

MEMORANDUM

May 22, 2025

To: Kevin Luecke

Organization: City of Madison

From: Adam Wood, AICP, Theja Putta, HaoChe Hung

Project: Madison Pedestrian and Bicycle Planning (SS4A)

Re: Bicycle LTS Methodology

This memo summarizes the findings and methodology used in Toole Design’s review of bicycling conditions, using a Bicycle Level of Traffic Stress (LTS) model. Our review focused on a citywide assessment of bikeway stress to establish context for the development of recommendations for the All Ages and Abilities bike network.

This memo describes two steps of the analysis:

1. Data consolidation to prepare for the analysis
2. The calculation of LTS scores for all streets and paths in the city

Data Consolidation

The analysis was performed using the *Transportation Planning Centerlines* GIS dataset downloaded from the City of Madison Open Data Portal. Where necessary, this data was augmented with other data sources using semi-automated spatial and non-spatial GIS methods to create a consolidated dataset with attributes that are required for LTS calculations.

Segment Attributes and Data Sources

The analysis includes a polyline GIS layer for network segments and a points layer for intersections. Table 1 describes the attributes consolidated on to the base network segments and their data sources.

Table 1. Data Consolidation Attributes and Data Sources

	Relevant Layer Attributes	Data Sources	Process Description
AADT	<ul style="list-style-type: none"> “aadt” – AADT value “aadt_source” – notes on the source 	Transportation Planning Centerlines	AADT values are embedded within the Transportation Planning Centerlines downloaded from City of Madison Open Portal
Number of Lanes	<ul style="list-style-type: none"> “ft_lanes” – lanes in forward direction 	Transportation Planning Centerlines	Lane data is calculated based on the “one_way” and “lanes_each_direction”

	“tf_lanes” – lanes in reverse direction (only relevant for two-way segments)		column value, and gaps were filled as noted in the assumption section of this memo.
Speed	“speed_limit” – speed limit	Transportation Planning Centerlines	Speed limit values are embedded within the Transportation Planning Centerlines, and gaps were filled as noted in the subsequent sections of this memo.
Bike Facilities	“ft_bike_infra” – bike lane type in forward direction “tf_bike_infra” – bike lane type in reverse direction	Transportation Planning Centerlines, Bike Paths	Centerlines include existing bike lane information and use City’s bike paths layer for off-street trails.
Bike Lane Width	“ft_biking_width” – width of bike lane in forward direction “tf_biking_width” – width of bike lane in reverse direction	Transportation Planning Centerlines	Biking width is available in the centerline layer provided by City.
Parking Lanes and Width	“ft_park” – parking lane type in forward direction “tf_park” – parking lane type in reverse direction “ft_parking_width” – width of parking lane in forward direction “tf_parking_width” – width of parking lane in reverse direction “parking_source” – notes on the source	Transportation Planning Centerlines, Street Parking Restrictions	Parking lane width data does not exist in the centerline data and was therefore assumed based on the width of outside shoulder data. We used the parking type from the City’s Street parking restrictions layer to inform parking turnover rate. Note that this is only relevant for on-street bike lanes and buffered bike lanes.

Filling Data Gaps

Once all the above data is spatially conflated to the base network, there were some gaps in the attribute data. For any segment missing AADT, lanes, or speed data gaps these values were imputed from adjacent segments where possible. To prevent imputing errors, only those adjacent segments with matching functional class and name are used for this. This imputing process is done iteratively as each new iteration adds more data to the network. The fields with notes about the source (usually with a suffix of “_source”) were updated to include which iteration the imputing was done. Larger iteration number indicates that the segment is more steps away from the original source than the case with a smaller iteration number.

Any data gaps present after the imputing process were filled using assumptions based on functional classification. Table 2 shows the assumptions used for different functional class values (column name - “functional_class”).

Table 2. Assumptions for Missing Data

Functional Class	AADT (Urban)	Lanes per Direction	Speed
Principal Arterials	20000	3	35
Minor Arterials	12500	2	30
Collectors	5000	1	25
Local, private road unclassified	500	0 (unlaned)	20
	5000	1	25

Review and Manual Adjustments

The automated data consolidation method is not perfect and can have some results not accurately represent real world conditions. Toole Design staff reviewed the data consolidation results using a combination of desktop review and local knowledge to identify and flag these inaccuracies. These were manually adjusted, and their corresponding source columns were updated so that they may be identified if needed.

Calculate Level of Traffic Stress

Level of Traffic Stress (LTS) is the stress on a bicyclist due to roadway and traffic conditions. It was first proposed by Furth, Mekuria, and Nixon in 2012.¹ LTS values can range from 1 to 4, with LTS 1 being the lowest stress and LTS 4 being the highest stress. LTS 1 and LTS 2 are generally considered low-stress, which is acceptable to the majority of the adult population. Furth et al. have since released updated LTS criteria (v.2.0)² with more refined stress values for segments. A segment’s LTS value depends on factors such as number of lanes, traffic volume, speed, presence of bike facility, parking lane, width of bike lanes, etc. The LTS criteria used in this project are a slight modification of LTS v2.0 based on our previous work in the field and discussion with the MPO staff. These LTS criteria are shown in Appendix A.

LTS scores are calculated for every roadway segment within the study area. These scores were written to attributes named “ft_seg_stress” for the forward direction and “tr_seg_stress” for the reverse direction. The forward direction does not follow any defined cardinal direction, but it is the direction that the line is drawn in GIS. The study area is chosen to include any street segment that is within 0.1 miles of the City boundary. This enables any network analysis to accurately capture the effect of trips utilizing the network just outside the City boundary.

LTS Scores Calculation

LTS scores were calculated using an automated script that executes the logic from the LTS criteria in Appendix A. Any bike paths, trails, and cycletracks get an LTS value of 1 while limited access highway are not included in the analysis. Segment LTS scores were calculated for each direction separately as the traffic conditions may not always be the same in both directions of travel. Note that attributes with a prefix “tr_” are not relevant for one-way streets indicated by “one_way = ‘ft’”. A simple way to see which direction a given line is drawn is to use an arrow to symbolize the layer in GIS software.

¹ <https://transweb.sjsu.edu/sites/default/files/1005-low-stress-bicycling-network-connectivity.pdf>

² <https://cpb-us-w2.wpmucdn.com/sites.northeastern.edu/dist/e/618/files/2014/05/LTS-Tables-v2-June-1.pdf>

Appendix – A

Mixed Traffic Criteria

Number of lanes	Effective ADT*	Prevailing Speed						
		≤ 20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50+mph
Unlaned 2-way street (no centerline)	0-750	LTS 1	LTS 1	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	751-1500	LTS 1	LTS 1	LTS 2	LTS 3	LTS 3	LTS 4	LTS 4
	1501-3000	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	3000+	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
1 thru lane per direction (1-way, 1-lane street or 2-way street with centerline)	0-750	LTS 1	LTS 1	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	751-1500	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4	LTS 4
	1501-3000	LTS 2	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4
	3001-6000	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
	6001-10000	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
	10001+	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
2 thru lanes per direction	0-6000	LTS 3	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	6001-12000	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
	12001+	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
3+ thru lanes per direction	any ADT	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4

* Effective ADT = ADT for two-way roads; Effective ADT = 1.67*ADT for one-way roads

Bike Lanes and Shoulders not Adjacent to a Parking Lane

Number of lanes	Bike lane width	Prevailing Speed					
		< 25 mph	30 mph	35 mph	40 mph	45 mph	50+ mph
1 thru lane per direction, or unlaned	6+ ft	LTS 1	LTS 1	LTS 2	LTS 3	LTS 3	LTS 4
	4 or 5 ft	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4
2 thru lanes per direction	6+ ft	LTS 2	LTS 2	LTS 3	LTS 4	LTS 4	LTS 4
	4 or 5 ft	LTS 2	LTS 2	LTS 3	LTS 4	LTS 4	LTS 4
3+ lanes per direction	any width	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4

Notes:

1. If bike lane / shoulder is frequently blocked, use mixed traffic criteria.
2. Qualifying bike lane / shoulder should extend at least 4 ft from a curb and at least 3.5 ft from a pavement edge or discontinuous gutter pan seam
3. Bike lane width includes any marked buffer next to the bike lane.

Bike lanes alongside a parking lane

Number of lanes	Bike lane reach = Bike + Parking lane width	Prevailing Speed				
		≤ 20 mph	25 mph	30 mph	35 mph	40+ mph
1 lane per direction	15+ ft	LTS 1	LTS 1	LTS 2	LTS 2/3*	LTS 4
	14 ft	LTS 2	LTS 2	LTS 2/3*	LTS 3	LTS 4
	12-13 ft	LTS 2	LTS 2/3*	LTS 2/3*	LTS 3	LTS 4
2 lanes per direction (2-way) 2-3 lanes per direction (1-way)	15+ ft	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4
	14 ft	LTS 2/3*	LTS 2/3*	LTS 3	LTS 4	LTS 4
	12-13 ft	LTS 2/3*	LTS 2/3*	LTS 3	LTS 4	LTS 4
other multilane		LTS 3	LTS 3	LTS 3	LTS 4	LTS 4

* Rating depends on parking turnover. Low turnover (areas *without* time-limited parking restrictions) = LTS 2, high turnover (areas *with* time-limited parking restrictions) = LTS 3.

Notes:

1. If bike lane is frequently blocked, use mixed traffic criteria.
2. Qualifying bike lane must have reach (bike lane width + parking lane width) > 12 ft
3. Bike lane width includes any marked buffer next to the bike lane.