# APPENDIX D

LEVEL OF TRAFFIC STRESS METHODOLOGY

# WHAT IS LEVEL OF TRAFFIC STRESS?

When people bicycle on roadways, they encounter varying levels of stress from traffic. A quiet residential street with a 25-mile-per-hour speed limit is considered a very low-stress environment for cyclists. But a six-lane suburban highway with a 40-mile-per-hour speed limit represents a high-stress environment for cyclists who must share the roadway with traffic. As a result, fewer people are likely to bicycle on the highway.

Level of traffic stress (LTS) is an approach that quantifies the amount of discomfort that people feel when they bicycle close to traffic. The methodology was developed in 2012 by the Mineta Transportation Institute and San Jose State University<sup>1</sup>.

The LTS methodology assigns a numeric stress level to streets and trails based on attributes such as traffic speed, traffic volume, number of lanes, frequency of parking turnover, ease of intersection crossings and others.

When a street has a moderate or high level of stress, it may be a sign that bicycle infrastructure, like separated bike lanes or shared use paths, is needed to make it a place where more people will feel comfortable riding.

An analysis of over 3,500 miles of streets and trails in Montgomery County shows that while three-quarters of the network qualifies as a low-stress environment, these low stress areas form "islands of connectivity" separated by major highways and other high-speed roads. Most people are uncomfortable bicycling on high-speed roads in such environments. These low stress-tolerant groups, accounting for about 60 percent of the County's population, would be unlikely to bicycle without a network of separated bikeways and other enhancements connecting the "islands." One of the goals of the Bicycle Master Plan is to recommend ways of creating a connected bikeway system in the County that will appeal to a wider range of riders.

#### **STRESS LEVEL 1**



- Very low stress, requires little attention
- Equivalent to neighborhood roads, cycle tracks, trails

#### **STRESS LEVEL 2**



- Low stress, suitable for 60 percent of the population
- Equivalent to low-volume / low-speed roads

#### **STRESS LEVEL 3**



- Moderate stress, suitable for 10 percent of the population
- Equivalent to bicycling on four-lane roads with bike lanes

#### **STRESS LEVEL 4**



- High stress, suitable for 1 percent of the populationEquivalent to bicycling in traffic on 40+ mph roads
- <sup>1</sup> Mekuria, Maaza, Peter G. Furth, and Hilary Nixon, Low-Stress Bicycling and Network Connectivity, San Jose, CA: Mineta Transportation Institute, 2012.

NONTGOMERY COUNTY BICYCLE MASTER PLAN | APPENDIX D

For a bicycle network to attract the broadest segment of the population, it must provide low-stress connectivity, defined by the methodology as "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." This tool will be used to identify roadway segments and crossings where a bicycle treatment is needed to reduce the stress level.

The Level of Traffic Stress method offers several advantages over other planning tools. First, the data is generally available through publicly accessible mapping tools, such as Google Streetview.

Second, it provides a consistent approach to evaluating traffic stress. Third, it can be tied to the "four types of transportation cyclists" classification so that planners can determine how well existing planned bicycle networks are connected for different user groups.

The analysis applies a "weakest link" logic, wherein the stress level is assigned based on the lowest-performing attribute of the street. For example, even if a segment has mostly low-stress characteristics, the occurrence of one higher-stress attribute (for example, frequent bike lane blockage) dictates the stress level for the segment. The Level of Traffic Stress methodology identifies four stress levels:

- LTS 4 High stress, suitable for few adults (about 4 percent of adults).
- LTS 3 Moderate traffic stress, for some adults (about 10 percent of adults).
- LTS 2 Low traffic stress, suitable for most adults (about 50 percent of adults).
- LTS 1 Very low traffic stress, suitable for most children.

The Level of Traffic Stress (LTS) methodology focuses on the following criteria for evaluating traffic stress on road segments, intersection approaches and unsignalized crossings.

#### Segments:

- Number of traffic lanes.
- Speed limit or prevailing speed.
- Frequency of on-street parking turnover.
- Presence of a bikeway facility (such as sidepaths, bike lanes, separated bike lanes, etc).

#### Intersection Approaches:

- Presence of right turn lane(s).
- Length of right turn lane.
- Turn lane configuration (bike lane shifts vs. bike lane continues straight).

Unsignalized Crossings:

- Width of cross street.
- Speed limit of cross street.
- Presence or absence of median refuge.

To achieve a bicycling network that appeals to a broad segment of the population, the Bicycle Master Plan will focus on reducing traffic stress levels to a low stress (LTS 2) countywide and to a very low stress (LTS 1) around schools.

To convey level of traffic stress to decision makers and the public, the Planning Department created a Bicycle Stress Map that describes traffic stress, provides videos of several traffic stress levels and indicates how each road and trail in the County was evaluated.



The Montgomery County Planning Department's Bicycle Stress Map www.mcatlas.org/bikestress

# REVISED LEVEL OF TRAFFIC STRESS

While the LTS methodology has proved to be a highly useful approach to understanding the challenges to bicycling in Montgomery County, the Montgomery County Planning Department felt that the LTS methodology did not fully capture stress levels on some of the roads in the County. To provide a more nuanced analysis of traffic stress, the Department created a revised methodology. The following discussion explains the differences between the original LTS and the revised LTS.

# **2.1 ADDITIONAL STRESS LEVELS**

The revised LTS methodology seeks to create a more fine-grained analysis, creating three additional stress levels: LTS 0 (no traffic stress), LTS 2.5 (moderate / low traffic stress) and LTS 5 (very high traffic stress).

When added to the original LTS categories, the revised approach comprises seven stress levels:

- LTS 0 None
- LTS 1 Very Low
- LTS 2 Low
- LTS 2.5 Moderate Low
- LTS 3 Moderate High
- LTS 4 High
- LTS 5 Very High

LTS 0 creates a new category of bikeway for completely separated bicycling infrastructure. This classification reflects the absence of traffic on trails and paths that exist outside of roadway right-of-way. It helps to distinguish those places with no traffic stress from areas with very low stress. From a policy perspective, the effect of adding this level is limited, however, staff felt it was important to be able to communicate the differences between trails in independent right-of-ways and sidepaths and separated bike lanes to the public. Trails in independent right-ofways tend to have long segments with no interaction with traffic. Sidepaths and separated bike lanes tend to cross intersecting driveways with greater frequency and are set back from the road in varying widths.

LTS 2.5 creates a new category because the gulf between the comfort levels of LTS 2 and LTS 3 is large. While the literature states that approximately 60 percent of the population will feel comfortable riding on LTS 2 roads, only 10 percent of the population will feel comfortable riding on LTS 3 roads – a 50 percent difference. This large gap in the two categories leaves out many streets (and bicyclists) that fall somewhere in between.

LTS 5 creates a new category of roads with very high speed limits to reflect that very few bicyclists are likely to brave these roads. The policy implications of adding this level is limited since bicycling on such roads is almost nonexistent. However, distinguishing roads with very high traffic speeds (exceeding 40 mph) from other Level 4 roads is important because there are many existing bicyclists in Montgomery County who will ride on Level 4 roads, but few who will ride on LTS 5 roads.

#### **2.2 SEPARATED BIKEWAYS**

Under the original LTS methodology, all separated bikeway infrastructure, including trails, sidepaths and separated bike lanes, were assigned the lowest stress rating, LTS 1. The Planning Department felt that not all separated bike facilities are very low stress and that the stress level can vary based on how these bikeways are designed. The revised LTS therefore proposes the following changes:

• Shared Use Paths: There is a wide range in the stress level of shared use paths, based on the speed of an adjacent roadway, the width of the buffer between the street and the path, and the frequency of driveways. This range includes the following:

- » Independent rights-of-way: Independent rightsof-way, such as railroad and utility corridors or along waterways were assumed to have a LTS 0 (ie, no traffic stress), except where they cross a street.
- » Sidepaths with wide buffers and few driveways: Sidepaths are assumed to be suitable for most children (LTS 1) if the sidepath is separated from traffic by a minimum 5-foot-wide buffer, has few driveways and a posted speed limit of 35 mph or less. On higher speed roads, the LTS is 2, unless there is a very wide buffer separating the sidepath from traffic.
- » Sidepaths with narrow buffers and many driveways: Sidepaths are assumed to have a stress level of LTS 2 (suitable for most adults) when the sidepath is separated from traffic by less than a 5-foot-wide buffer, has many driveways or a posted speed limit of 35 mph or less. On higher speed roads, the stress level is LTS 2.5.
- Separated Bike Lanes: Separated bike lanes that are buffered from traffic by a row of parked cars or a wide landscaped generate a lower level of stress. When the separation consists of flexible delineator posts or bollards, there is a higher level of stress, depending on the speed of traffic and the number of traffic lanes.
  - » Buffered by on-street parking: A separated bike lane that is buffered from traffic by on-street parking has a stress level of LTS 1 (suitable for many children).
  - » Buffered by a wide separation: A separated bike lane that is buffered from traffic by a landscaped panel has a stress level of LTS 1 (suitable for most children) when the posted speed limit is 35 mph or less. On roads with speeds of more than 35 mph, the stress level rises to LTS 2 (suitable for most adults), unless the buffer is wide.

» Buffered by flexible delineator posts or bollards: While flexible delineator posts and bollards provide some separation from traffic, the buffer is typically narrow and generally is unsuitable for children (except on 2 to 3 lane roads with a maximum speed limit of 25 mph). Over 35 mph, the road has a stress level of LTS 2.5 (suitable for some adults).

## 2.3 EFFECT OF FREQUENTLY BLOCKED BIKE LANES

According to the original LTS methodology, bike lanes that are frequently blocked (by double-parked cars, cars pulling in and out of a parking space, and people getting in and out of cars) increase the stress level to LTS 3 because cyclists are forced to temporarily merge into the adjacent travel lane.

While areas with high parking turnover create additional stress, the original LTS approach assumes that only LTS 3 cyclists will bicycle in this environment (roughly 10 percent of the adult population). While we lack empirical data to prove it, it seems excessive to assume that only 10 percent of the adult population will be comfortable bicycling on streets with a high degree of parking turnover. Therefore, the revised level of traffic stress assigns a stress level of 2.5 to bike lanes that are frequently blocked. (Note: our proxy for frequently blocked bike lanes was presence in a commercial area.)

#### 2.4 ARE ALL TWO-LANE ROADS CREATED EQUAL?

The original Level of Traffic Stress treats roads such as Sligo Creek Parkway the same as a two-lane residential street with a 25-mph speed limit and a painted centerline. However, many bicyclists would consider Sligo Creek Parkway to be the more stressful experience because it lacks context cues to advise motorists to expect bicyclists.

To reflect that many cyclists experience more stress on roads such as Sligo Creek Parkway, the Planning Department used the presence of on-street parking and lower traffic volumes (less than 6,000 daily vehicles) to differentiate residential two-lane streets from two-lane streets like Sligo Creek Parkway. Therefore, 2 to 3 lane streets with 25-mph speed limits and a centerline and no on-street parking are moderate stress roads (LTS 3). The presence of on-street parking reduces the stress level. Where on-street parking is not present, the street may still be categorized as low stress as long as it has fewer than 6,000 vehicles per day. While parking is not a perfect proxy for capturing these variables, it is a good estimator of whether a street is likely to be in an environment that will generate less stress for cyclists.

Additionally, the original level of traffic stress treats 2 to 3 lane roads with 25 mph speed limits and no centerline as very low stress roads (LTS 1). However, on roads without higher traffic volumes (less than 3,000 vehicles per day), the LTS was increased to 2 (low stress).

## 2.5 SPEED TRIGGER FOR TABLE 3: CRITERIA FOR BIKE LANES NOT ALONGSIDE A PARKING LANE

The original LTS states that speeds of 40 mph or faster trigger a high stress level (LTS 4). The revised LTS reduces the stress level to moderate (LTS 3) on 2 to 3 lane roads with bike lanes and on 4 to 5 lane roads with a raised median.

# 2.6 ADDITIONAL UTILIZATION OF THE LTS 2.5 CATEGORY

As discussed previously, the addition of a LTS 2.5 category allows the large gap between the stress tolerance of the LTS 2 and LTS 3 categories to be bridged and identify an intermediate level of stress. This new category was used in several instances:

 For undivided roads with bike lanes that are infrequently obstructed and a posted speed limit of 25 or 30 mph, the original LTS is 1 or 2 (depending on the bike lane width) if there are 2 to 3 lanes, LTS 3 if there are 4 to 5 lanes, and LTS 3 if there are 6 or more lanes. The addition of the LTS 2.5 category allows for differentiation between the 4 to 5 lane roads and the 6 and wider lane roads.

## **2.7 INDUSTRIAL STREETS**

Stress levels on streets identified as industrial in the County's master plans are assigned a minimum LTS of 2.5, given the greater volume of truck traffic on these roads.

# **DIFFERENCES** BETWEEN ORIGINAL AND REVISED LEVELS OF TRAFFIC STRESS

The following charts summarize the differences between the original level of traffic stress and the revised LTS. The changes are evaluated in mixed traffic, roads with bike lanes and roads with separated bikeways (sidepaths, independent rights-of-way and separated bike lanes).

#### Notes

8 🔨 🔨

- a. if road is residential or posted speed limit is less than 25 mph
- b. if there is a raised median
- c. if Average Daily Traffic is less than 6,000 ADT
- d. if Average Daily Traffic is less than 3,000 ADT
- e. if buffer is wide
- f. if a road is residential and buffer is at least 5 feet wide
  - = differences from original level of traffic stress

**Intersections: Original Level of Traffic Stress** Unsignalized Intersections

LTS is the more stressful of (1) and (2) below:

1. Intersection LTS (see table; right)

Or

2. Street Segment LTS (see previous pages)

	# of Lanes of Street Being Crossed									
Posted Speed Limit	No M	edian Re	efuge	Median Refuge (≥6 ft wide)						
on Street Be- ing Crossed	2 to 3	4 to 5	6+	2 to 3	4 to 5	6+				
≤25	1	2	4	1	1	2				
30	1	2	4	1	2	3				
35	2	3	4	2	3	4				
≥40	3	4	4	3	4	4				

Intersections: Original Level of Traffic Stress Signalized Intersections

LTS of the street segment (see pages 8-13) is carried through the intersection.

**Intersections: Revised Level of Traffic Stress** Unsignalized Intersections

LTS is the more stressful of (1) and (2) below:

1. Intersection LTS (see table; right)

Or

2. Street Segment LTS (see previous pages)

	# of Lanes of Street Being Crossed							
Posted Speed Limit	No M	edian Re	efuge	Median Refuge (≥6 ft wide)				
on Street Be- ing Crossed	2 to 3	4 to 5	6+	2 to 3	4 to 5	6+		
≤25	1	2	4	1	1	2		
30	2	2.5	4	1	2	2.5		
35	2.5	3	4	1	2.5	3		
≥40	3	4	4	2	2.5	4		

Intersections: Revised Level of Traffic Stress Signalized Intersections

LTS of the street segment (see pages 8-13) is carried through the intersection.

MONTGOMERY COUNTY BICYCLE MASTER PLAN | APPENDIX D <

#### Street Segments: Original Level of Traffic Stress

		Mixed Traffic				Priority Shared Lane Markings			
Posted Speed Limit	# of Through	No Parking Parking							
(mph)	Lanes	Center Line	No Center Line	Center Line & High Park- ing Turn- over	Cer Line 8 Park Turn	k Low king	No Cen- ter Line & Non-Resi- dential	No Center Line & Residential	
	2-3	2	1	2	2	<u>)</u>	1	1	
≤25	4-5	3	n/a	3	3	5	n/a	n/a	
	≥6	4	n/a	4	4	ļ	n/a	n/a	
	2-3	3	2	3	3	3	2	2	
30	4-5	4	n/a	4	4	ļ	n/a	n/a	
	≥6	4	n/a	4	4	ļ	n/a	n/a	
	2-3								
35	4-5	4	4	4	4	ļ	n/a	n/a	
	≥6								
	2-3								
40	4-5	4	4	4	4	1	n/a	n/a	
	≥6								
	2-3								
≥45	4-5	4	4	4	۷	ļ	n/a	n/a	
	≥6								

## Street Segments: Revised Level of Traffic Stress

			Mixed Traffic								
Posted # of Speed Through	# of Through	No Pa	arking	Parking							
Limit (mph)	Lanes	Center Line	No Center Line	Center Line & High Park- ing Turn- over	Center Line & Low Parking Turnover	No Cen- ter Line & Non-Residen- tial	No Center Line & Residential				
	2-3	3 (2c)	2 (1d)	2.5	2	2.5	2 (1d)				
≤25	4-5	3	n/a	3	3	n/a	n/a				
	≥6	4	n/a	4	4	n/a	n/a				
	2-3	3	2	3	3	2.5	2				
30	4-5	4	n/a	4	4	n/a	n/a				
	≥6	4	n/a	4	4	n/a	n/a				
	2-3										
35	4-5	4	4	4	4	n/a	n/a				
	≥6										
	2-3										
40	4-5	4	4	4	4	n/a	n/a				
	≥6										
	2-3										
≥45	4-5	5	5	5	5	n/a	n/a				
	≥6										

# Street Segments: Original Level of Traffic Stress

					Bike Lanes				
Posted			No Parking			Par	king		
Speed Limit	# of Through		uenly ucted		Pa	nly Obstruct rking Turno		Frequently	
(mph)	Lanes	Bike Lane ≤ 5.5 ft	Bike Lane ≥ 6.0 ft	Frequently Obstruct- ed	Bike Lane + Parking	Bike Lane + Parking = 14.0 - 14.5 ft	Bike Lane + Parking = 15.0 ft	Obstruct- ed / High Parking Turnover	
	2-3	2	1	3	3 (2a)	2	1	3	
≤25	4-5	3 (2b)	3 (2b)	3			3		
	≥6		3		3				
	2-3	2	1	3	3 (2a)	2	2	3	
30	4-5	3 (2b)	3 (2b)	3			3	n.	
	≥6		3				3		
	2-3								
35	4-5		3				3		
	≥6								
	2-3								
40	4-5		4			2	4		
	≥6								
	2-3								
≥45	4-5		4			2	4		
	≥6								

# Street Segments: Revised Level of Traffic Stress

					Bike Lanes				
Posted			No Parking			Parl	king		
Speed Limit	# of Through	Infrequenly e	/ Obstruct- d			nly Obstruct rking Turno		Frequently	
(mph)	Lanes	Bike Lane ≤ 5.5 ft	Bike Lane ≥ 6.0 ft	Frequently Obstruct- ed	Bike Lane + Parking	Bike Lane + Parking = 14.0 - 14.5 ft	Bike Lane + Parking = 15.0 ft	Obstruct- ed / High Parking Turnover	
	2-3	2	1	2.5	2.5 (2a)	2	1	2.5	
≤25	4-5	2.5 (2b)	2.5 (2b)	2.5		-	3		
	≥6		3		3				
	2-3	2	2	2.5	2.5	2	2	2.5	
30	4-5	2.5 (2b)	2.5 (2b)	2.5			3		
	≥6		3			Ţ	3		
	2-3								
35	4-5		3	2.5 2.5	3				
	≥6								
	2-3		3						
40	4-5		4 (3b)			n,	/a		
	≥6		4						
	2-3								
≥45	4-5		4			n,	/a		
	≥6								

Street Segments: Original Level of Traffic Stress

		Share	ed Use Pa	ath	Separated Bike Lanes			
Posted Speed Limit (mph)	# of Through Lanes	with Buffer w < 5 ft (and f no railing) (o OR Many A	Sidepath with Buf- fer ≥ 5 ft or railing) AND Few Driveways	Indepen- dent ROW	Flex Posts	Bike Lanes with Buffer < 5 ft (and no railing) OR Many	fer ≥ 5 ft (or railing)	Parked Cars
	2-3							
≤25	4-5	1			1			
	≥6							
	2-3							
30	4-5	1			1			
	≥6							
	2-3							
35	4-5	1			1			
	≥6							
	2-3							
40	4-5		1				1	
	≥6							
	2-3							
≥45	4-5	1			1			
	≥6							

Street Segments: Revised Level of Traffic Stress and Separated Bike Lanes

		Sh	ared Use Pa	ath	Separated Bike Lanes			
Posted Speed Limit (mph)	# of Through Lanes	Sidepath with Buffer < 5 ft (and no railing) OR Many Driveways	fer ≥ 5 ft (or railing) AND Few	Indepen- dent ROW	Flex Posts	Bike Lanes with Buffer < 5 ft (and no railing) OR Many		Parked Cars
	2-3				1			
≤25	4-5	2 (1f)	1	0	2	2 (1f)	1	1
	≥6				2.5			
	2-3				2			
30	4-5	2 (1f)	1	0	2.5	2 (1f)	1	1
	≥6				2.5			
	2-3				2			
35	4-5	2 (1f)	1	0	2.5	2 (1f)	1	1
	≥6				2.5			
	2-3							
40	4-5	2	2 (1e)	0	2.5	2	2 (1e)	n/a
	≥6							
	2-3							
≥45	4-5	2	2 (1e)	0	2.5	2	2 (1e)	n/a
	≥6							

Street Segments: Revised Level of Traffic Stress Shared Streets

Posted Speed Limit (mph)	# of Through Lanes	Bikeable Shoulder	Neighborhood Greenway	Shared Street	
	2-3	2			
≤25	4-5	2.5 (2b)	1	1	
	≥6	3			
	2-3	2			
30	4-5	2.5 (2b)	1	1	
	≥6	3			
	2-3				
35	4-5	3	1	1	
	≥6				
	2-3	3			
40	4-5	4(3b)	1	1	
	≥6	2.5 (2b) 1 3 2 2.5 (2b) 1 3 3 1 3 1			
	2-3				
≥45	4-5	4	1	1	
	≥6				

18 \ \ \ \ \ \ \ \ MONTGOMERY COUNTY BICYCLE MASTER PLAN | APPENDIX D