or absence of traffic signals,
- presence or absence of crossing islands, and
- a variety of detailed information about roundabouts.

The time and expense of assessing bicycle LTS for this project will depend largely on the availability of the required data. We assume that most of the required data will be available in usable form for most of the streets to be assessed, or that reasonable assumptions can be made (see table below). If data are not available and if reasonable assumptions cannot be made, then data must be collected specifically for this project either by field visits or utilizing available online satellite imagery and/or services such as Google StreetView. The more data must be collected specifically for this project, the greater the time and expense.

Table 7: Bicycle LTS data needs, sources & assumptions		
Type of Data Needed	*Potential Source(s)*	*Potential Assumptions if Data Are Unavailable*
Number of lanes	Local agencies, Caltrans	Local agencies may be able to provide reasonable assumptions based on functional classification, standard cross-sections, or other available data.
Centerline presence/absence		
Overall street width		
Average daily traffic	Local agencies, Caltrans	Models maintained by Caltrans or other agencies or private companies may be used if recent direct counts are not available.
Prevailing speed	Local agencies, Caltrans	If recent speed surveys are unavailable, speed limits may be substituted. We propose adding (at least) 2.5 mph to the speed limit to estimate prevailing speed.
Bike lane presence/absence	HCAOG bike map, local agencies, Caltrans	The HCAOG bike map was recently updated and ground-truthed by volunteers, so data should be reliable, especially when cross-referenced with information from local agencies and Caltrans.
Bike lane buffer presence/absence	HCAOG bike map, local agencies, Caltrans	Based on knowledge of local conditions, we propose assuming that there is no buffer in any given location unless there is information to the contrary.
Bike lane width	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on date of original installation and other local knowledge. If no additional information is available, we propose assuming a functional width of 4 feet. (Nominally wider bike lanes locally are often partly obstructed and/or include unrideable gutter pans, drains, etc.).
Bike lane buffer width	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge.
Parking lane presence/absence	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on standard cross-sections or other local knowledge.
Parking lane width		
Traffic signal presence/absence	Local agencies, Caltrans	For the relatively few traffic signals in our region, we believe Caltrans and local agencies have accurate data.
Crossing island presence/absence	Local agencies, Caltrans	We propose assuming that there is no island in any given location unless there is any information to the contrary.
Roundabouts	Local agencies, Caltrans, direct inspection	Some of the data required for roundabout LTS assessment are likely not available from agencies and will require direct inspection (such as whether there is a “practical” sidepath and whether a bicyclist must look over their shoulder before crossing). We view this as feasible due to the small number of roundabouts locally.

Pedestrian Level of Traffic Stress

Pedestrian LTS and the related concept of pedestrian level of service have received substantial attention from researchers. However, unlike with bicycle LTS, there is no consensus, in either academic literature or planning and engineering practice, on a particular form of pedestrian LTS.[17] As such, we propose using a version of the Oregon Department of Transportation's pedestrian LTS criteria,[18] which were also proposed for Caltrans' district Active Transportation Plans.[19] The Oregon pedestrian LTS scheme has the added advantage of mirroring the 4-tier rating system of Furth's bicycle LTS scheme, offering greater consistency between the bicycle and pedestrian LTS criteria.

When we considered potential simplifying assumptions or modifications to these criteria or simplifying assumptions, we also reviewed sources such as the Montgomery County (Maryland) Pedestrian Level of Comfort methodology,[20] the pedestrian traffic stress scheme proposed for European cities by Vogt et al.,[21] Raad and Burke's review of pedestrian level of service schemes,[22] and the naturalistic study of pedestrian stress levels by LaJeunesse et al.[23]

Street or Road Segments

We propose to follow the Oregon criteria for street or road segments. However, note that we have re-ordered the four sets of criteria to put criteria involving sidewalk width and land use context first. We have done this because we expect these data to be more widely available and to allow high stress segments to be "screened out" first, thereby avoiding more labor-intensive data collection related to metrics such as buffer type and width.

To save time and effort, we can first apply the criterion that requires the least data and/or triggers the highest LTS, which will obviate the need for further analysis and data collection. The first set of criteria we will apply are sidewalk width and condition. The following table is from Oregon Department of Transportation Exhibit 14-21

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[17] There is a current effort underway to develop a standardized pedestrian LTS. See https://www.pedbikesafety.org/23uwm05

[18] Oregon Department of Transportation. 2020. Analysis Procedures Manual Version 2: Chapter 14 – Multimodal Analysis: p.14-35 et seq. See https://www.oregon.gov/odot/Planning/Documents/APMv2_Ch14.pdf

[19] The plans did not end up actually assessing pedestrian LTS, however. For proposed methodology, see: Caltrans, Toole Design, Cambridge Systematics and WSP. 2019. California Active Transportation Plans Data Framework and Applications.

[20] Montgomery County Planning Department. 2020. Montgomery County's Pedestrian Plan: Pedestrian Level of Comfort Methodology. See https://mcatlas.org/pedplan/images/FINAL_PLOC_Methodology_APPENDIX.pdf

[21] Vogt, Johanna, Lisa Kessler and Klaus Bogenberger. 2022. On the Level of Traffic Stress for Pedestrians. Proceedings of the 10th symposium of the European Association for Research in Transportation (hEART). See https://mediatum.ub.tum.de/doc/1688423/document.pdf

[22] Raad, Nowar and Matthew I. Burke. 2018. What are the most important factors for pedestrian level-of-service estimation? A systematic review of the literature. Transportation Research Record Vol. 2672(35).

[23] LaJeunesse, Seth, Paul Ryus, Wesley Kumfer, Sirisha Kothuri and Krista Nordback. 2021. Measuring pedestrian level of stress in urban environments: naturalistic walking pilot study. Transportation Research Record Vol. 2675(10).

Table 8: Pedestrian LTS based on sidewalk conditions						
Actual/effective sidewalk width (ft)		*Sidewalk condition*				
		Good	*Fair*	*Poor*	*Very Poor*	*No Sidewalk*
Actual	<4	High	High	High	High	High
	4 to <5	High	High	High	High	High
	5 to <6	LTS 2	LTS 2	High	High	High
Effective	≥6 feet	LTS 1	LTS 1	LTS 2	High	High

Note: LTS 3 and LTS 4 are identified as "high" stress.

Sidewalk width is one of the most widely used variables in pedestrian LTS schemes.[24] It has significant influence on pedestrian comfort based on the ability to walk or use a mobility device, and particularly the ability to pass others or walk side-by-side.[25]

As part of width, effective sidewalk width (i.e., the clear, unobstructed path) is critically important; sidewalk obstructions are another of the most commonly used variables for estimating pedestrian LTS. Sidewalk condition is similarly important, especially from an equity perspective, because people using wheelchairs and other mobility devices may not be able to use a sidewalk in poor condition, they may be forced into the street.

For discussion ~ We expect that data on sidewalk condition and effective width/obstructions are not widely available, since both can change rapidly and are generally not regularly assessed. Assessing these factors in this project would be extremely time-consuming and likely beyond the available budget. To reduce data collection, we propose adopting an assumption that any sidewalk with an actual width of less than 6 feet is in poor condition, while any sidewalk with an actual width of 6 ft or more is in good or fair condition. We believe this assumption is justified because: (a) there are likely obstructions on most segments reducing the effective sidewalk width below the actual width; (b) sidewalk cracking, rough areas and faulting—all conditions which would lead to being categorized as in poor condition under the Oregon criteria[26]—are widespread. Conversely, a sidewalk that is at least 6 feet wide is likely to have at least some unobstructed clear path in reasonable condition. This assumption is further supported by the scarcity of pedestrian-scale lighting in this region, and the suggestion from the Oregon methodology that assessors should consider increasing the pedestrian LTS by one level (higher) in the absence of illumination.[27]

Note that this assumption would result in any segment with a sidewalk less than 6 feet wide being designated "high stress," while any segment with a sidewalk 6 feet or wider would be rated LTS 1 (pending application of the other criteria below). The assumption could be modified if agencies can provide information that sidewalk in specific areas is in good condition and with minimal obstructions (e.g., new or recently repaired).

The next set of Oregon criteria we consider is based on land use context. Among variables studied directly, land use context has one of the highest impacts on physical measures of pedestrian stress.[28] The following table is from Oregon Department of Transportation Exhibit 14-24.

[24] Raad and Burke 2018
[25] Vogt et al. 2022
[26] Oregon Department of Transportation 2020 p.14-40
[27] Oregon Department of Transportation 2020 p.14-44
[28] LaJeunesse et al. 2021

Table 9: Pedestrian LTS based on general land use	
Overall Land Use	*Pedestrian LTS*
Urban/suburban residential, central business districts, neighborhood commercial, parks and other public facilities, governmental buildings/plazas, offices/office parks	LTS 1
Low density development, rural subdivisions, unincorporated communities, strip commercial, mixed employment	LTS 2
Light industrial, big box/auto-oriented commercial	High
Heavy industrial, intermodal facilities, freeway interchanges	High

Note: LTS 3 and LTS 4 are identified as "high" stress.

The final two sets of the Oregon criteria are based on (1) physical buffer type and prevailing or posted speed, and (2) total buffering width and number of travel lanes (Table 11). All of these (or closely related) factors are common to most pedestrian LTS schemes.[29] LaJeunesse et al. (2018) found that functional classification—a proxy for traffic speed and volume—had a significant impact on physical measures of pedestrian stress, and attributed the effect at least in part to the effect of traffic noise. Noise has a well-documented impact on human stress levels, and traffic noise perceived by pedestrians is closely related to traffic speeds, distance from traffic (total buffering width) and physical barriers/landscaping.

The following tables are modified from Oregon Department of Transportation Exhibits 14-22 and 14-23, respectively.

Table 10: Pedestrian LTS based on physical buffers and traffic speeds				
*Buffer type**	*Prevailing or posted speed*			
	≤25 mph	*30 mph*	*35 mph*	*≥40 mph*
No buffer (curb tight)	LTS 2	High	High	High
Solid surface	LTS 2‡	LTS 2	LTS 2	LTS 2
Landscaped	LTS 1	LTS 2	LTS 2	LTS 2
Landscaped with trees	LTS 1	LTS 1	LTS 1	LTS 2
Vertical	LTS 1	LTS 1	LTS 1	LTS 2
Note: *If two or more buffer types apply, use the most appropriate buffer, typically the lower stress level. ‡If street furniture, street lights, lighting, planters, etc. are present then LTS can be lowered to LTS 1.				

Note: LTS 3 and LTS 4 are identified as "high" stress.

Table 11: Pedestrian LTS based on total buffering width and number of lanes					
Total number of travel lanes (both directions)	*Total buffering width (ft)**				
	<5	*5 to <10*	*10 to <15*	*15 to <25*	*≥25*
2	LTS 2	LTS 2	LTS 1	LTS 1	LTS 1
3	High	LTS 2	LTS 2	LTS 1	LTS 1
4-5	High	High	LTS 2	LTS 1	LTS 1
6+	High	High	High	LTS 2	LTS 2
Note: *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.					

Note: LTS 3 and LTS 4 are identified as "high" stress.

[29] Raad and Burke 2018

Intersections and Crossings

A high-stress intersection can change the character of what would otherwise be a low-stress route, so characterizing intersection LTS is important. The adopted RTP also calls for calculating the “number of barriers to low-stress bike/ped transportation.” A high-stress road or street crossing is one type of barrier to low-stress transportation; thus the RTP provides another reason to assess intersection LTS.

There is not much available research on the pedestrian stress-inducing effects of various intersection configurations. We assess the Oregon criteria for assessing pedestrian LTS at crossings to be reasonable, and we propose using it for this project. Crucially, these criteria specify that any intersection without ADA-compliant curb ramps cannot be rated at less than LTS 3.[30] For the purposes of this project, therefore, any intersection without compliant curb ramps will be rated “high stress.”

The following table summarizes the Oregon criteria for LTS of signalized intersections as they apply to this project.

Table 12: Pedestrian LTS at signalized intersections	
Intersection Conditions	*LTS*
Default for signalized intersections (i.e., none of the features listed below)	LTS 1
Any of these features: • Permissive left or right tuns for drivers • Lack of illumination • Lack of pedestrian signal countdown head	LTS 2
Any of these features: • Multiple or narrow (<6 ft) refuge islands • Lack of ADA-compliant curb ramps • More than 6 lanes crossed at once • Non-standard geometry (more than 4 legs, or highly skewed approaches) • Permanently closed or limited crosswalks • Free-flow or yield-controlled channelized right turns for drivers	High

Note: LTS 3 and LTS 4 are identified as “high” stress.

The following table summarizes the Oregon criteria for LTS of roundabouts.

Table 13: Pedestrian LTS at roundabouts	
Single lane crossing	LTS 1
Double lane crossing or splitter island less than 10 ft wide	LTS 2

The following tables summarize the Oregon criteria for unsignalized intersections without a median island and are modified from Oregon Exhibits 14-25 and 14-26. Note that LTS 3 and 4

[30] Oregon Department of Transportation 2020 p.14-47

are distinguished for arterial crossing tables, because these ratings can potentially be modified later by crosswalk enhancements, reducing them as low as LTS 2.

Table 14: Pedestrian LTS at local & collector unsignalized intersection crossings			
a. Illuminated	*No Median Refuge*		*Median Refuge Present**
Speed limit or prevailing speed	*1 lane crossed*	*2 lanes crossed*	*Maximum 1 thru-/turn lane crossed per direction*
Up to 25 mph	LTS 1	LTS 1	LTS 1
30 mph	LTS 1	LTS 2	LTS 1
35 mph	LTS 2	LTS 2	LTS 2
40+ mph	High	High	High
b. Not Illuminated	*No Median Refuge*		*Median Refuge Present**
Speed Limit or Prevailing Speed	*1 lane crossed*	*2 lanes crossed*	*Maximum 1 through/turn lane crossed per direction*
Up to 25 mph	LTS 2	LTS 2	LTS 2
30 mph	LTS 2	High	LTS 2
35 mph	High	High	High
40+ mph	High	High	High

Notes:

1. Use criteria for arterial crossings with a median refuge if ADT exceeds 5,000 or total number of lanes exceeds 2.
2. Street may be considered a one-lane road when there is no centerline and oncoming vehicles commonly yield to each other.

*Refuge should be at least 10 feet for LTS 1; lower LTS by one level for refuges 6 to <10 feet.

Note: LTS 3 and LTS 4 are identified as "high" stress.

Table 15: Pedestrian LTS at arterial unsignalized intersection crossings without a median refuge							
a. Illuminated	*Total lanes crossed (both directions)*						
Speed limit or prevailing speed	*2 lanes*			*3+ lanes*			*4+ lanes*
	<5,000 ADT	*5,000-9,000 ADT*	*>9,000 ADT*	*<8,000 ADT*	*8,000-12,000 ADT*	*>12,000 ADT*	*Any ADT*
Up to 25 mph	LTS 2	LTS 2	LTS 3 (High)	LTS 3 (High)	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)
30 mph	LTS 2	LTS 3 (High)	LTS 3 (High)	LTS 3 (High)	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)
35 mph	LTS 3 (High)	LTS 3 (High)	LTS 4 (High)	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)
40+ mph	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)
a. Not Illuminated	*Total lanes crossed (both directions)*						
Speed limit or prevailing speed	*2 lanes*			*3+ lanes*			*4+ lanes*
	<5,000 ADT	*5,000-9,000 ADT*	*>9,000 ADT*	*<8,000 ADT*	*8,000-12,000 ADT*	*>12,000 ADT*	*Any ADT*
Up to 25 mph	LTS 3 (High)	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)
30 mph	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)
35 mph	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)
40+ mph	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)
Note: For one-way streets, use the criteria for arterial unsignalized intersection crossings of 3 or more lanes with a median refuge..							

Note: LTS 3 and LTS 4 are identified as “high” stress.

More than any other road users, pedestrians are likely to cross a street outside of an intersection. Pedestrians have the legal right to cross streets outside of a crosswalk (or against a traffic light) when safe, since California enacted the Freedom to Walk Act (AB 2147) in 2022. Therefore, it is important to assess the LTS for pedestrians crossing outside of intersections. The Oregon pedestrian LTS criteria for “unsignalized intersections without a median refuge” (Table 15) apply equally well to non-intersection crossing locations.[31] <u>We propose assuming that, for the purposes of this project, the pedestrian LTS of crossing outside an intersection is identical to the pedestrian LTS for unsignalized intersection of the relevant segment without a median island (except in the case of an improved mid-block crossing).</u>

The following table summarizes the Oregon criteria for unsignalized intersections with a median island from Oregon Exhibits 14-28 and 14-29. Note that LTS 3 and LTS 4 are distinguished separately for arterial

[31] Even where a median island exists away from an intersection, ADA-accessible facilities for accessing and crossing the island are typically not present. We do not view it as appropriate to lower LTS ratings as a result of an inaccessible median island, which may in these cases act more as a barrier for some individuals.

crossing tables, because these ratings can potentially be modified later by crosswalk enhancements, reducing them to as low as LTS 2.

Table 16: Pedestrian LTS at arterial unsignalized intersection crossings with a median refuge								
a. Illuminated	*Total lanes crossed (both directions)*							
Speed limit or prevailing speed	*1 lane*	*2 lanes*			*3+ lanes*			*4+ lanes*
	Any ADT	*<5,000 ADT*	*5,000-9,000 ADT*	*>9,000 ADT*	*<8,000 ADT*	*8,000-12,000 ADT*	*>12,000 ADT*	*Any ADT*
Up to 25 mph	LTS 1*	LTS 1*	LTS 2	LTS 2	LTS 1*	LTS 2	LTS 3 (High)	LTS 4 (High)
30 mph	LTS 2	LTS 2	LTS 2	LTS 2	LTS 2	LTS 2	LTS 3 (High)	LTS 4 (High)
35 mph	LTS 2	LTS 2	LTS 2	LTS 3 (High)	LTS 3 (High)	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)
40+ mph	LTS 3 (High)	LTS 3 (High)	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)
a. Not Illuminated	*Total lanes crossed (both directions)*							
Speed limit or prevailing speed	*1 lane*	*2 lanes*			*3+ lanes*			*4+ lanes*
	Any ADT	*<5,000 ADT*	*5,000-9,000 ADT*	*>9,000 ADT*	*<8,000 ADT*	*8,000-12,000 ADT*	*>12,000 ADT*	*Any ADT*
Up to 25 mph	LTS 2	LTS 2	LTS 3 (High)	LTS 3 (High)	LTS 2	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)
30 mph	LTS 3 (High)	LTS 3 (High)	LTS 3 (High)	LTS 3 (High)	LTS 3 (High)	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)
35 mph	LTS 3 (High)	LTS 3 (High)	LTS 3 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)
40+ mph	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)	LTS 4 (High)
Note: *Refuge should be at least 10 feet for LTS 1; lower LTS by one level for refuges 6 to <10 feet.								

The following table summarizes the Oregon criteria for reducing pedestrian LTS at arterial crosswalks . The table is modified from Oregon Exhibit 14-27. Note that these measures cannot lower pedestrian LTS more than two levels, and they cannot result in reducing the pedestrian LTS of an arterial intersection below LTS 2.[32]

[32] Oregon Department of Transportation 2020 p.14-48

Table 17: Pedestrian LTS adjustments for arterial crosswalk enhancements	
Treatment	*LTS adjustment*
Crosswalk markings*	-0.5
Roadside signage*	-0.5
Additional (pedestrian scale) illumination	-0.5
Pedestrian-activated beacon (e.g., RRFB)	-1.0
In-street signs	-1.0
Curb extensions/bulb-outs	-0.5
Raised crosswalk	-1.0
Standard 12" flashing beacon	-0.5
Note: *Not applicable for pedestrian median refuges as crosswalk markings and roadside signage are assumed as part of the basic installation.	

We propose applying Table 17 LTS adjustments to both arterial intersections and improved arterial mid-block crossing locations. The National Association of City Transportation Officials (NACTO) recommends a maximum crosswalk spacing of 200 feet in most contexts, meaning that a crosswalk is never more than 100 feet away from any location on a street.[33] Assuming this is a reasonable estimate of the distance a pedestrian will walk to access a crosswalk, we propose that the LTS rating for arterial crosswalk enhancements should be applied to a segment extending 100 feet on either side of the crosswalk.

Data Availability, Collection, and Assumptions

Just as with bicycle LTS, applying the pedestrian LTS criteria to this project will require accurate data about every street, road and highway segment in the Greater Humboldt Bay. We expect that there will be larger data gaps and more active data collection necessary for pedestrian LTS assessment than for bicycle LTS assessment. We will need data listed in Table 18 .

The time and expense of assessing pedestrian LTS for this project will depend largely on the availability of the required data. While the variety of data types required for the assessment is broad, we expect that much of the required data will be available in usable form for most of the streets to be assessed, or that reasonable assumptions can be made (see table below). Additionally, many of the data categories will only apply for arterials and signalized intersections, which will further reduce the need for labor-intensive data collection. If and where data are not available, and if reasonable assumptions cannot be made in the absence of direct data, then data must be collected specifically for this project either by field visits or utilizing available online satellite imagery and/or services such as Google StreetView.

[33] See https://nacto.org/publication/urban-street-design-guide/intersection-design-elements/crosswalks-and-crossings/

Table 18: Pedestrian LTS data needs, sources & assumptions

Type of Data Needed	*Potential Source(s)*	*Potential Assumptions if Data Are Unavailable*
Needed for pedestrian LTS but not for bicycle LTS		
ADA-compliant curb ramp presence/absence	Local agencies, Caltrans	We propose assuming presence or absence by neighborhood or area based on consultation with local agencies and Caltrans
Functional classification	Caltrans map	Data are available
Actual sidewalk width	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on standard cross-sections or other local knowledge.
Effective sidewalk width	Unknown	We propose assumptions that bypass the need to know effective sidewalk width. See text for additional details.
Sidewalk condition	Unknown	We propose assuming that sidewalks with an actual width <6 ft are in poor condition, while sidewalks with an actual width ≥6 ft are in good or fair condition. See text for additional details.
General land use context	Local agencies	General plan land use maps should be available for all jurisdictions.
Sidewalk buffer type	Local agencies, Caltrans	Based on local knowledge, we propose assuming that there is no buffer in any given location in the absence of any information to the contrary.
Sidewalk buffer width	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge.
Illumination status	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge. Regarding additional, pedestrian-scale illumination used to lower LTS at arterial intersections, we propose assuming that there is none in the absence of any information to the contrary.
Needed only for pedestrian LTS on arterials		
Crossing island width	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge. In the absence of any other information, we propose assuming that crossing islands are <10 ft wide.
Crosswalk markings presence/absence	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge. In the absence of any other information, we propose assuming that crosswalk markings across arterials are absent at the intersections of arterials and local roads.
Turn lane presence/absence	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge. In the absence of any other information, we propose assuming that turn lanes are absent except at intersections of arterials and local roads.
In-street pedestrian signage presence/absence	Local agencies, Caltrans	Based on local knowledge, we propose assuming that in-street signage is absent.
Roadside pedestrian signage presence/absence	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge.

Pedestrian flashing beacon locations	Local agencies, Caltrans	There are relatively few pedestrian flashing beacons in our region, and we believe Caltrans and local agencies have accurate data.
Pedestrian activated beacon locations	Local agencies, Caltrans	There are relatively few pedestrian-activated beacons in our region, and we believe Caltrans and local agencies have accurate data.
Raised crosswalk locations	Local agencies, Caltrans	There are relatively few raised crosswalks in our region, and we believe Caltrans and local agencies have accurate data.
Bulb-out presence/absence	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge.
Needed only for pedestrian LTS at signalized intersections		
Permissive turning rules at intersections	Local agencies, Caltrans	Based on local knowledge, we propose assuming permissive turning rules at signalized intersections in the absence of information to the contrary.
Pedestrian countdown signal head presence/absence	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge.
Non-standard intersection geometry	Local agencies, Caltrans	This may require a map review of arterials.
Slip lane presence/absence	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge.
Needed for both pedestrian and bicycle LTS		
Number of lanes	Local agencies, Caltrans	Local agencies may be able to provide reasonable assumptions based on functional classification, standard cross-sections, or other available data.
Average daily traffic	Local agencies, Caltrans	Models maintained by Caltrans or other agencies or private companies may be used if recent direct counts are not available.
Prevailing speed	Local agencies, Caltrans	If recent speed surveys are unavailable, speed limits may be substituted. We propose adding (at least) 2.5 mph to the speed limit for a more reasonable estimate of prevailing speed.
Bike lane presence/absence	HCAOG bike map, local agencies, Caltrans	The HCAOG bike map was recently updated and ground-truthed by volunteers, so data should be reliable, especially when cross-referenced with information from local agencies and Caltrans.
Bike lane buffer presence/absence	HCAOG bike map, local agencies, Caltrans	Based on knowledge of local conditions, we propose assuming that there is no buffer in any given location in the absence of any information to the contrary.
Bike lane width	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on date of original installation and other local knowledge. Based on knowledge of local conditions, if no additional information is available, we propose assuming a functional width of 4 ft (nominally wider bike lanes locally are often partly obstructed and/or include unrideable gutter pans, drains, etc.).
Bike lane buffer width	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on local knowledge.
Parking lane presence/absence	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on standard cross-sections or other local knowledge.

Parking lane width	Local agencies, Caltrans	Local agencies and Caltrans may be able to provide reasonable assumptions based on standard cross-sections or other local knowledge.
Traffic signal presence/absence	Local agencies, Caltrans	There are relatively few traffic signals in our region, and we believe Caltrans and local agencies have accurate data.
Crossing island presence/absence	Local agencies, Caltrans	Based on local knowledge, we propose assuming that there is no island in any given location in the absence of any information to the contrary.
Roundabouts	Local agencies, Caltrans, direct inspection	The data required for pedestrian LTS for roundabouts should be easily available.

Steps for Proposed Methodology

Segments

Street segments are sometimes defined as starting and ending with each new cross-street. We propose defining segments somewhat more broadly as lengths of right-of-way over which relevant variables do not change significantly. This should significantly reduce the number of segments to be assessed without significantly affecting the precision or accuracy of the analysis. We will solicit input from local agencies and Caltrans on appropriate segment boundary locations.

Step-wise Screening Process

Where different criteria could produce different results, LTS for a segment is defined by the most stressful (highest LTS) result. Therefore, segments that are high-stress based on any particular variable can be “screened out” for the purpose of further analysis. For example, based on Tables 1-3, any segment with a prevailing speed of 38.5 mph or greater (approximately equivalent to a speed limit of 35 mph or greater) would be classified as high-stress for bicyclists, and would not require any further data collection. Combining multiple sources of data—such as prevailing speed and average daily traffic (ADT)—allows screening out of even more segments .

For pedestrian LTS, we expect that most of the street network will be classified as high-stress by initially applying the assumption that segments with a sidewalk with an actual width less than 6 feet are in poor condition. Under this assumption, most of the street network would not require detailed analysis and would not call for all of the data listed in Table 18.

Weaknesses of the Proposed Methodologies

While every effort has been made to reduce the complexity of both the bicycle and pedestrian LTS assessments, the methodologies nevertheless involve a large number of variables and even greater quantities of data. The more complexity and the greater the number of required data sources, the more expensive and the less replicable the methodology will be.

Conversely, simplifying the methodologies by step-wise screening has its own weaknesses. Most notably, applying this technique may mean that many street segments do not have all of the relevant data associated with them in the final work product (i.e., if they are “screened out” as high stress after application of only one or two criteria). This means that proponents of future projects meant to reduce LTS on high-stress facilities may need to collect additional data in order to assess the post-project LTS.

Another weakness of the proposed methodologies arises from lumping together LTS 3 and LTS 4 as "high stress." While this is a crucial simplification, applying this technique will mean that information gathered about each segment will be less nuanced. This will make it more challenging to assess the experiences of a variety of user groups with a variety of stress tolerances—and some people with higher tolerances may object to the "high stress" classification.

The accuracy and representativeness of the results of this methodology will rely in large part on the choices to either make simplifying assumptions or collect actual data on a variety of LTS criteria. Further discussion with HCAOG, Caltrans, local agencies, and other project partners is needed before deciding which assumptions are reasonable and where data collection efforts should be focused.

Uncertainties and Other Considerations

The availability, quality and format of many of the required data are largely unknown at this writing. The exact proportion of facilities that can be easily "screened out" using available data is also unknown. The answers to these questions will have a significant impact on the feasibility, replicability, and accuracy of the proposed methodologies.

Further discussion with project partners is also needed to determine the exact form of the final work product. Relevant considerations include:

- How will asset (segment and intersection) data used for LTS assessment interface with GIS mapping products to be developed by other project partners? (SOW: "Determine parameters for setting up database for spatial analysis and visual information products.")
- Once the LTS analysis is complete, the results will likely need to be used in connectivity and access analyses, and possibly other assessments as well. How will the final product be used by project partners to accomplish other project objectives, such as identifying low-stress "connectivity or gaps" and identifying "high-potential areas" for infill development?
- How will the final product be updated over time to reflect new safety projects that change LTS?
- What protocols will be used to address segment, intersection, and crossing LTS ratings which may conflict with each other, or segments with different LTS ratings on different sides of the street? For example, the segment LTS is assessed separately from the crossing LTS for the same segment and may produce a different result. Similarly, intersection LTS will often be different from the underlying segment LTS.

Step-by-Step Methodology and Replicability

We propose to develop specific step-by-step methodologies after we better characterize data availability and finalize the underlying methodological approaches and assumptions. We will likely develop the instructions in the form of flow charts, decision trees, or similar formats.

Successfully replicating the methodologies will depend largely on the availability of data and the assumptions that assessors are willing to make. Data availability may vary from place to place, limiting replicability.