



PI-0420 Statewide Bicycle Level of Traffic Stress Map

Requested by

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Executive Summary

Background

Bicycling has many benefits, such as decreasing vehicle miles traveled (VMT), lowering pollution, and encouraging physical exercise. However, it is only used by a small portion of commuters. One reason for this is a lack of perceived safety on the road. There are over a hundred bicycle fatalities a year in California. Despite the growing emphasis on multimodal transportation, Caltrans currently lacks a unified framework to assess and visualize the comfort and safety levels of bicycling facilities in relation to traffic operations. One tool to improve bicycle usage is Bicycle Level of Traffic Stress (BLTS), a measure of bicyclist comfort on roads. The levels can be defined as 1- All ages and abilities, 2 – Interested but concerned, 3 – Enthusiastic and confident, and 4 – Strong and fearless. BLTS can be used to choose routes, improve infrastructure, and increase comfort and safety.

This preliminary investigation will research previous literature on BLTS methodology and example maps to help guide researchers to create a California BLTS map.

To gather information for this Preliminary Investigation, Caltrans performed a literature on BLTS methodologies and searched for state, regional, and city BLTS maps while examining their methodologies.

Summary of Findings

BLTS Methodologies

Previous research has studied a variety of different variables that can be used to calculate BLTS. The foundation comes from a paper by the Mineta Transportation Institute in 2012. Other different methods were developed to improve or customize this method or to make the data easier to obtain. These include an innovative geographical information system approach. Different methods were compared to each other, but they were found to differ substantially in their results. On the other hand, an OpenStreetMap derived method found its results to match well with ground-truth scores.

BLTS Maps

Research found statewide, regional, and city BLTS maps. Maps were either dynamic (could be zoomed-in) or static. The following maps are included in this PI:

Statewide Maps

- Colorado
- Maryland
- Oregon
- Washington

Regional Maps

- San Joaquin County
- Tahoe Regional Planning Agency

City Maps

- Berkeley
- Los Angeles Department of Transportation
- City of Pacifica
- Palo Alto
- Sacramento

Most of the methodologies were all based on the Mineta methodology with some modifications, such as modifications for rural roads, roadways shoulder, heavy vehicle traffic, additional bicycle features, and shared lane marking. The Washington map was solely based on number of lanes, AADT, and target speed. Berkeley's map replaces speed with ADT.

We also examined the varied use of speed in calculating BLTS and found a variety of methods, some using posted, some using prevailing, and some using either depending on the context.

Gaps in Findings

We did not find any examples of real-time maps which respond to immediate road conditions, specifically traffic levels. The technology to create real-time maps exists but has not been applied to BLTS and the data sources have not been identified.

Next Steps

The next step is to decide which methodology and factors to use to calculate LTS and obtain or create this data for the full roadway network. Afterwards, calculate LTS values and build the dynamic map. This will require creating and using examples of GIS dynamic mapping.

Detailed Findings

Research on BLTS Methodologies and Mapping Guidelines

Below are detailed summaries of the previous research and guidelines related to BLTS methodologies.

“An adaption of the level of traffic stress based on evidence from the literature and widely available data,” Cary Bearn, Charlene Mingus, and Kari Watkins, *Research in Transportation Business & Management*, Vol. 29, pages 50-62, 2018. Report available at <https://www.sciencedirect.com/science/article/pii/S2210539517301293>

This study created an adapted LTS measure based on traffic, roadway, and bikeway characteristics. From the abstract: Bicyclist quality of service measures are often difficult to apply on the network rather than facility level. Analyzing bicycle infrastructure on the network level is a critical process for managing bicycle infrastructure planning, design, and construction. The Level of Traffic Stress (LTS) measure fills this need for a network level measure. However, the originally proposed LTS measure leaves some gaps related to the designation of facilities and requires data that may be difficult to collect on a network level. The adapted LTS measure proposed here is based on traffic, roadway, and bikeway characteristics data available to most planning and engineering agencies and on evidence from the literature. The adapted LTS was used to classify and analyze bike network connectivity in two case studies to assess the methodology and demonstrate practical applications in infrastructure management. The first was a six-mile buffer zone of the Atlanta BeltLine Eastside Trail, and the second was a three-mile transit access zone around three transit stations in southwest Atlanta. The analysis was done in ArcGIS and provides results that can be easily interpreted by the public and decision makers, while relying on quantifiable traffic and roadway characteristics.

“Analysis Procedures Manual Version 2,” Oregon Department of Transportation. July 2025. Available at <https://www.oregon.gov/odot/Planning/Documents/APMv2.pdf>

“14.4 Bicycle Level of Traffic” explains the methodology for calculating bicycle level of traffic stress. It includes the changes from the original Mineta methodology.

Bicycle and Pedestrian Infrastructure Inventory Pilot,” Colorado Department of Transportation. March 2017. Internal document.

Includes explanation of Colorado Department of Transportation’s “enhanced” methodology for calculating BLTS, including rural and heavy vehicle modifications.

“Comparing Methods and Data Sources for Classifying Bicycle Level of Traffic Stress: How Well Do Their Outcomes Agree?” Chester Harvey, Daniel A Rodriguez, and Kevin Fang, *Sustainable Cities and Society*, Vol. 101, Issue 0, February 2024. Report available at <https://www.sciencedirect.com/science/article/abs/pii/S2210670723007606>

This study compared seven LTS methods with different data sources and found many different outcomes. It was found that the simplest LTS method and least precise dataset provided the most consistent outcomes.

From the abstract: Level of Traffic Stress (LTS) metrics are widely used to examine how bicyclists may perceive stress along urban streets and identify opportunities for infrastructure improvements. The intuitiveness of the original method, which condensed 18 input variables into four levels, has made LTS very popular among practitioners. Nonetheless, it can be challenging to collect all required inputs. In response, numerous alternative methods have been developed with fewer or different inputs drawn from more general sources, such as OpenStreetMap (OSM) or GIS datasets from local agencies. These

methods tend to use the same four-level schema, suggesting that they are commensurate, though this may be an inappropriate assumption. The authors examine agreement between seven LTS methods calculated from three data sources throughout two major U.S. cities and find substantial differences between many outcomes. Interestingly, the simplest LTS method and the least precise dataset, OSM, provided the most consistent outcomes. This suggests using simpler albeit less precise approaches to improve commensurability between LTS analyses. For more detailed analyses, the authors recommend site studies with on-the-ground measurements rather than relying on LTS to characterize subtleties. They also encourage clear labeling of LTS methods and data sources to avoid confusion about how results can be interpreted and compared.

“Design Manual,” Washington State Department of Transportation. September 2024. Available at <https://www.wsdot.wa.gov/publications/manuals/fulltext/M22-01/design.pdf>

This explains Washington State Department of Transportation’s the Bicycle Level of Traffic Stress methodology.

“Evaluating OpenStreetMap’s Performance Potential for Level of Traffic Stress Analysis,” David Wasserman, Alex Rixey, Xinyi (Elynor) Zhou, Drew Levitt, and Matt Benjamin, *Transportation Research Record: Journal of the Transportation Research Board*, 2019. Report available at <https://journals.sagepub.com/doi/10.1177/0361198119836772>

This study compared OpenStreetMap-derived LTS predictions with ground-truthed LTS scores and found that they were comparable.

From the abstract: Increasingly, metropolitan areas are prioritizing growth in the share of trips taken by bicycle to improve health outcomes, transportation affordability, and environmental performance of the transport system. Evidence is building that network quality is an important determinant in bicycle commuting and route choice. One prominent metric of facility attractiveness is bicycle level of traffic stress (LTS). In tandem, OpenStreetMap (OSM) is becoming an important source of network data for routing and for generating measures of multimodal accessibility. Although there are studies that examine the completeness of OSM tags and utilize OSM data to compute LTS on networks, none of them examine the accuracy of these analyses. The goal of this paper is to evaluate the accuracy of OSM-derived LTS predictions and offer quality assurance strategies to reduce inaccurate predictions. This study compares OSM-derived LTS predictions with ground-truthed LTS scores created by Montgomery County. It finds that OSM-derived LTS networks provide comparable results to the ground-truthed data. The OSM-derived LTS scores correctly identified 89.9% of the length of the network as either high (LTS 3 or 4) or low stress (LTS 1 or 2). However, this study demonstrates there is a higher potential for error within certain street typologies and urban contexts, and that low-stress accessibility calculations can be very sensitive to even a small number of incorrectly classified segments. Finally, practices to improve the quality of OSM-derived LTS predictions and low-stress accessibility calculations are suggested.

“Low-Stress Bicycling and Network Connectivity,” Maaza Mekuria, Peter Furth, and Hilary Nixon. *Mineta Institute*. May 2012. Report available at <https://transweb.sjsu.edu/sites/default/files/1005-low-stress-bicycling-network-connectivity.pdf>

This is the foundational report on bicycle level of traffic stress and its methodology.

From the abstract: For a bicycling network to attract the widest possible segment of the population, its most fundamental attribute should be low-stress connectivity, that is, providing routes between people’s origins and destinations that do not require cyclists to use links that exceed their tolerance for traffic stress, and that do not involve an undue level of detour. The objective of this study is to develop measures of low-stress connectivity that can be used to evaluate and guide bicycle network planning. We propose a set of criteria by which road segments can be classified into four levels of traffic stress

(LTS). LTS 1 is suitable for children; LTS 2, based on Dutch bikeway design criteria, represents the traffic stress that most adults will tolerate; LTS 3 and 4 represent greater levels of stress.

As a case study, every street in San Jose, California, was classified by LTS. Maps in which only bicycle-friendly links are displayed reveal a city divided into islands within which low-stress bicycling is possible, but separated from one another by barriers that can be crossed only by using high-stress links. Two points in the network are said to be connected at a given level of traffic stress if the subnetwork of links that do not exceed the specified level of stress connects them with a path whose length does not exceed a detour criterion (25% longer than the most direct path).

For the network as a whole, we demonstrate two measures of connectivity that can be applied for a given level of traffic stress. One is “percent trips connected,” defined as the fraction of trips in the regional trip table that can be made without exceeding a specified level of stress and without excessive detour. This study used the home-to-work trip table, though in principle any trip table, including all trips, could be used. The second is “percent nodes connected,” a cruder measure that does not require a regional trip table, but measures the fraction of nodes in the street network (mostly street intersections) that are connected to each other.

Because traffic analysis zones (TAZs) are too coarse a geographic unit for evaluating connectivity by bicycle, we also demonstrate a method of disaggregating the trip table from the TAZ level to census blocks. For any given TAZ, origins in the home-to-work trip table are allocated in proportion to population, while destinations are allocated based on land-use data. In the base case, the fraction of work trips up to six miles long that are connected at LTS 2 is 4.7%, providing a plausible explanation for the city’s low bicycling share. We show that this figure would almost triple if a proposed slate of improvements, totaling 32 miles in length but with strategically placed segments that provide low-stress connectivity across barriers, were implemented.

“Low-Stress Bicycle Network Mapping: Innovative Approach to Applying Level of Traffic Stress,” Conor Semler, Meredyth Sanders, Darren Buck, James Graham, Alek Pochowski, and Stephanie Dock, *Transportation Research Record: Journal of the Transportation Research Board*, 2017. Report available at <https://journals.sagepub.com/doi/10.3141/2662-04>

The District Department of Transportation (Washington D.C.) used an innovative geographic information system approach with existing roadway information.

From the abstract: Washington, D.C., has been a national leader in the adoption of innovative bicycle facilities. However, with much of the low-hanging fruit already plucked (i.e., bicycle facilities already in place), the District Department of Transportation (DOT) needed a mechanism to prioritize investments. Thus the District DOT developed a bicycle level of traffic stress (LTS) map as part of a Multimodal Congestion Management Study. Existing roadway information, combined with an innovative geographic information system approach, was used to create the map and to prioritize and expedite the collection of supplemental roadway information. The results confirmed existing perceptions about the availability of bicycle facilities in the District and identified previously unidentified gaps in the overall bicycle network. In addition, the methodology used to develop the LTS network map provided a proof-of-concept for other jurisdictions to use as they look to develop their own LTS network maps. With this information, the District DOT can now prioritize future bicycle infrastructure investments. It also has a mechanism to update the LTS map as additional data are collected and new facilities are constructed.

“Maryland Bicycle Level of Traffic Stress,” Maryland Department of Transportation. Available at <https://share.google/WM3e6LOGk4C4Ti6pj>

This document shows the criteria for determining Bicycle Level of Traffic Stress with modifications made by the Maryland Department of Transportation.

“Measuring Bicycle Stress Level,” TranSafety, Inc, *Transafety Reporter*. Vol.12, Issue 9, pages 5-6, 1994. Report available at <https://search.worldcat.org/search?q=n2:0884612X>

An early study on the influence of curb lane width, curb lane traffic flow, and speed of curb lane traffic on bicycle stress level.

From the abstract: For cyclists, the shortest route to a destination is not always the safest, and consequently, not the chosen route. This article reviews the results of a study undertaken by the Traffic Division of Madison, Wisconsin, to determine the influence of different variables on the stress levels of cyclists. The three variables evaluated were: curb lane width, curb lane traffic flow, and speed of curb lane traffic. Proposed stress levels and felt stress measurements of experienced, casual, and youth riders were compared. Results of the study are reported.

BLTS Maps

Some maps are online GIS maps which can be zoomed in to while others are static maps. Links to the online maps are provided while screenshots of the static maps are included along with links.

Statewide Maps

The following were the only statewide BLTS maps which were found at this time.

- *Colorado Department of Transportation - Priority Active Connections Explorer (PACE)*

<https://experience.arcgis.com/experience/dcdf831f62e1450e9753808d05b7d1fa/page/About>

(Select the "Heat Map" function and use the layer list in the bottom right corner to turn on the "Safety Level of Traffic Stress" score layer under the "Safety" dropdown.)

Colorado’s methodology was based on the Mineta method. It also incorporated Oregon Department of Transportation’s “enhanced” LTS, including roadway shoulders and rural road modifications for rural roads which might present a low level of stress even though they would be classified as high level of stress. They also modified LTS to be more sensitive to heavy vehicle traffic by increasing LTS score “when the total vehicle per day is greater than 1,500 and percent heavy truck traffic is more than 10% of the traffic stream.”

- *Maryland Bicycle Level of Traffic Stress (LTS)*

<https://data.imap.maryland.gov/datasets/maryland::maryland-bicycle-level-of-traffic-stress-lts/explore?location=39.004895%2C-76.639602%2C11>

The Maryland Department of Transportation’s Bicycle Level of Traffic Stress (BLTS) map is based on the metrics established by the Mineta Transportation Institute with additional criteria refined by Dr. Peter G. Furth (June 2017) and Montgomery County’s Revised Level of Traffic Stress.

- *Oregon Department of Transportation TransGIS*

<https://gis.odot.state.or.us/transgis/>

Compared to the original Mineta report, ODOT's methodology "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."

- *Washington State Department of Transportation Active Transportation Level of Traffic Stress (LTS)*

<https://www.arcgis.com/apps/mapviewer/index.html?panel=gallery&layers=36ba1d681bbb46f0a5792b9ff9dac21b&catalog=334d0110332a496bb5c0305d19359724>

This map shows Active Transportation Level of Traffic Stress, a metric calculated without reference to bicycle facilities. It uses number of lanes, AADT, and target speed.

Regional Maps

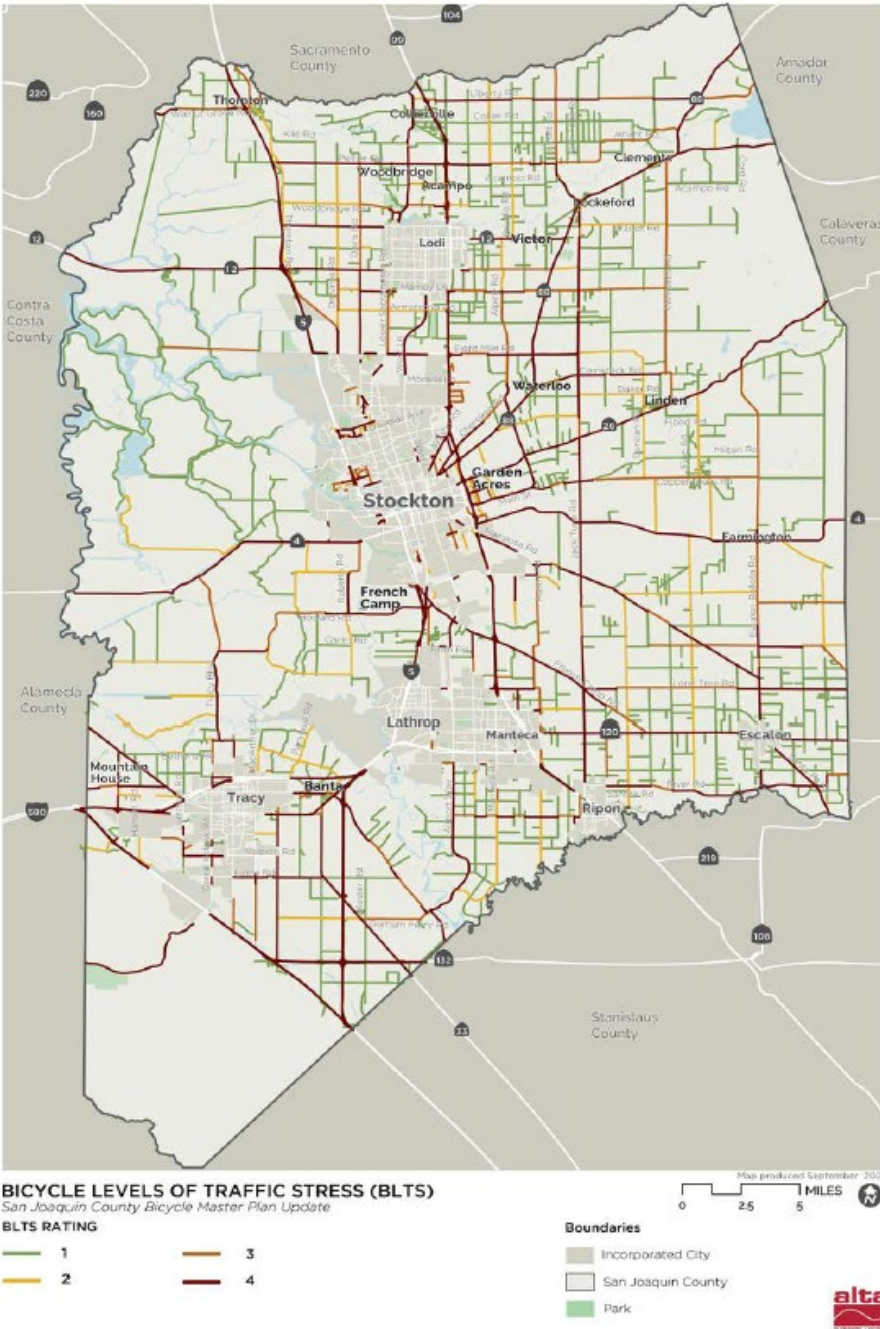
Regional maps were also found, including the Californian example below.

- *San Joaquin County Bicycle Master Plan Update - Bicycle Levels of Traffic Stress*

<https://share.google/Loz1wF9NuchjL6zg5>

The plan only provides minimal information on the analysis process and a short, general description of Bicycle Level of Traffic Stress (LTS). It excludes most city roads.

Figure 2-10: Bicycle Levels of Traffic Stress



- *Tahoe Regional Planning Agency Bicycle Level of Traffic Stress: Segments*
<https://share.google/Wz40zUxRTRgtFVIOo>

This analysis used the Oregon Department of Transportation’s Oregon Analysis Procedural Manual. This map does not show residential roads.



City Maps

Likewise, many cities have created BLTS maps. Below is a sample of city BLTS maps in California.

- *Berkeley Bicycle Plan 2017 Appendix C Level of Traffic Stress*

<https://share.google/bSvKlByIPPx6li4ZZ>

This analysis was performed for both segments and intersections. It followed the Mineta methodology with the exception of replacing speed with ADT.

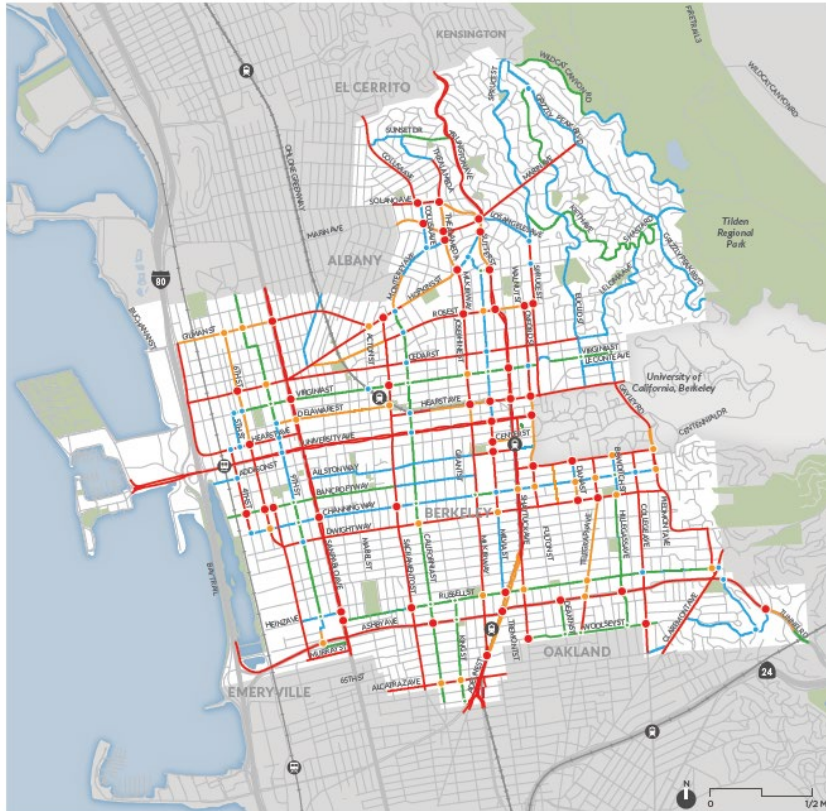


FIGURE C-1: LEVEL OF TRAFFIC STRESS



- Los Angeles Department of Transportation (LADOT) Level of Traffic Stress (LTS) Standard Operating Procedure

https://drive.google.com/file/d/1Wl_iw9AKP6f-8Hliq7DpvQ97FEmbOQ9/view?pli=1

According to the Standard Operating Procedure, “For LTS of streets, the LADOT methodology altered the bike lane type consideration to reflect the types of bike facility lanes in Los Angeles. For intersections, the LADOT method added considerations for whether the intersection was signalized and the type of treatment present (Rapid Red Flashing Beacon – RRFB, Smart Crosswalks, bike boxes, etc.). For the unsignalized factor, the LADOT methodology changed the parameter values (number of lanes and speed limit) for intersections with no crossing island and with a crossing island.

- City of Pacifica Bicycle & Pedestrian Master Plan

<https://share.google/kGnvY7EiqVml8ONB>

This map does not include residential streets, which should generally be considered LTS 1 or 2 facilities. The plan did not state what methodology was used.

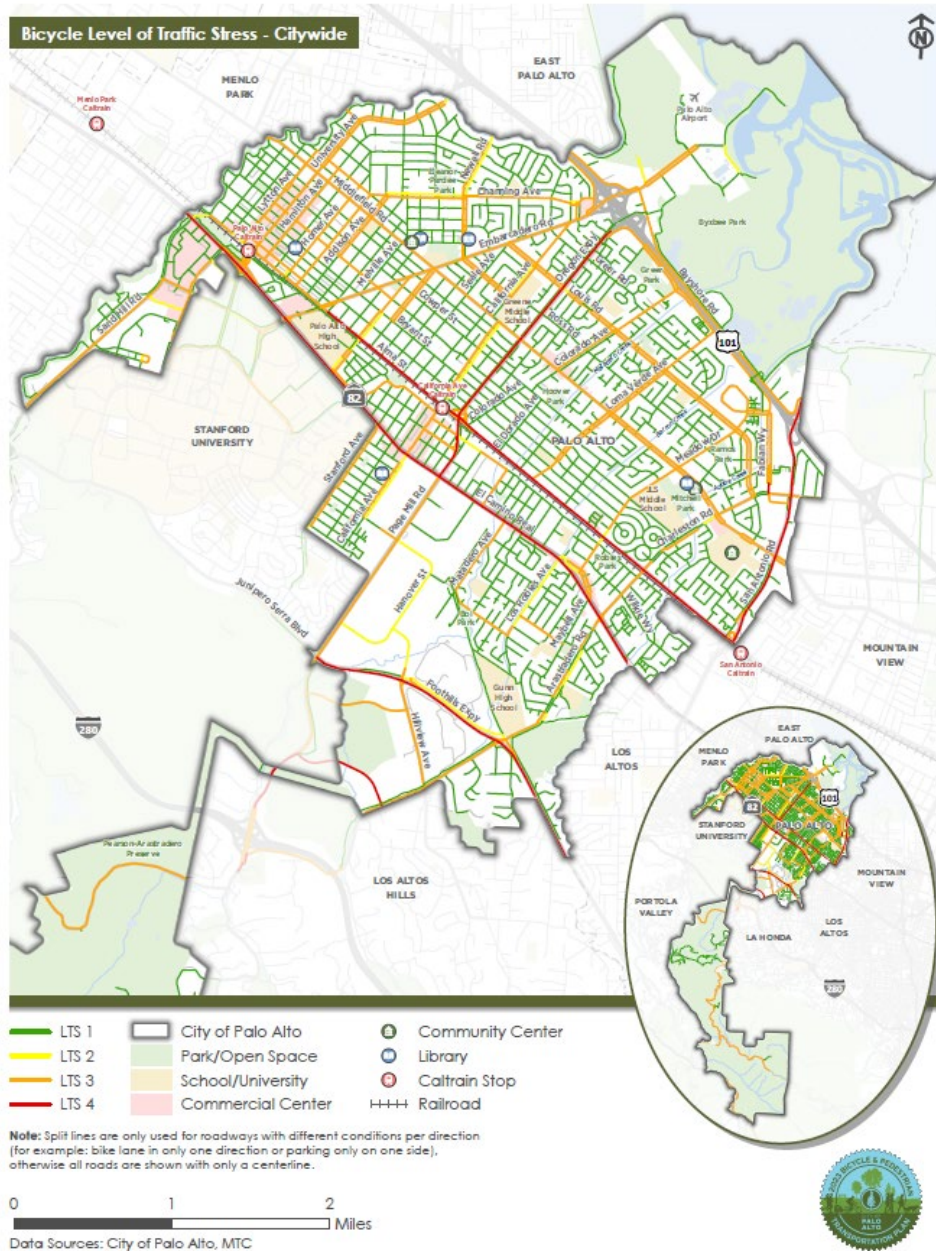
FIGURE 8: LEVEL OF TRAFFIC STRESS RESULTS



- Palo Alto Bicycle Level of Traffic Stress Map

<https://www.paloalto.gov/Departments/Transportation/Bicycling-Walking/bikepedplan/BTP-Update-Existing-Conditions-Analysis>

This map finds LTS for all roads in city limits.



Sacramento Active Transportation Plan – Gap Analysis: Bicycle Level of Traffic Stress (BLTS)
<https://share.google/dqDCh6gerQTcJCAfC>

This methodology was based on the Mineta Transportation Institute’s methodology but included techniques for conflating different datasets and processing OpenStreetMap data.

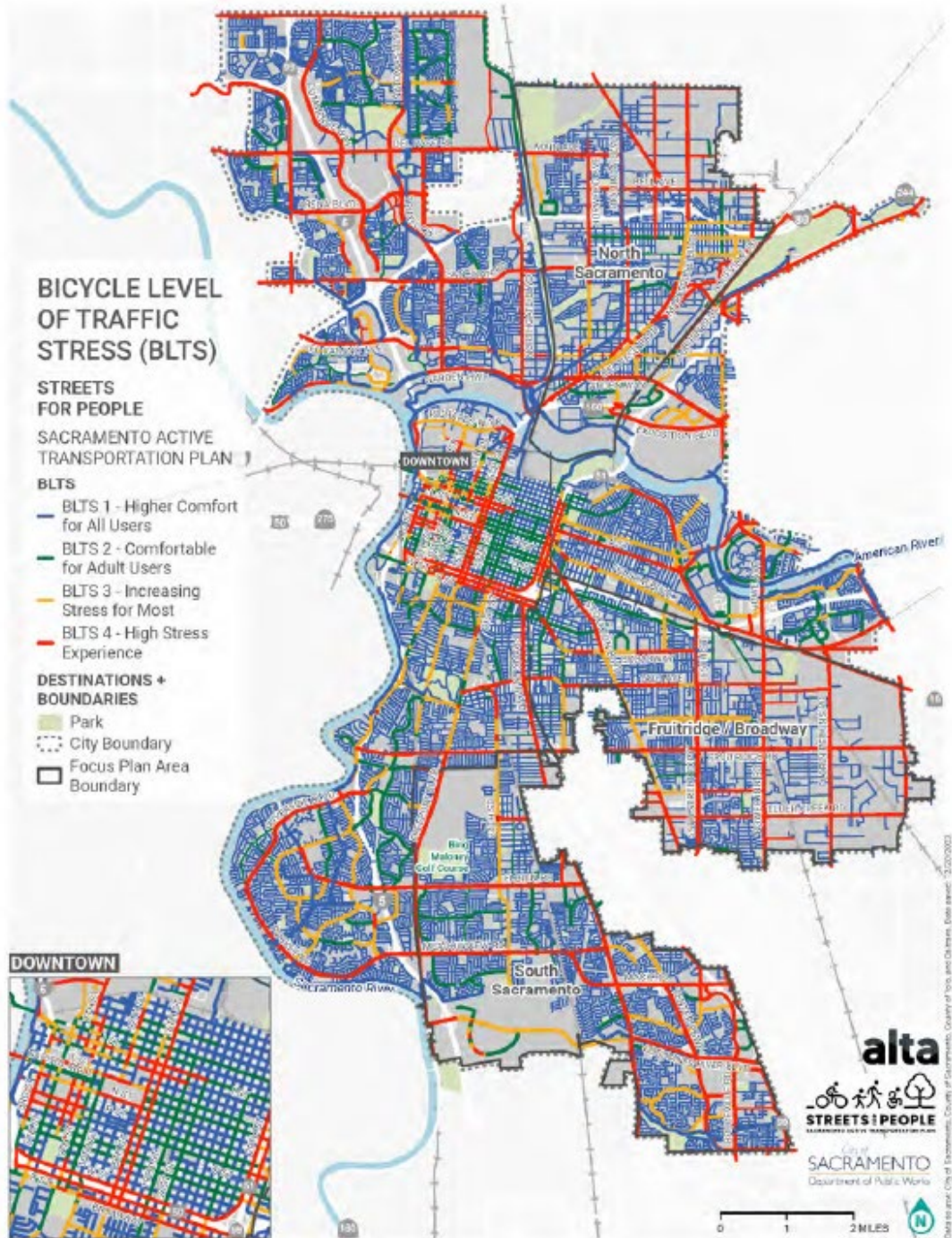


Figure 11. BLTS Analysis Results (Citywide)

Posted or Prevailing Speed

One question regarding BLTS criteria and maps is whether the posted or the prevailing speed is used. The table below lists which is used for the maps above.

Map	Posted or Prevailing Speed
Colorado Department of Transportation - Priority Active Connections Explorer (PACE)	Posted
Maryland Bicycle Level of Traffic Stress (LTS)	Prevailing
Oregon Department of Transportation TransGIS	Posted speed or prevailing speed if different
Washington State Department of Transportation Active Transportation Level of Traffic Stress (LTS)	BLTS uses target speed (design operating speed)
San Joaquin County Bicycle Master Plan Update - Bicycle Levels of Traffic Stress	Information not provided.
Tahoe Regional Planning Agency Bicycle Level of Traffic Stress: Segments	Posted speed or prevailing speed if different
Berkeley Bicycle Plan 2017 Appendix C Level of Traffic Stress	Replaced with ADT
Los Angeles Department of Transportation (LADOT) Level of Traffic Stress (LTS) Standard Operating Procedure	Posted or prevailing speed
City of Pacifica Bicycle & Pedestrian Master Plan	Information not provided
Palo Alto Bicycle Level of Traffic Stress Map	Posted or prevailing speeds
Sacramento Active Transportation Plan – Gap Analysis: Bicycle Level of Traffic Stress (BLTS)	Posted

The table above reveals that different maps used different metrics, either posted, prevailing, or a mixture depending on appropriateness.

Regarding the mixed method, the Mineta Transportation Institute’s “Low-Stress Bicycling and Network Connectivity” states: “Traffic speed clearly affects cyclists’ comfort. Measures of observed speed are generally not available on a widespread basis. Speed limit can be an adequate surrogate if a city systematically adjusts the speed limit to the prevailing speed or uses systematic means such as speed cameras or traffic calming to make actual speeds comply with the speed limit. The former is the case in San José, where one can see a wide variety of speed limits; they are typically 25 mph on residential streets with no centerline and 25, 30, 35, 40, or 45 mph on higher-order streets. These speed limits generally correspond with actual traffic speeds; therefore, speed limit was used as the prevailing speed measure in the San José application.

In other cities, speed limit may not be a good indicator of operating speed. In Boston, for example, the statutory speed limit of 30 mph applies equally to local streets, where traffic often runs at speeds of 25 mph, and to arterials where prevailing speeds can exceed 35 mph. In such a case, it might be possible to develop a function that predicts prevailing speed from available data such as number of lanes, functional class, intersection spacing, and possibly other factors in addition to speed limit.”

Contacts

The author(s) engaged with the individuals below to gather information for this investigation.

State Agencies

Colorado

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