North Avenue Corridor Study

Level of Traffic Stress Evaluation Methodology

The Level of Traffic Stress approach recognizes that traffic stress—a combination of perceived danger, noise, and exhaust fumes associated with riding in or adjacent to vehicle traffic—is the greatest deterrent to cycling. Roger Geller's often cited breakdown of cyclist types (Figure 1) estimates that a large majority of the population is in the "interested but concerned" category in terms of how they view their potential to use a bicycle. This group of people would likely ride bicycles if they were separated from automobile traffic.

Figure 1: Four Types of Transportation Cyclists

Source: Roger Geller, City of Portland, OR

The Level of Traffic Stress (LTS) approach to evaluating bicycle facilities classifies street segments and crossings with these types of cyclists in mind, where lower stress facilities are related to higher degrees of separation from vehicle traffic. LTS is defined as:

- LTS 1: A level of traffic stress tolerable by most children.
- LTS 2: A level of traffic stress tolerable by the mainstream adult population, those who are "interested but concerned" (primary target for most bikeways; mimics Dutch standards).
- LTS 3: A level of traffic stress tolerable by the "enthused and confident" cyclists who still prefer their own space for riding.
- LTS 4: A level of traffic stress tolerable only by those characterized as "strong and fearless."

Application:
Street segments and intersections/crossings are rated separately under the LTS method. Facilities along segments are rated as shown in Table 1. Stand-alone paths and cycle tracks offer full separation and protection from automobile traffic, and are thus rated LTS 1. Bike lanes and mixed traffic facilities can vary from LTS 1 to 4 according to a handful of criteria discussed below.

Table 1: LTS Criteria for Segment Facilities

Segment Type	Level of Traffic Stress
Stand-alone paths	LTS 1
Cycle tracks	LTS 1
Bike lanes	LTS can vary from 1 to 4
Mixed traffic	LTS can vary from 1 to 4

The level of traffic stress evaluation criteria for bike lanes are found in Tables 2 and 3, depending upon whether a bike lane is adjacent to a parking lane. Bike lane evaluation follows a weakest link approach; that is, if a bike lane is rated LTS 1 according to street width, bike lane/parking lane width, and speed limit, but is rated LTS 3 according to bike lane blockage, then the whole segment is rated LTS 3.

Table 2: Criteria for Bike Lanes Alongside a Parking Lane

Category	**LTS ≥ 1**	**LTS ≥ 2**	**LTS ≥ 3**	**LTS ≥ 4**
Street Width (through lanes per direction)	1	(no effect)	2 or more	(no effect)
Sum of Bike Lane and Parking Lane Width (includes marked buffer and paved gutter)	≥ 15 ft.	14 to 14.5 ft.*	13.5 ft.	(no effect)
Speed Limit or Prevailing Speed	≤ 25 mph	30 mph	35 mph	≥ 40 mph
Bike Lane Blockage (typically applies in commercial areas)	Rare	(no effect)	frequent	(no effect)

Note: (no effect) = factor does not trigger an increase to this level of traffic stress
** If speed limit < 25 mph or Class = residential, then any width is acceptable for LTS 2*

Table 3: Criteria for Bike Lanes Not Alongside a Parking Lane

Category	**LTS ≥ 1**	**LTS ≥ 2**	**LTS ≥ 3**	**LTS ≥ 4**
Street Width (through lanes per direction)	1	2, if directions are separated by a raised median	> 2, or 2 without a separating median	(no effect)
Bike Lane Width (includes marked buffer and paved gutter)	≥ 6 ft.	≤ 5.5 ft	(no effect)	(no effect)
Speed Limit or Prevailing Speed	≤ 30 mph	(no effect)	35 mph	40 mph
Bike Lane Blockage (may apply in commercial areas)	Rare	(no effect)	frequent	(no effect)

Note: (no effect) = factor does not trigger an increase to this level of traffic stress

Level of traffic stress in mixed traffic (i.e. shared roads, neighborhood greenways, advisory bike lanes) is evaluated against vehicle speed and street width, shown in Table 4. Low stress mixed-traffic facilities require fewer lanes and lower speed limits.

Table 4: Criteria for Level of Traffic Stress in Mixed Traffic

	Street Width		
Speed Limit	**2-3 Lanes**	**4-5 Lanes**	**6+ Lanes**
≤ 25 mph	LTS 1 or 2*	LTS 3	LTS 4
30 mph	LTS 2 or 3*	LTS 4	LTS 4
≥ 35 mph	LTS 4	LTS 4	LTS 4

** Use lower value for streets without marked centerlines or classified as residential and with fewer than 3 lanes; use higher value otherwise.*

At signalized intersections, through cyclists and right-turning vehicles conflict with one another. LTS ratings for **signalized intersections** focus on this interaction. Intersection stress levels are aggregated with adjacent segments using the same weakest link approach; that is, if a segment is LTS 2 but an intersection is LTS 4, the continuous bicycle facility comprised of these two elements is LTS 4. Intersection evaluation criteria are listed in Tables 5 and 6.

Table 5: Level of Traffic Stress Criteria for Pocket Bike Lanes (i.e. bike lane between a through lane and right-turn lane)

Configuration	LTS
Single right-turn lane up to 150 ft. long, starting abruptly while the bike lane continues straight, and having an intersection angle and curb radius such that turn speed is ≤ 15 mph.	LTS ≥ 2
Single right-turn lane longer than 150 ft., starting abruptly while the bike lane continues straight, and having an intersection angle and curb radius such that turn speed is ≤ 20 mph.	LTS ≥ 3
Single right-turn lane in which the bike lane shifts to the left but the intersection angle and curb radius are such that turning speed is ≤ 15 mph.	LTS ≥ 3
Single right-turn lane with any other configuration; dual right-turn lanes; or right-turn lane along with an option (through-right) lane.	LTS ≥ 4

Table 6: Level of Traffic Stress Criteria for Mixed Traffic in the Presence of a Right-turn Lane (i.e. shared right-turn lane)

Configuration	LTS
Single right-turn lane with length ≤ 75 ft. and intersection angle and curb radius limit turning speed to 15 mph.	(no effect on LTS)
Single right-turn lane with length between 75 and 150 ft., and intersection angle and curb radius limit turning speed to 15 mph.	LTS ≥ 3
Otherwise.	LTS ≥ 4

Level of traffic stress criteria for **unsignalized crossings** (Tables 7 and 8) depend on the presence of a median refuge as well street width and vehicle speeds, similar to criteria for mixed-traffic facilities. Unsignalized crossing criteria apply to both pedestrians and cyclists.

Table 7: Level of Traffic Stress Criteria for Unsignalized Crossings without a Median Refuge

Speed Limit of Street Being Crossed	Width of Street Being Crossed		
	Up to 3 lanes	4-5 Lanes	6+ Lanes
≤ 25 mph	LTS 1	LTS 2	LTS 4
30 mph	LTS 1	LTS 2	LTS 4
35 mph	LTS 2	LTS 3	LTS 4
≥ 40 mph	LTS 3	LTS 4	LTS 4

Table 8: Level of Traffic Stress Criteria for Unsignalized Crossings with a Median Refuge at Least Six Feet Wide

Speed Limit of Street Being Crossed	Width of Street Being Crossed		
	Up to 3 lanes	4-5 Lanes	6+ Lanes
≤ 25 mph	LTS 1	LTS 1	LTS 2
30 mph	LTS 1	LTS 2	LTS 3
35 mph	LTS 2	LTS 3	LTS 4
≥ 40 mph	LTS 3	LTS 4	LTS 4

Crossings are an important consideration when evaluating stress levels. For example, using the weakest link approach, a side street rated LTS 2 that intersects a wide and stressful arterial rated LTS 4 would be listed as LTS 4. Otherwise, at the network level, this side street would appear to be a continuous LTS 2 facility. An example of stress mapping is found here: http://www.axumcorp.com/sjbikemap.htm

Though not originally included in the 2012 development of LTS criteria, Peter Furth (civil engineering professor at Northeastern University and primary author of *Low-Stress Bicycling and Network Connectivity*) has developed a set of criteria for **roundabouts** for the North Avenue Corridor Study. Roundabout LTS criteria are broken into two scenarios: bicycles on a separate path or within mixed traffic. Key to either of these scenarios is the assumption that roundabouts are designed with a) splitter islands between entry and exit lanes to provide pedestrian refuge and with b) adequate deflection on both the entry and exit to control vehicle speeds for a safe pedestrian and cycling environment. Note that bike lanes within roundabouts are not preferred and should not be installed because they are unsafe.

Separate cycle paths are preferred for roundabouts because they eliminate the stress of cycling alongside traffic. However, there is still some level of traffic stress at locations where these paths cross a roundabout's entry and exit lanes. The LTS criteria for **roundabouts with a separate cycle path** focus on these crossings over entry and exit lanes.

Table 9: Level of Traffic Stress Criteria for Roundabouts with a Separate Cycle Path

Type of Entry/Exit being Crossed	LTS for non-tangential* entry or exit lane	LTS for tangential* entry or exit lane
Single entry lane	1	2
Single exit lane	1	2
Dual entry lane	1	3
Dual exit lane	3	4

** 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 when exiting the roundabout, the exit lane is non-tangential.*

Note that a shared sidewalk with ramps to and from a bike lane can qualify as a separate path around roundabouts only if all of the following four criteria are met:

Table 10: Criteria for Whether a Sidewalk around a Roundabout Qualifies as a Practical Cycling Path

Criterion	Support	Example*
Pavement width is at least 6 ft.	Allows a pedestrian to pass by a bike, assuming there are no edge obstructions such as a curb or wall preventing a cyclist from riding near the pavement edge	
Where the path crosses entry / exit legs, the offset from the outer edge of the roundabout roadway to the crossing should be no more than 30 ft.	If the offset exceeds 30 ft, circulating bikes will have to go so far out of their way that it cannot be considered as a practical bike path.	(Not qualifying) Offsets for two of the crossings are 50 ft.
The path geometry should not have turns sharper than 90 degree and should enable a cyclist to see, without looking over their shoulder, whether it's safe to cross at least 10 ft before reaching the crossing.	Ten feet is the stopping distance needed for a cyclist going 5 mph. If the sidewalk geometry requires speeds below 5 mph, it is not a practical cycling path.	(Not qualifying) Crossings begin only 4 ft after a 90 degree turn. For a cyclist 10 ft before the crossing to see whether it's safe to cross, they would have to look over their shoulder.
If the bicycling path on an approach or departure leg is in the street, whether in a bike lane or in mixed traffic, ramps should provide a transition between street and sidewalk that is reasonably direct and that provides for safe re-entry to the street.		(Qualifying) Ramps at a reasonable angle for bicycling. Re-entry ramps spill cyclists into a bike lane.

**Click here for a roundabout example in Davis, CA (Hutchison Dr. at Hutchison Pl.) where crosswalk offsets are too long (nearly 70 feet) and a circulating cyclist has to look over their shoulder because the sidewalk is too close to the roundabout's approaching legs.*

If these criteria are not met, then the roundabout should be evaluated assuming that bicycles will be in mixed traffic.

Some roundabouts do not have cycling facilities. In this **mixed-traffic roundabout** scenario, cyclists must ride with circulating vehicle traffic within the roundabout's travel lanes, thus the level of traffic stress relates primarily to total circulating vehicle volumes and number of lanes.

Table 11: Level of Traffic Stress Criteria for Roundabouts with Mixed Traffic (No Cycle Path)

Number of Circulating Lanes	ADT (Sum over all entry legs)	LTS
1	4,000 or less	1
1	4,001 to 6,000	2
1	Greater than 6,000	3
2 or more*	Any	4

** If a roundabout has two circulating lanes over only part of the roundabout, it should be counted as having two circulating lanes.*

For single- lane roundabouts, Dutch guidelines recommend a separate cycle track when average daily traffic, summed over the entry legs of a roundabout, exceeds 6,000 vehicles per day; this guideline is used as the threshold for LTS 2. It is well documented that children in the Netherlands, however, report feeling uncomfortable riding in mixed traffic roundabouts except where traffic is light, and so the LTS 1 threshold is set at 4,000 vehicles per day.

If a roundabout offers cyclists the choice of riding in mixed traffic or in a practical cycling path outside the roundabout, evaluate its LTS using the lower stress option, which will usually be the separate path.

Pros:

- Provides a clear relationship between LTS ratings and user tolerance.
- Establishes a minimum level of service required to serve the mainstream population.
- Doesn't require traffic volume (except for mixed-traffic roundabout scenario) or lane width data.
- Intuitive, easy to understand approach that is transparent and can be easily communicated to the public.
- Increasingly used by municipalities, for example Boulder, Ottawa, Providence, San Francisco, San Jose. Memphis and Washington, DC are considering this approach.

Cons:

- Does not currently account for stressors other than traffic, for example steep hills, pavement quality, crime danger, noise, aesthetics of the surroundings, and absence of lighting or snow removal.