Bicycle Level of Service Analysis

How to Measure the Bicycle-Friendliness of Capital District Roadways

July 2019

CDTC
CAPITAL DISTRICT
TRANSPORTATION COMMITTEE

CDTC Bicycle Level of Service Analysis

INTRODUCTION

Level of service (LOS) has been used as a measure to evaluate the speed or flow of vehicular through traffic on streets and at intersections. Road segments and intersections are assigned a value of A-F, with A indicating a free-flow of traffic unaffected by other vehicles and F suggesting the number of vehicles exceeds the capacity, or amount of traffic that can be served, of the roadway. LOS has been the primary metric for evaluating roadways and intersections for decades and has had a significant influence on the design of the region's transportation system. CDTC's long range plan, New Visions, lays the groundwork for a regional system of connected and accessible Complete Streets that provide mobility options to all through its policy and investment principles. The plan promotes Smart Growth, Transit-Oriented Development, and strategic investments in bicycle, pedestrian and transit facilities. Over-reliance on LOS rewards poor land use decisions that thwart this vision.

LOS tells us about vehicle delay on roadways and intersections but it doesn't necessarily provide a good measure of overall system performance. It does not measure the quality or comfort of other modes using the same roadway and navigating same intersection. A dense neighborhood with a mix of land uses and good walkability may carry a low LOS measure. On the other hand, LOS tends to reward new development in sprawling greenfield locations because they disperse vehicle traffic over a larger area. This type of development leads to more overall driving and increased congestion at major intersections, and is inconsistent with the New Visions principles.

Some planners and engineers have applied LOS to other modes, but, like LOS, applying a narrow measure to transit, walking, or bicycling doesn't measure overall system performance. CDTC explored several different methodologies that measure the approximate safety, quality, and comfort of bicyclists on roadway segments. None of the methodologies that were evaluated address accessibility or connectivity of a particular roadway segment, but they can be used, at larger geographies (i.e. neighborhood, municipal, regional) to assess the accessibly and connectivity of a network. Like all tools, these methodologies should be used and evaluated based on the planning context.

This paper provides an overview of four methodologies reviewed by CDTC staff and a small subcommittee of the Bicycle and Pedestrian Advisory Committee that included staff from Creighton Manning Engineering, Alta Planning & Design, and Greenman-Pedersen Inc. Methodologies were reviewed and tested on several road segments throughout the Capital District. These methodologies included: Level of Traffic Stress (LTS) developed by the Mineta Transportation Institute, the Bicycle Level of Service (BLOS) from the Highway Capacity Manual, the Bicycle Network Analysis created by People for Bikes, and the Bicycle Environmental Quality Index (BEQI) developed by the San Francisco Department of Public Health.

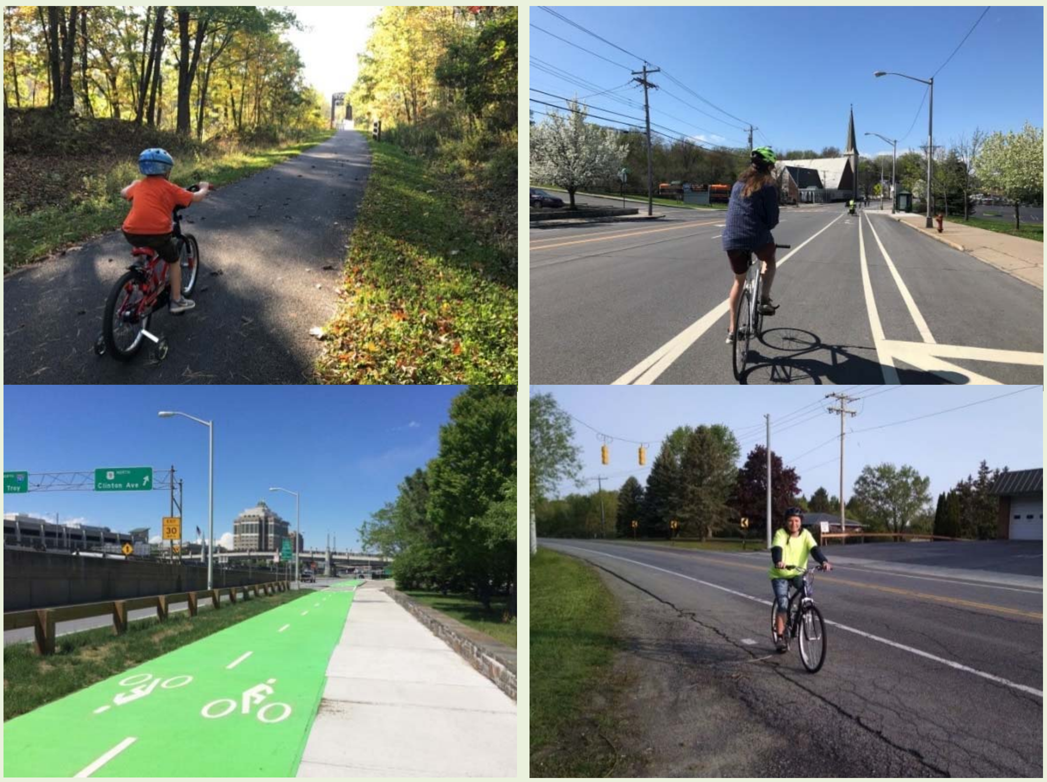
What is Accessibility?

Creating access is the ultimate goal of most transportation facilities. It refers to people's ability to reach destinations and the things you need, safely and conveniently. Accessibility is also associated with the usability of facilities by individuals with disabilities or mobility impairments. For the purposes of this paper, accessibility refers to the general comfort and connectivity of the transportation system for transit users, pedestrians, and bicyclists. CDTC supports additional measures and methods for measuring access to transportation facilities for individuals with disabilities and provides planning guidance to local governments on requirements under the Americans with Disabilities Act, specifically related to sidewalks.

Based on these analyses, we recommend using LTS for network analysis and BLOS for evaluating design alternatives. These planning contexts are typical in CDTC's Transportation and Community Linkage Studies and will be CDTC's preferred methods in such studies unless stated otherwise. CDTC will also further explore the use of the LTS method to develop a bicycle suitability map for the region. Factors such as planning context, availability of data, and resources played a significant role in this determination and we will continue to evaluate and explore methodologies.

Historically, CDTC has used a Bicycle LOS method based on research documented in *Transportation Research Record 1578* published by the Transportation Research Board of the National Academy of Sciences in 1997. The method was adopted by the Florida Department of Transportation and was long held as the recommended standard determining existing and anticipated bicycle conditions by transportation planners and engineers. This method has been employed on various transportation planning projects and other initiatives in the Capital District since the early 2000s. It has been CDTC's preferred methodology in its Transportation and Community Linkage Program. Since then, the research on non-automobile LOS has been expanded and minimum design standards for bicycle facilities have changed. As new methodologies have emerged, CDTC has tested them on bicycle and/or pedestrian focused plans, but no method has appeared to be superior.

BICYCLE FACILITIES IN THE CAPITAL DISTRICT



Clockwise from left: Albany County Rail-Trail, Bethlehem; Nott Terrace, Schenectady, Mohawk-Hudson Bike-Hike Trail, Albany; Western Turnpike, Guilderland

Initially, we evaluated and compared various methodologies with the intention of choosing and adopting the method that fit Capital District communities the best. The goal was to identify a methodology appropriate for Transportation and Community Linkage Studies and a methodology, if different, for creating a bicycle suitability map for the region. As we applied the methodologies to several road segments in the region for comparison (see Figure 2), we found strengths and weaknesses in all of them, depending on the context in which they were used. See Table 1 for the recommended methodology based on planning context and required tasks.

METHODOLOGIES: AN OVERVIEW

Bicycle Environmental Quality Index (BEQI)

The BEQI was developed to assess the bicycle environment on roadways and evaluate what streetscape improvements could be made to promote bicycling in San Francisco. It was established by the San Francisco Department of Public Health in 2007 and focused on 5 categories of roadway and intersection characteristics that were determined to influence bicycle use – intersection safety, vehicle traffic, street design, safety, and land use. The model assigns 1 of 5 types to a segment or intersection based on characteristics of the roadway, which are color coded with red being the worst and darker green the best for bicyclists.

The ratings are determined based on a range of data collected mostly through observational surveys. In order to test the methodology, extensive data collection was required. Due to limited resources, CDTC ruled out this methodology. Additional information about this method can be found in Appendix A.

Figure 1. Bicycle Environmental Quality Index (BEQI)

Source: https://merritt.cdlib.org/d/ark%3A%2F13030%2Fm5vq4gtf/1/producer%2F892128603.pdf

Bicycle Network Analysis (BNA)

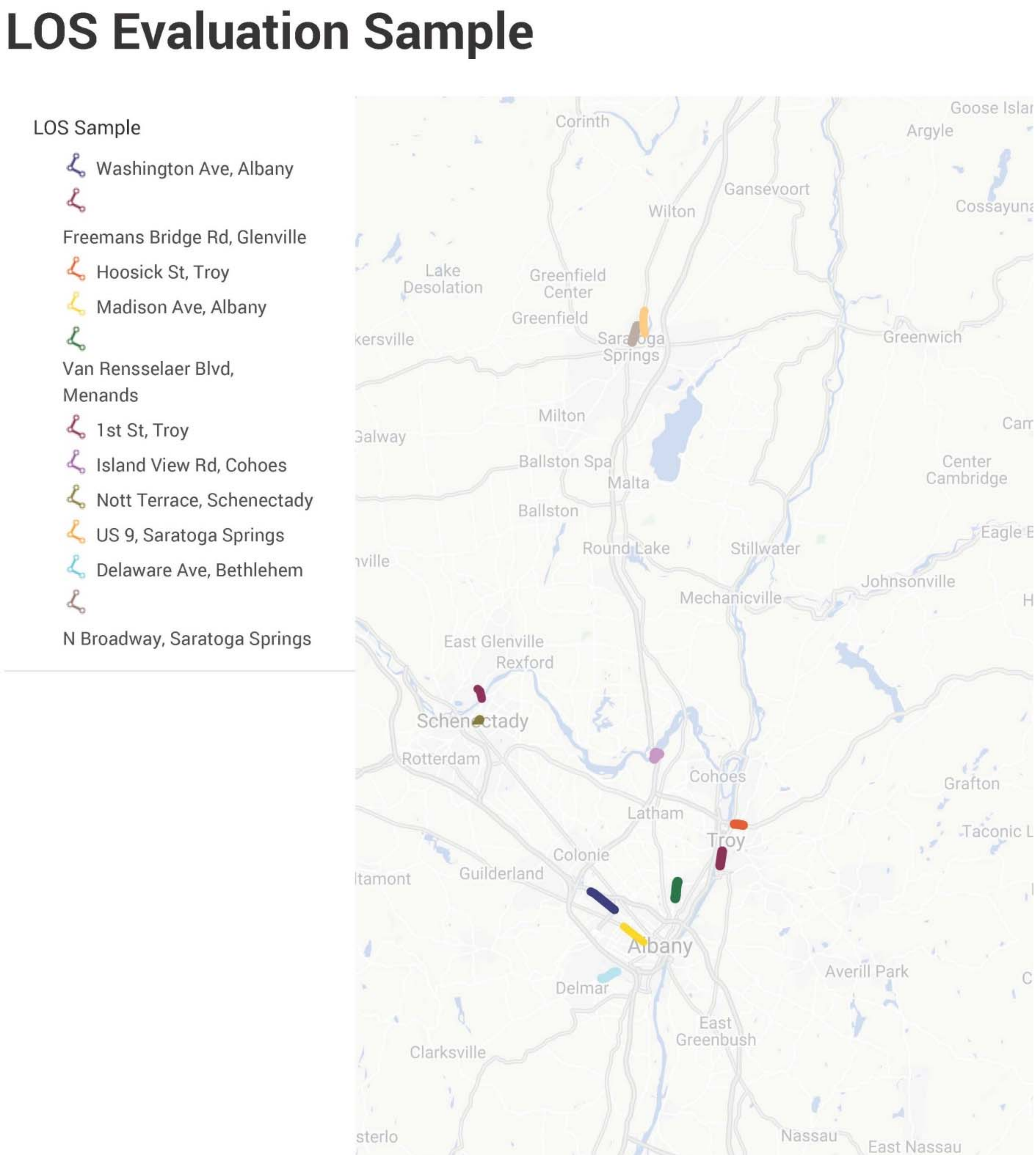
The BNA was created by People for Bikes, an industry coalition of bicycling suppliers and retailers whose mission is to “make every bike ride safer, easier to access, and more fun.” The BNA method helps communities measure the quality of their low-stress bike network by assessing the degree to which people can comfortably get to the places they way to go, by bike. The BNA relies on data from two sources: the U.S. Census and OpenStreetMap (OSM). Census blocks serve as the basic unit of analysis. OSM is a “volunteered geographic information” system, or crowd sourced geographic database.

The BNA model uses the Mineta Transportation Institute’s Level of Traffic Stress (LTS), but focuses only on very low stress segments, or in user terms, “a typical adult with an interest in riding a bicycle but who is concerned about interactions with vehicular traffic.” It then applies the LTS to OSM data, using a system of tags for bicycle facilities and destinations. This is where the BNA model becomes more resource intensive. People for Bikes recommends hosting “Map-a-Thons” to crowd source accurate, necessary data needed to perform the analysis. OSM data is inconsistent from city to city and not always dependable. We found many inaccuracies in the OSM for the City of Albany. After consulting several professionals on the BNA model, we eliminated this methodology as a feasible option.

With accurate data, we believe the BNA model could be valuable in not only illustrating bicycle user comfort of road segments, but in providing an analysis of the overall network and the usefulness of low stress segments connecting people to where they want to go, like jobs, transit, shopping, and recreational opportunities. Figure 3. BNA for City of Albany shows how People for Bikes depicts the BNA score for each place. The City of

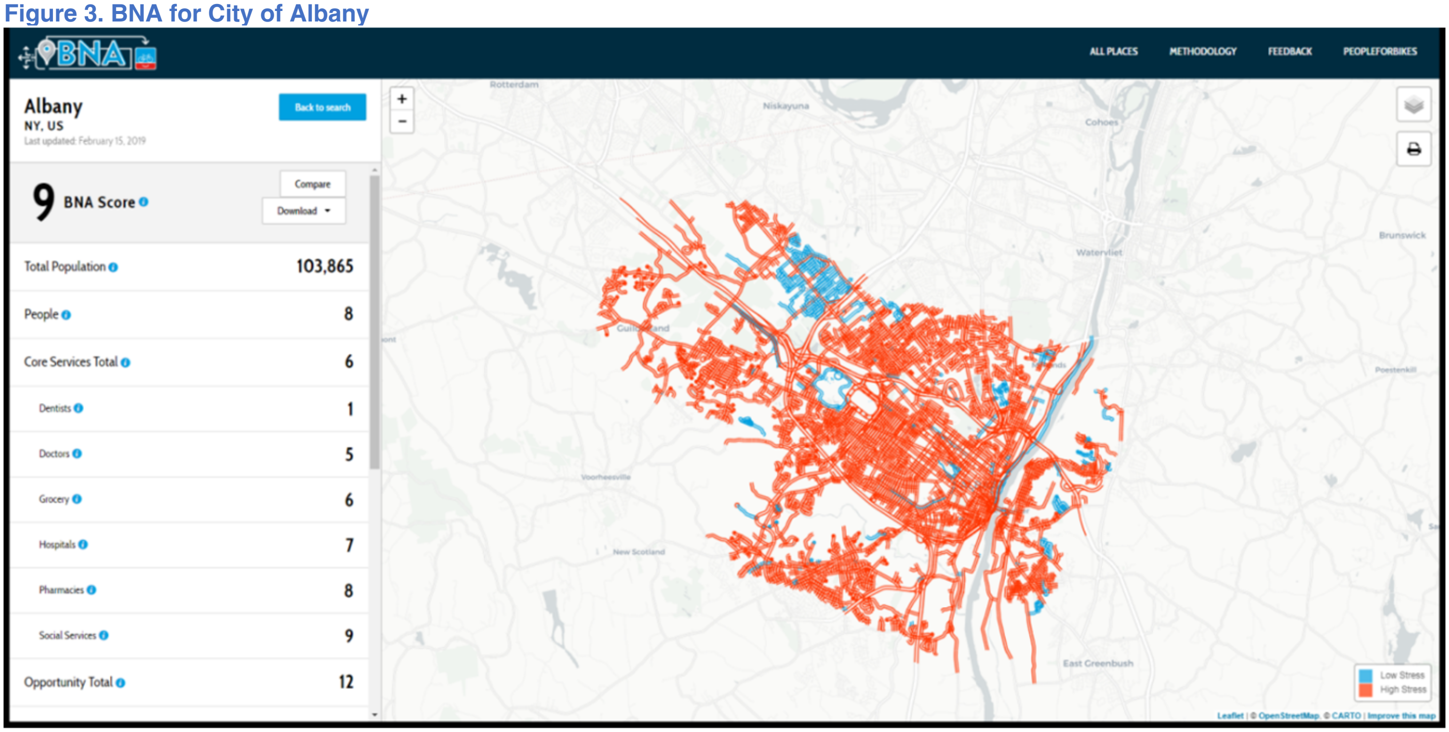
Albany was the only location within the Capital District with a BNA score, but as stated earlier, CDTC found many

Figure 2. LOS Road Segment Sample



inaccuracies in the OSM data used to calculate the score. The road sample used to test the LTS model later in this document will also show why most road segments in the region score high in terms of stress. Additional information about the BNA model can be found in Appendix B or at https://bna.peopleforbikes.org/#/.[1]

Figure 3. BNA for City of Albany



Source: *https://bna.peopleforbikes.org/#/places////*

Bicycle Level of Service (BLOS)

The BLOS model is based on proven research documented in *Transportation Research Record 1578* published by the Transportation Research Board of the National Academy of Sciences and presented in the 2010 Highway Capacity Manual (HCM). CDTC endorsed the original form of BLOS and has used it since 2003. After tests on varying roadway types throughout the country, the model was refined to better quantify the effects of high-speed truck traffic on bicycle suitability. BLOS model Version 2.0 was used in this analysis.

There is a similar model for Pedestrian Level of Service (PLOS) and Transit Level of Service (TLOS) that was not included in this evaluation but may be evaluated in the future as resources allow. BLOS assigns a grade of A through F to a segment of roadway based on the perceived level of service the segment provides to bicyclists. The PLOS and BLOS comprise a portion of the HCM's Multimodal Level of Service methodology (MMLOS). Factors that most influence BLOS are roadway width; bike lane, shoulder, or other striping combinations; traffic volume; pavement surface conditions; motor vehicle speed and type; and on-street parking.

Performing a BLOS analysis of a roadway requires a significant but feasible amount of data collection. The data required for BLOS computation includes:

- Average Daily Traffic
- Percent heavy vehicles
- Number of lanes of traffic
- Lane configuration (i.e. divided, one-way, center turning lane, undivided)
- Posted speed limit

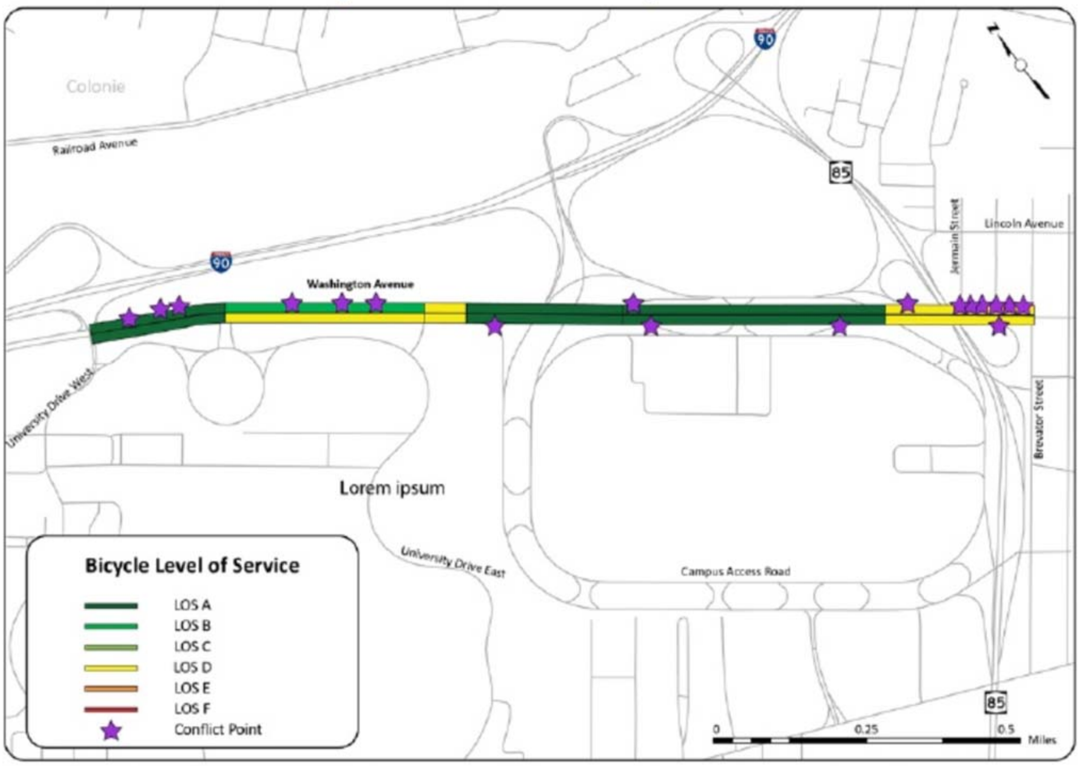
[1] People for Bikes https://bna.peopleforbikes.org/#/

- Total width of pavement
- Width of pavement for striped on-street parking
- Width of pavement between the outside lane stripe and the edge of the pavement
- Percent of occupied on-street parking (during time of survey)
- Pavement condition based on the Federal Highway Administration's five-point pavement rating[2]
- Presence of designated bike lane

$$\mathbf{BLOS = a_1 ln\ (Vol_{15}/L_n) = a_2SP_t\ (1+10.38HV)^2 + a_3(1/PR_5)^2 + a_4(We)^2 + C}$$

The BLOS model uses a complicated formula and the score resulting from the equation is stratified into service categories "A, B, C, D, E, and F," which are traditional vehicle level of service ratings. Additional details for the BLOS formula can be found in Appendix C.**Error! Reference source not found.** shows the results of a BLOS analysis of Washington Avenue in Albany that was conducted as part of the Washington Patroon Corridor Study.

Figure 4. BLOS as Conducted for the Washington Patroon Corridor Study



Level of Traffic Stress (LTS)

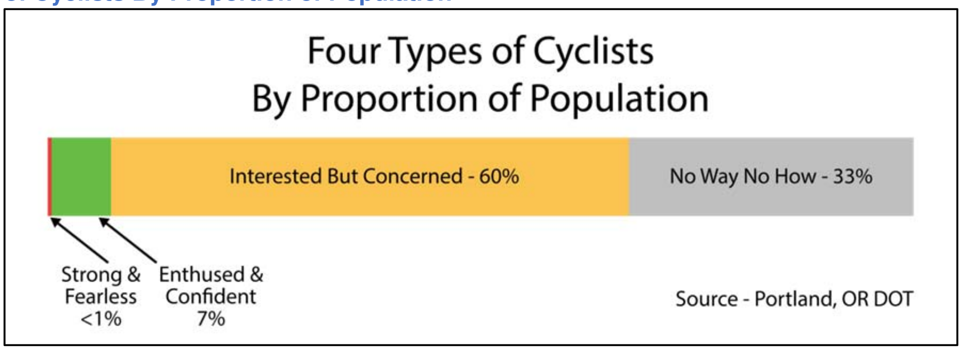
This methodology was developed by the Mineta Transportation Institute at San Jose University. The LTS is a set of criteria that classifies road segments into four levels of stress based on Dutch bikeway design criteria, representing a more realistic level of traffic stress that most adults will tolerate. Cyclists are typically classified into four groups as illustrated in

Figure 5. It is a model that moves planners away from merely measuring the miles of bicycle facilities as a measure of progress and towards measuring bicyclists' level of comfort in traveling between home, work, and

[2] See Table 2 for how CDTC applied FHWA's five-point pavement rating system in the model.

other destinations. It helps highlight quiet streets that do not necessarily have designated bike facilities yet create a low-stress environment for bicyclists and serve as part of a community's bicycle network. So rather than limiting bicyclists to a set of streets and paths that cities and regions advise bicyclists to use as primary routes, low stress streets identified using LTS may well represent where people, particularly less confident cyclists, actually ride.

Figure 5. Four Types of Cyclists By Proportion of Population



LTS measures traffic stress and bicyclist comfort based on several roadway characteristics:

- Number of lanes
- Traffic speeds
- Presence of a parking lane
- Presence of a designated bike facility
- Whether bikes are in mixed traffic
- Whether a shoulder or bike lane is adjacent to parking

Prevailing traffic speeds and the number of lanes are the two most significant factors determining LTS. Roadways with the lowest levels of traffic stress are classified as LTS 1 and the highest levels of traffic stress are classified as LTS 4. In 2017, LTS Version 2.0 was released as a more refined model that included traffic volumes as a factor. For the purposes of this analysis, CDTC used LTS Version 2.0. The research behind the LTS model can be found in Appendix B.[3ii]

The LTS does not, in itself, measure accessibility, but a network analysis using the LTS model can help planners and engineers identify connectivity gaps between activity generators and destinations. If determining the priority of certain bike facility or pavement projects, an LTS analysis can prioritize a short segment of road that may not seem worthy of a designated bike facility, but if it connects two low stress areas of streets, it can demonstrate significant network benefits. Since the model is based on the four classifications of cyclists, in can be calibrated based on local preferences and levels of perceived comfort. Some cities and regions have conducted visual surveys to gather data on public perceptions of traffic stress and adjusted the LTS model to their local needs. For example, if the majority of potential bicyclists do not perceive any road where bikes are mixed with traffic to be comfortable, then that city or region may adjust the model so that only separated multi-use paths are classified as LTS 1.

LTS is intended to measure the bike-friendliness of road segments, however, improvements for bicyclists generally translate into improvements for pedestrians as well. And the factors that make a road segment more or less friendly for bicycle travel, effect the pedestrian-friendliness and walkability. While this analysis did not include the evaluation of intersections, the LTS model provides criteria for rating intersections based on the type of crossing, vehicle speeds, and the number of lanes that are required to be crossed. This LTS model measures stress in terms of exposure, which is generally how pedestrian-friendliness is graded.

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[3] Furth, Peter. "Level of Traffic Stress Criteria for Road Segments, Version 2.0, June, 2017." http://www.northeastern.edu/peter.furth/wp-content/uploads/2014/05/LTS-Tables-v2_june-1.pdf.

Data

As noted in the previous section, each model requires different data inputs. The BNA and BEQI models required more data than we could immediately access. Table 1 on the next page contains the required inputs, the source we used, which model uses it, and notes on assumptions made when data was unavailable.

Results

We tested the LTS and BLOS models on 64 segments on 11 different roadways that are located throughout the CDTC area. The roadways varied in terms of volumes, widths, surrounding land uses and other characteristics. There was an effort to include roads that had recently been reconfigured or undergone a major redesign, such as Madison Avenue in Albany, 1st Street in Troy, and Van Rensselaer Boulevard in Menands.

The models were not directly comparable because they use different scales. The LTS model categorizes road segments on a scale of 1-4, with 1 being the best, and the BLOS model uses a scale of A-E, with A being the best. With this in mind, many segments yielded different scores for each model. Several segments received a BLOS of A while simultaneously receiving an LTS of 3 or 4. Most segments with disparate scores yielded a better rating from the BLOS model. However, there were some disparate segments that received a lower BLOS than LTS, meaning the BLOS model identifies the segment as less comfortable for bicyclists.

Comparing the results from each model, it is evident that the LTS methodology is sensitive to vehicle speeds above all other roadway characteristics. All on-road bicycle facilities in the Capital District, regardless of the level of protection or designation as a bike route, are excluded from an LTS 1 score because the minimum speed limit in New York is set at 30 mph (there are some exceptions to this in limited areas, like villages). If LTS 1 indicates a facility that is comfortable for all users, including children, this designation is reserved for off-road trails in the Capital District only.

On the other hand, BLOS is most sensitive to lane widths, traffic volumes, and heavy vehicles. According to the BLOS model, wider lane widths yield better BLOS scores so it does not distinguish roadways that force bicyclists to mix with traffic versus those that provide designated space (i.e. shoulder, bike lane). Heavy vehicles pose a danger to bicyclists and generally create an unpleasant environment for bicyclists. The model baseline average for heavy vehicle traffic is 1%, which is very low. Where data was available, heavy vehicle traffic was 2-6%. Data for the percent of heavy vehicles was not available for every roadway segment and may disqualify the model to be used depending on the planning context.

The next section compares the models' assessment of bicycling conditions on several Capital District roadways. The LTS and BLOS scores for each segment can be found in the table, along with several roadway characteristics. Each table is accompanied by images or photos of the roadway to help readers contextualize the scores.

Table 1. Comparing BLOS and LTS

	Bicycle Level of Serivce		Level of Traffic Stress	
TOPIC	**PRO**	**CON**	**PRO**	**CON**
Data Needs		More data-intensive, requires roadway width & AADT to run model	Less data-intensive & can use assumptions as substitutes for missing or uncertain data	
Level of Acceptance	Endorsed by FHWA		Approved and adopted by at least one DOT and one MPO	
Familiarity	Well understood by engineers and most planners	Not easily understood by the public	Used and understood by advocacy groups and other organizations; easily understood by public	
Visualization	A-F ratings with corresponding color coding		4 levels with corresponding color which can be easily translated to types of cyclists	
Level of detail	Considers more roadway characteristics and more detailed which can be helpful in analyzing site-specific alternative designs			Better for network analysis than site specific conditions
Helps further New Visions goals		Does not recognize or weight designated bicycle facilities like cycle tracks or separated bike lanes	Model heavily weights speed	
Application	Favors more suburban types of roadways			Best used in urban environments

Table 2. Data Required for BLOS & LTS Models

Input	Source	Model(s)	Notes
Average Daily Traffic (ADT)	NYSDOT RIS GIS NYSDOT Traffic Data Viewer	LTS BLOS	Both models require this input, which can be found in multiple sources
% Heavy Vehicles	NYSDOT RIS GIS NYSDOT Traffic Data Viewer	BLOS	
# of Traffic lanes	NYSDOT RIS GIS Google Earth	LTS BLOS	Both models require this input, which can be found in multiple sources
Lane Configuration	Google Earth	BLOS	
Posted Speed Limit	NYSDOT RIS GIS	BLOS	
Total Width of Pavement	NYSDOT RIS GIS	BLOS	Where pavement widths were unavailable, used judgment based on visual information, assumed shoulder width of 5 feet and travel lane of no less than 11 feet.
Width of pavement for striped on street parking	Google Earth	BLOS	Where pavement widths were unavailable, used judgment based on visual information, assumed 7 foot parking lane.
Width of pavement between the outside lane stripe and the edge of the pavement	NYSDOT RIS GIS	BLOS	Where pavement widths were unavailable, used judgment based on visual information, assumed shoulder width of 5 feet.
% of occupied on street parking	Google Earth	BLOS	Estimated based on visual survey of number of occupied vs. available parking spaces.
Pavement condition based on the FHWA 5-point pavement rating	Google Earth	BLOS	Based on FHWA 5-point pavement rating, assigned a 5 to pavement known to be new in last 2 years and 4 to all other segments based on Google Earth Streetview.
Presence of bike lane	NYSDOT RIS GIS Google Earth	LTS BLOS	Both models require this input, which can be found in multiple sources
Prevailing Speed	NYSDOT RIS GIS	LTS	Where prevailing speed data wasn't available, assumed +5 mph to posted speed

Washington Avenue, Albany

Description: *The photo on the left is an aerial view of Washington Ave. at the I-90 Exit 2 ramps looking east. The horizontal line shaded green shows that the roadway is approximately 100 feet wide.*

Photo Source: *Creighton Manning Engineering*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Washington Ave	I-90 Exit 2	SUNY Center	Bike lane not adjacent to parking	2	2	N	Y	*10,243*	30	LTS 3	A
Washington Ave	SUNY Center	I-90 Exit 2	Bike lane not adjacent to parking	2	1	N	Y	*9,946*	30	LTS 3	A
Washington Ave	SUNY Center	SUNY East	Bike lane not adjacent to parking	2	2	N	Y	*10,243*	30	LTS 4	D
Washington Ave	SUNY East	SUNY Center	Bike lane not adjacent to parking	2	1	N	Y	*9,946*	30	LTS 3	B

Description: *The photo above is of Washington Ave looking westbound just after the entrance to Patroon Creek, a development containing a mix of medical offices, commercial uses, and multi-family housing.*
Photo Source*: Google*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Washington Ave	SUNY East	1365 Washington Ave	Bike lane not adjacent to parking	2	1	N	Y	*10,243*	30	LTS 4	D
Washington Ave	1365 Washington Ave	SUNY East	Bike lane not adjacent to parking	2	1	N	Y	*9,946*	30	LTS 4	D
Washington Ave	1365 Washington Ave	WB Harriman On Ramp	Bike lane not adjacent to parking	2	0	N	Y	*10,243*	30	LTS 3	A
Washington Ave	WB Harriman On Ramp	1365 Washington Ave	Bike lane not adjacent to parking	2	0	N	Y	*9,946*	30	LTS 3	A

***Description**: The photo above is a bicyclist crossing a yield-control merge on Washington Ave. heading eastbound.*
***Photo Source:** Creighton Manning Engineering*

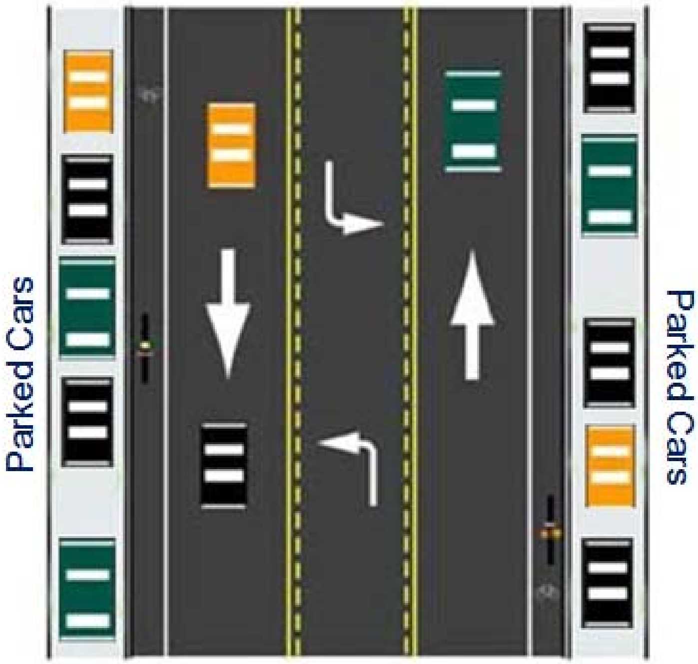
Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Washington Ave	WB Harriman on Ramp	EB Harriman Ramp	Bike lane not adjacent to parking	2	0	N	Y	*8,497*	30	LTS 3	A
Washington Ave	EB Harriman on Ramp	WB Harriman on Ramp	Bike lane not adjacent to parking	2	0	N	Y	*7,447*	30	LTS 3	A
Washington Ave	EB Harriman on Ramp	Brevator	Mixed traffic	2	0	N	N	*8,497*	30	LTS 4	D
Washington Ave	Brevator	EB Harriman on Ramp	Mixed traffic	2	0	N	N	*7,447*	30	LTS 4	D

Freemans Bridge Road, Glenville

Description: *Photo on left shows kids riding onto Freemans Bridge Rd, southbound, from the nearby Mohawk-Hudson Bike-Hike Trail, and over bridge that crosses the Mohawk River. Photo on right is looking north on Freemans Bridge Rd from bridge over Mohawk River.*
Photo Source: *Planning 4 Places*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Freemans Bridge Rd	Maxon Rd	Boat Launch	Mixed traffic	2	0	N	Y	*13,561*	40	LTS 4	D
Freemans Bridge Rd	Boat Launch	Maxon Rd	Mixed traffic	2	1	N	Y	*13,325*	40	LTS 4	D
Freemans Bridge Rd	Boat Launch	60 Freemans Bridge Rd	Mixed traffic	2	1	N	Y	*6,069*	40	LTS 3	C
Freemans Bridge Rd	60 Freemans Bridge Rd	Boat Launch	Mixed traffic	2	1	N	Y	*6,200*	40	LTS 3	C
Freemans Bridge Rd	60 Freemans Bridge Rd	Rte 50	Mixed traffic	1	0	N	Y	*6,069*	40	LTS 4	D
Freemans Bridge Rd	Rte 50	60 Freemans Bridge Rd	Mixed traffic	1	0	N	Y	*6,200*	40	LTS 4	D

Madison Avenue, Albany



Description*: The image on the left is a mock-up of the new configuration of Madison Ave. The photo on the right was taken shortly after the first phase of the Madison Ave. Road Diet was completed and looks east on Madison Ave from the intersection of S. Allen St., also known as "The Point."*
Photo Source*: All Over Albany*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Madison Ave	S. Allen St.	W. Lawrence St.	Bike lane alongside a parking lane	1	1	Y	N	*7,053*	30	LTS 3	D
Madison Ave	W. Lawrence St	S Allen St.	Bike lane alongside a parking lane	1	1	Y	N	*6,667*	30	LTS 3	D

Description: *The photo on the left is Madison Ave. looking west at N. Main Ave and the photo on the right is a short distance up the road looking east in the area of the College of St. Rose.*
Photo Source: *All Over Albany (left) and Creighton Manning Engineering (right)*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Madison Ave	W. Lawrence St.	S. Main Ave.	Bike lane alongside a parking lane	1	1	Y	N	*7,053*	30	LTS 3	C
Madison Ave	S. Main Ave.	W. Lawrence St.	Bike lane alongside a parking lane	1	1	Y	N	*6,667*	30	LTS 3	C
Madison Ave	S. Main Ave.	New Scotland Ave	Bike lane alongside a parking lane	1	1	Y	N	*7,053*	30	LTS 3	C
Madison Ave	New Scotland Ave	S. Main Ave.	Bike lane alongside a parking lane	1	1	Y	N	*6,667*	30	LTS 3	D

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Van Rensselaer Boulevard, Menands

Description: *The photo on the far left is Van Rensselaer Blvd. looking south and next to it is a photo looking north near Wards Ln.*

Photo Source: *TimesUnion (left) and All Over Albany (right)*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Van Rensselaer Blvd	Menands Rd	Wards Ln.	Bike lane not adjacent to parking	1	1	Y	Y	*3,837*	45	LTS 3	B
Van Rensselaer Blvd	Wards Ln.	Menands Rd.	Bike lane not adjacent to parking	1	1	Y	Y	*3,610*	45	LTS 3	B
Van Rensselaer Blvd	Wards Ln.	Northern Blvd.	Bike lane not adjacent to parking	1	1	Y	Y	*3,810*	45	LTS 3	B
Van Rensselaer Blvd	Northern Blvd.	Wards Ln.	Bike lane not adjacent to parking	1	1	Y	Y	*3,984*	45	LTS 3	B

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1st Street, Troy

Description: *The photo on the left shows bicyclists stopped in the buffered bike lane, northbound on 1st St. between Ida St. and Adams St. and the Google Streetview image on the rights shows 1st looking south between Madison and Tyler St.*
Photo Source: *CDTC and Google*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
1st St.	Adams St.	Ida St.	Bike lane not adjacent to parking	1	0	Y	N	*2,491*	30	LTS 2	D
1st St.	Ida St.	Madison St.	Bike lane not adjacent to parking	1	0	Y	N	*2,475*	30	LTS 2	D
1st St.	Madison St.	Tyler St.	Bike lane alongside a parking lane	1	0	Y	Y	*2,475*	30	LTS 2	C
1st St.	Tyler	Polk St.	Mixed traffic	1	0	N	N	2475	30	LTS 3	C

Island View Road, Cohoes

Description: *Above are Google Streetview images of Island View Rd. The image on the left shows Island View Rd heading west under the Twin Bridges (I-87). The image on the right is near a trailhead for the Mohawk-Hudson Bike-Hike Trail on Island View Rd. facing east.*
Photo Source: *Google*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Island View Rd.	Dunsbach Ferry Rd	MHBHT	Mixed traffic	1	0	N	N	*<1000*	30	LTS 2	B
Island View Rd.	MHBHT	Dunsback Ferry Rd	Mixed traffic	1	0	N	N	*<1001*	30	LTS 2	B

Nott Terrace, Schenectady

Description: *The Google Streetview image on the left is looking north towards the intersection of Nott Terrace with Union Street and the phone on the right is looking south towards the entrance to the bike path in Vale Park, in the vicinity of the Museum of Innovation and Science*
Photo Source: *Google (left) and CDTC (right)*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Nott Terrace	Union St.	Eastern Ave	Mixed traffic	2	1	N	N	*6,357*	30	LTS 3	C
Nott Terrace	Eastern Ave	Union St.	Mixed traffic	0	3	N	N	*7,058*	30	LTS 3	C
Nott Terrace	Eastern Ave	Franklin St.	Bike lane not adjacent to parking	1	1	Y	N	*6,357*	30	LTS 2	C
Nott Terrace	Franklin St.	Eastern Ave.	Bike lane not adjacent to parking	1	1	Y	N	*7,058*	30	LTS 2	B

Marion Avenue/ Maple Ave/ US 9, Saratoga

***Description*:** *The Google Streetview image on the left is facing northbound and the image on the right is facing southbound near Maple Avenue Middle School.*
***Photo Source*:** *Google*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Marion Ave (US 9)	NY 29	Maple Ave	Mixed traffic	1	1	N	N	*6,422*	40	LTS 4	D
Marion Ave (US 9)	Maple Ave	NY 29	Mixed traffic	1	1	N	N	*6,371*	40	LTS 4	D
Maple Ave (US 9)	Maple Ave	Glen Mitchell Rd/Loughberry Lake Rd	Bike lane not adjacent to parking	1	0	N	Y	*6,422*	40	LTS 3	B
Maple Ave (US 9)	Glen Mitchell Rd/Loughberry Lake Rd	Maple Ave	Bike lane not adjacent to parking	1	0	N	Y	*6,371*	40	LTS 3	B
Maple Ave (US 9)	Glen Mitchell Rd/Loughberry Lake Rd	Northern Pines Rd	Bike lane not adjacent to parking	1	0	N	Y	*6,422*	40	LTS 3	B
Maple Ave (US 9)	Northern Pines Rd	Glen Mitchell Rd/Loughberry Lake Rd	Bike lane not adjacent to parking	1	0	N	Y	*6,371*	40	LTS 3	B

CDTC Bicycle Level of Service Analysis

North Broadway, Saratoga Springs

Description: *The photo on the left shows bicyclists riding southbound on N. Broadway between Van Dam St. and Rock St. and the Google Streetview image on the right is looking north heading towards Skidmore College.*
Photo Source: *CDTC and Google*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
N Broadway	Van Dam St. / NY 29	Rock St.	Bike lane alongside a parking lane	1	0	Y	N	*1,368*	30	LTS 2	C
N Broadway	Rock St.	Van Dam St. / NY 29	Bike lane alongside a parking lane	1	0	Y	N	*1,213*	30	LTS 2	C
N Broadway	Rock St.	4th St.	Bike lane alongside a parking lane	1	0	Y	N	*1,368*	30	LTS 2	A
N Broadway	4th St	Rock St.	Bike lane alongside a parking lane	1	0	Y	N	*1,213*	30	LTS 2	A
N Broadway	4th St.	Skidmore College	Bike lane not adjacent to parking	1	0	Y	N	*1,368*	30	LTS 2	B
N Broadway	Skidmore College	4th St.	Bike lane not adjacent to parking	1	0	Y	N	*1,213*	30	LTS 2	B

Delaware Avenue, Bethlehem

Description: *The photo on the left is looking west on Delaware Ave at Mason Rd and the Google Streetview image on the right is looking east between Euclid and Elsemere.*
Photo Source: *Timesunion (left) and Google (right)*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Delaware Ave NY 443	Elsmere Rd	Euclid Ave	Mixed traffic	2	0	N	Y	*18,200*	40	LTS 4	E
Delaware Ave NY 443	Euclid Ave	Elsmere Rd	Mixed traffic	2	0	N	Y	*18,200*	40	LTS 4	E
Delaware Ave NY 443	Euclid Ave	Park n Ride driveway	Mixed traffic	2	0	N	N	*18,200*	40	LTS 4	D
Delaware Ave NY 443	Park n Ride driveway	Euclid Ave	Mixed traffic	2	0	N	N	*18,200*	40	LTS 4	D

Description: *The Google Streetview image above shows Delaware Ave. heading east towards the City of Albany. It is just before the Delaware Ave. crosses the Normanskill.*
Photo Source: *Google*

Road Name	From	To		Thru Lanes (No.)	Turning Lanes (No.)	Bike lane (y/n)	Shoulder (y/n)	Avg. Daily Traffic	Posted Speed Limit	LTS	BLOS
Delaware Ave NY 443	Park n Ride driveway	800' W of Old Delaware	Mixed traffic	2	0	N	Y	*15,600*	40	LTS 4	E
Delaware Ave NY 443	800' W of Old Delaware	Park n Ride driveway	Mixed traffic	2	0	N	Y	*15,600*	40	LTS 4	E
Delaware Ave NY 443	800' W of Old Delaware	Normanskill Bridge	Bike lane not adjacent to parking	1	0	N	Y	*15,600*	40	LTS 3	D
Delaware Ave NY 443	Normanskill Bridge	800' W of Old Delaware	Bike lane not adjacent to parking	1	0	N	Y	*15,600*	40	LTS 3	D

Low Traffic Stress Facilities

In Table 3 below, the four levels of traffic stress are translated to the type of cyclist that the model assumes the facility will be comfortable for. This is based on **Error! Reference source not found.**, which breaks down cyclist types by percent of the population. Facilities with the lowest stress, that feel comfortable for most people, and safe for most children, are generally separated facilities (i.e. trail or physically separated bike lane or cycle track). The LTS model also suggests that very low volume roads with slow traffic can be comfortable for most people

Table 3. Translating LTS

LTS	Comfortable Enough For (Cyclist Type)	Characteristics
1	Most People	• Lowest stress • Comfortable for most ages and abilities
2	Interested, but Concerned	• Suitable for most adults • Presenting little traffic stress
3	Enthused and Confident	• Moderate traffic stress • Comfortable for those already biking in American cities
4	Strong and Fearless	• High traffic stress • Multilane, fast moving traffic

The sample used in this analysis did not include any roadway segments that met the LTS model's speed and volume thresholds for LTS 1. Because the minimum speed limit in New York State is set at 30 mph, these types of roadways are uncommon. However, the rule makes an exception for villages and school zones. Below is a Google Streetview snapshot of Peachtree Lane in the Village of Colonie, where speed limits are set at 25. Assuming cars are traveling 25mph and given the low average daily traffic of this particular segment (254), this is an example of one of the few LTS 1 roadways in the Capital District.

Figure 6. Peachtree Lane in the Village of Colonie

Other facilities that meet the thresholds for LTS 1 are separated bicycle and pedestrian facilities. In the Capital District, this is mainly reserved for trails, as illustrated in Figure 7 below. Trails, or what are commonly referred to as "multi-use" or "shared-use" paths, provide space separate from vehicle traffic for walking, bicycling, and other non-motorized transportation. There is a high expectation of safety and comfort here and they should receive a LTS 1 score in any mapping or network evaluation that employs the LTS model.

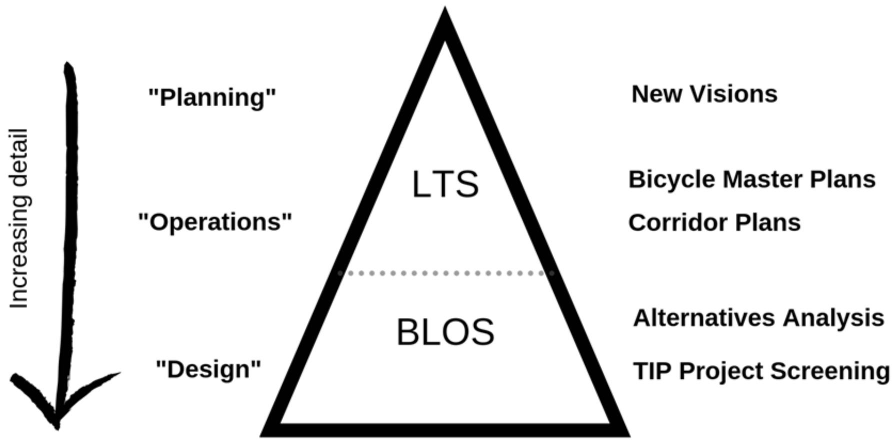
Figure 7. Examples of Separated bicycling facilities in the Capital District

Clockwise from top left: *Mohawk-Hudson Bike-Hike Trail, Schenectady; Mohawk-Hudson Bike-Hike trail, Albany; Zim Smith Trail, Malta; and Albany County Rail-Trail, Albany*

Choosing the Right Measure for the Capital District

Based on the analysis, we recommend that CDTC use the LTS model for all Community and Transportation Linkage Studies, tasks related to the long-range plan (New Visions), and for future bicycle suitability mapping. The LTS model allows for a quick assessment of system connectivity without the burden of extensive data collection. The data required should be available through existing inventories or easily obtainable. The visually-based results are easy to communicate to the public, as well as between staff and stakeholders managing transportation planning initiatives. This evaluation included LTS segment methodology but intersection approaches and crossings can also use the LTS model (see Appendix D).

Figure 8. Model Choice & Planning Context



While CDTC is confident that the LTS model is the preferred methodology for the Capital District, planners and engineers should always assess the planning context before embarking on tasks and projects related to transportation planning and measuring bike-friendliness. The LTS model should be used as prescribed in "Level of Traffic Stress Criteria for Road Segments, Version 2.0, June, 2017" as found in Appendix D. LTS does not measure bicycling demand, accessibility or surrounding land use connection, safety, or bicycle congestion and traffic. The model does not take bicycle facility type (sharrows vs. protected cycle-track) into consideration when determining LTS, but research suggests that buffered bike lanes improve cyclist comfort and safety. It also does not consider topography (hills), pavement condition, left turn lanes, or driveway/curb-cut density, which all impact bicycling comfort.

Despite the factors not included in LTS analysis, the model offers advantages over simply assessing routes based on whether they are equipped with bike lanes or other bicycle-specific infrastructure. Unlike the BLOS model, LTS considers the different types of bicyclists using the system and is easy to explain to the public and policymakers. The LTS methodology yields more meaningful results than BLOS, allowing bicyclists to choose routes based on how much traffic stress they are comfortable with. The simplicity of the methodology makes it easier to apply on a large scale, or future suitability mapping projects.

There are weaknesses in the LTS model because, although it has become popular, it is relatively new and lacks extensive research and validation.[4] Additionally, it is not directly applicable to rural areas. Recent research has indicated that LTS is a valid measure of a household's propensity to bicycle, but the model must continue to be studied and re-evaluated. The LTS model can be improved and calibrated to the local context through visual preference surveys. CDTC will conduct bicycle facility preference surveys on an ongoing basis, initially in the development of New Visions 2050 and all Community and Transportation Linkage Studies

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[4] Wang, Haizhong & Palm, Matthew & Chen, Chen & Vogt, Rachel & Wang, Yiyi, 2016. "Does bicycle network level of traffic stress (LTS) explain bicycle travel behavior? Mixed results from an Oregon case study," Journal of Transport Geography, Elsevier, vol. 57(C), pages 8-18.

thereafter. The data collected through these surveys will help LTS criteria to fit local bicycling preferences, reformat LTS tables, and remove any found inconsistencies.

CDTC transportation planning initiatives that include the evaluation of design alternatives, after an initial LTS analysis, should consider the use of the BLOS model to help guide decision-making. The BLOS model requires data that may not be available in existing inventories or easy to obtain. Any planning task that anticipates an evaluation of design alternatives should include sufficient budget and clearly outline a data collection and BLOS modeling task in the scope.

When resources allow, CDTC should pilot the use of the BNA model. This model would be a useful tool in measuring accessibility based on surrounding land uses and destinations. The BNA model is labor intensive and should be outsourced to a qualified consultant. It could be a useful tool for prioritizing corridors and segments for improvements and measuring network connectivity.

Using the LTS Model

CDTC recommends the use of the following tables for LTS analysis. These may be updated in the future as we collect data from visual preference and other public surveys on bicycle facility comfort. See Appendix D for methodology details.

Figure 9. LTS mixed traffic criteria

		Prevailing Speed						
Number of lanes	Effective ADT*	≤ 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 3	LTS 4
	1501-3000	LTS 2	LTS 2	LTS 2	LTS 3	LTS 4	LTS 4	LTS 4
	3000+	LTS 2	LTS 3	LTS 3	LTS 3	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 3	LTS 4
	1501-3000	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	3000+	LTS 3	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
2 thru lanes per direction	0-8000	LTS 3	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	8001+	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
3+ thru lanes per direction	any ADT	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4

* Effective ADT = ADT for two-way roads; Effective ADT = 1.5*ADT for one-way roads

Figure 10. LTS criteria for roadways with bike lanes & shoulders not adjacent to a parking lane

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

Figure 11. LTS criteria for roadways with bike lanes alongside a parking lane

Number of lanes	Bike lane reach = Bike + Pkg lane width	Prevailing Speed ≤ 25 mph	30 mph	35 mph
1 lane per direction	15+ ft	LTS 1	LTS 2	LTS 3
	12-14 ft	LTS 2	LTS 2	LTS 3
2 lanes per direction (2-way)	15+ ft	LTS 2	LTS 3	LTS 3
2-3 lanes per direction (1-way)		LTS 2	LTS 3	LTS 3
other multilane		LTS 3	LTS 3	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.

Additional guidance on evaluating the LTS for intersections and at roundabouts can be found in Appendix(ces) E and F. As noted earlier, the LTS model focuses on bicycles but the criteria for bike-friendliness at intersections and at roundabouts also applies to pedestrians.

Resources

Level of Traffic Stress Criteria for Road Segments, Version 2.0, by Peter Furth

Highway Capacity Manual Bicycle Level of Service

Bicycle Level of Service Applied Model by Sprinkle Consulting

People for Bikes' Bicycle Network Analysis

FHWA Guidebook for Measuring Multimodal Network Connectivity

Real-Time Human Perceptions: Toward a Bicycle Level of Service, Transportation Research Record 1578, TRB 1997

Defining the Madison Area Low-Stress Bicycle Network and Using it to Build a Better Regional Network, Madison Area Transportation Planning Board

DVRPC Bicycle LTS and Connectivity Analysis Documentation, Delaware Valley Regional Planning Commission

APPENDIX A

BICYCLE ENVIRONMENTAL QUALITY INDEX

(BEQI)

SFDPH Program on Health, Equity, and Sustainability
Urban Health and Place Team
Bicycle Environmental Quality Index – June 2010

Bicycle Environmental Quality Index (BEQI)

Description
The Bicycle Environmental Quality Index (BEQI) is a quantitative observational survey to assess the bicycle environment on roadways and evaluate what streetscape improvements could be made to promote bicycling in San Francisco. The survey has 21 empirically-based indicators, each of which has been shown to promote or discourage bicycle riding and connectivity to other modes of transport. Several of the indicators have been used in other bicycle indices from different regions in the country, while others are new concepts that have been found significant through other studies regarding healthy bicycle environments. SFDPH identified five main categories which embody important physical environmental factors for bicyclists: Intersection Safety, Vehicle Traffic, Street Design, Safety, and Land Use. Table 1 details each BEQI indicator under its broader environmental category. These indicators can be aggregated to create the final index (the BEQI), which can be reported as an overall index score, and/or deconstructed by the bicycle environmental categories shown in Table 1.

Table 1. BEQI Indicators by Bicycle Environmental Category

Intersection Safety	Vehicle Traffic	Street Design	Safety	Land Use
▪ Dashed intersection bicycle lane ▪ No turn on red sign(s) ▪ Bicycle Pavement Treatment & Amenities	▪ Number of vehicle lanes ▪ Vehicle speed ▪ Traffic calming features ▪ Parallel parking adjacent to bicycle lane/route ▪ Traffic volume ▪ Percentage of heavy vehicles	▪ Presence of a marked area for bicycle traffic ▪ Width of bike lane ▪ Trees ▪ Connectivity of bike lanes ▪ Pavement type/condition ▪ Driveway cuts ▪ Street slope	▪ Bicycle/pedestrian scale lighting ▪ Presence of bicycle lane sign(s)	▪Line of site ▪Bicycle parking ▪Retail use

Background and Development
In June 2007, the SFDPH developed a physical survey to assess the quality of the bicycle network on Treasure Island called the Bicycle Environmental Quality Index (BEQI). The values of the indicators listed in Table 1 were obtained by sending a survey to bicycle experts and members of the bicycle community in July 2007. The survey was promoted through the San Francisco Bicycle Coalition newsletter where 88 respondents completed the survey. The survey responses were used to devise numerical scores and weights for the BEQI. The total score for each street segment and intersection will reflect the bicycle quality for the area the BEQI is applied to. Data collection for the BEQI is based on a visual assessment of street segments and intersections by a trained observer. Two SF neighborhoods, Lakeshore and Treasure Island, were chosen as the two pilot study areas for the BEQI. Both locations were chosen because of the need for bicycle facility improvements The San Francisco Bicycle Coalition (SFBC) has a specific interest in the Lakeshore area and recommended this location, which was surveyed first. A group of SFBC members volunteered to survey both areas and participated in a BEQI training. A detailed field and technical manual with instructions on how to conduct the survey is in development.

SFDPH Program on Health, Equity, and Sustainability

Urban Health and Place Team

Bicycle Environmental Quality Index – June 2010

Collaborations/Constituencies Involved

As the BEQI is being developed, SFDPH continues to work closely with SFBC to finalize the indicators which determine a safe and adequate bicycle environment. SFDPH will be requesting a BEQI review from other City agencies.

Relevance to Health and Health Equity

Cycling to work, school shopping, or leisure activities can be both a sustainable and time-efficient exercise regimen for maintaining acceptable levels of fitness. Studies have shown that bicycle commuters work more efficiently, arrive to work eager and alert, and due to a cyclists' improved health, they have fewer job-related injuries. The use of non-motorized transportation provides exercise, reduces fatal accidents, increases social contacts and reduces air and noise pollution. Increased exercise protects against heart disease and exercise and is also recognized to have mental health benefits. Furthermore, traffic reduction on streets increases safety and opportunities for social interaction between residents and workers.

Applications, Policy Targets, and Next Steps

Results from the BEQI reveal the relative quality of the biking environment at a street-level scale in select San Francisco neighborhoods. Use of the BEQI can translate environmental variables into a set of provisions for a healthy bicycle environment and a BEQI assessment can inform neighborhood planning and prioritize improvements through the land use plans and environmental assessments. An application of the BEQI asks the following questions:

1) Does a place have adequate and safe bicycle facilities throughout the neighborhood?
   - BEQI indicators are used to assess baseline conditions
2) Does a plan or project advance bicycle facilities in the area?
   - Plans/projects are assess to evaluate the extent to which BEQI indicators are present
3) What recommendations for planning policies, implementing actions, or project design would advance the bicycle environment?
   - Concrete, specific recommendations are provided to the plan/project based on the evaluation

To better understand how the BEQI could be used in future transportation planning it would be valuable to identify and meet with other agencies to provide feedback on the BEQI. In addition it would be beneficial to hold focus groups to determine if all indicators are present and to re-analyze the value of each indicator. From focus groups, the BEQI indicator scores could be potentially re-weighted to determine a more accurate score for bicycle conditions.

For more information, please visit:

www.sfphes.org

APPENDIX B

BICYCLE NETWORK ANALYSIS

(BNA)

Methodology

The Bike Network Analysis (BNA) is a data analysis tool that measures how well bike networks connect people with the places they want to go. Because most people are interested in biking only when it's a comfortable experience, our maps recognize only low-stress biking connections.

We compute the BNA score over four steps: data collection, traffic stress analysis, destination access analysis, and score aggregation. Each of these steps is described below.

Data Collection

For U.S. cities, the BNA relies on data from two sources: The U.S. Census and OpenStreetMap (OSM). Census blocks delineated by the U.S. Census Bureau's 2010 Decennial Census serve as the basic unit of analysis for all connectivity measures. The 2010 Decennial Census also supplies block-level population data via the Census of Population and Housing, which the BNA uses to calculate the People score. We obtain block-level data detailing the geographic distribution of jobs from the U.S. Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) data, which underlies the Opportunity Employment score.

For U.S. territories, the BNA again employs U.S. census blocks as the unit of analysis. However, population data is not available at the block level, so we substitute block group data from the 2010 Decennial Census. We omit employment information because no comparable data to the LEHD exists for U.S. territories.

For cities outside of the U.S., we derive the geographic units of analysis, population data, and jobs data from comparable public datasets when available. We create custom geographic units in place of census blocks when no suitable alternative exists. If fine-grained population data is unavailable, we will infer the population distribution at a small scale from broader area population estimates. If we cannot identify comparable jobs data, we exclude it from the analysis. Please contact placesforbikes@peopleforbikes.org if you have questions about the data sources used for non-U.S. cities.

OSM data is available worldwide, providing a fully-routable network of on- and off-street transportation facilities including details about the types of bicycle facilities on any given street segment. OSM also supplies location and attribute data for all destination types in the analysis except population and jobs. The BNA downloads the most recent OSM data for the area within a city's boundary plus a buffer distance around the boundary equivalent to the default bikeshed distance designated in the tool, 2,680 meters or 1.67 miles. Although OSM data quality varies between cities and countries, anyone can edit OSM to improve the BNA's accuracy.

Traffic Stress Analysis

The BNA relies on the concept of a low-stress bike network. The concept of Traffic Stress has emerged as a useful way to think of bicycle facilities in terms of the types of users who would be comfortable riding on them in a given situation. Since our measures are concerned with low-stress bicycling, our methodology focuses on roadway characteristics that generally translate to a Level of Traffic Stress 1 or 2 rating based on the scale originally developed by the Mineta Transportation Institute. In practical terms, this corresponds with the comfort level of a typical adult with an interest in riding a bicycle but who is concerned about interactions with vehicular traffic.

The OSM data we use to build the bike network employs a system of tags to represent different elements of a roadway. A list of tags for bicycle facilities and destinations is available here. For a description of how OSM tags relate to on-the-ground bicycle facilities you can refer to these tagging guidelines. Please note that our methodology also accounts for some edge cases involving obsolete or non-standard tagging. For a full review of the logic, we invite you to review the source code.

Once we've built the transportation network, we rate every street segment and intersection for high or low traffic stress. There are several bicycle facility types that the original Traffic Stress methodology did not consider. We have followed the same basic approach but our methodology includes some new facility types. You can follow our logic using this analysis logic spreadsheet.

While OSM data gives us a great base on which to build, it can vary in terms of the availability of detailed roadway characteristics. To account for situations where OSM data is not sufficient, we developed default assumptions based on OSM's hierarchy of roads. (The defaults are given in the spreadsheet linked above.) The default assumptions are only used when OSM data is missing.

The BNA evaluates traffic stress for each link in the transportation network by applying the logic outlined in the spreadsheet to the street characteristics documented in OSM. The resulting Stress Network map visualizes the stress rating of every street segment with blue representing low-stress routes and orange representing high-stress routes.

Destination Access Analysis

Once we have established the street segment stress ratings, we evaluate every census block (or for non-U.S. cities, other geographic units) to determine which other census blocks are within biking distance and can be reached on the low-stress network. The BNA assumes a biking distance of 1.67 miles or 2,680 meters as measured along streets or paths, the distance an average rider would travel in ten minutes biking ten miles per hour. No one likes a detour so we also assume that a low-stress route is only available if it doesn't force a person to go out of their way by more than 25% compared to a car trip. We also assume that a census block is connected to any road that either follows its perimeter or serves its interior. In practice, this means you can get to a destination whose front door is on a stressful street if you can get to a low-stress street around the corner. Finally, we assume that two census blocks are connected if and only if there is an unbroken low-stress connection between them. In other words, even a short stretch of stressful biking negates a potential connection. This is consistent with the Traffic Stress concept and also highlights the importance of a continuous network, rather than the patchwork of facilities that is common in many U.S. cities.

We use the transportation network to route from each census block to every other census block within biking distance, noting whether a low-stress connection between the two is possible. We also summarize the number and types of destinations available in each census block. Using this information paired with the knowledge of which census blocks are connected on the low-stress network, we calculate the total number of destinations accessible on the low-stress network and compare that with the total number of destinations that are within biking distance regardless of whether they are accessible via the low-stress network. Destinations outside of the city boundary but within the surrounding buffer area are included in the analysis to enable calculating accessibility from points located on the edge of the city boundary. This means that the quality of the bike network in neighboring cities or unincorporated areas will affect a city's BNA score if there are destinations located within that buffer area.

Points are assigned on a scale of 0 to 100 for each destination type based on the number of destinations available on the low-stress network as well as the ratio of low-stress destinations to all destinations within biking distance. The scoring places higher value on the first few low-stress destinations by assigning points on a stepped scale. Beyond the first few low-stress destinations, points are prorated up to 100 based on the ratio of low-stress to high-stress connections to those destinations. For example, a census block with low-stress access to only one park out of five nearby parks would receive 30 points. A census block with low-stress access to two parks out five would receive 50 points (30 for the first park, 20 for the second). A census block with low-stress access to four parks out of five would receive 85 points (30 for the first, 20 for the second, 20 for the third, and 15 out of the remaining 30 points for connecting one of the remaining two parks).

The BNA's six scoring categories are:

1. People: Access to other people in the city based on the resident population distribution
2. Opportunity: Access to jobs and educational institutions
3. Core Services: Access to critical services such as health care
4. Recreation: Access to public recreation outlets
5. Retail: Access to shopping areas
6. Transit: Access to major transit hubs

Three of the scoring categories are composed of a mix of destination types constituting subcategories. For instance, the Recreation category encompasses the subcategories Community Centers, Parks, and Trails. In these cases, the category score is calculated by combining the scores of each of its member destination type/subcategory scores. Weights for each destination type are used to represent their relative importance within the category. For census blocks where a destination type is not reachable by either high- or low-stress means, that destination type is excluded from the calculations. For example, the Opportunity score within a city with no institute of higher education is produced by excluding the Higher Education destination type so the score is unaffected by its absence. As noted in the Data Collection phase, U.S. territories and non-U.S. cities may lack jobs data comparable to the LEHD, in which case they will not receive an Opportunity Employment score and the overall Opportunity score will only reflect access to educational institutions.

We use the category scores to calculate one overall score for each census block, weighting each category according to its relative importance. The step thresholds, destination scoring, and weighting assumptions are all described in this spreadsheet.

Score Aggregation

BNA scoring operates at two geographic levels. Up to now, the description has focused on scoring of individual census blocks. Census block scores are visualized on the Census Blocks with Access heat map where blue blocks are relatively well connected and orange blocks are poorly connected.

We use Census block scores to calculate scores for the whole city by weighting each census block according to its population and then averaging destination type (subcategory) scores across the city. We then apply the same category weights used in the block-level calculations to calculate citywide category scores and an overall city score. Like the block-level calculation, the citywide calculation excludes destination types that are not represented anywhere in the city. For example, if a city has no rail stations or bus transfer stations, the transit score is not factored into the overall score.

APPENDIX C
BICYCLE LEVEL OF SERVICE
(BLOS)

Appendix A. Bicycle Level of Service Model Summary

The *Bicycle Level of Service Model (Bicycle LOS Model)* is an evaluation of bicyclist perceived safety and comfort with respect to motor vehicle traffic while traveling in a roadway corridor. It identifies the quality of service for bicyclists or pedestrians that currently exists within the roadway environment.

The statistically calibrated mathematical equation entitled the *Bicycle LOS Model*[1] *(Version 2.0)* is used for the evaluation of bicycling conditions in shared roadway environments. It uses the same measurable traffic and roadway factors that transportation planners and engineers use for other travel modes. With statistical precision, the *Model* clearly reflects the effect on bicycling suitability or "compatibility" due to factors such as roadway width, bike lane widths and striping combinations, traffic volume, pavement surface condition, motor vehicle speed and type, and on-street parking.

The *Bicycle Level of Service Model* is based on the proven research documented in *Transportation Research Record 1578* published by the Transportation Research Board of the National Academy of Sciences. It was developed with a background of over 150,000 miles of evaluated urban, suburban, and rural roads and streets across North America. Many urban planning agencies and state highway departments are using this established method of evaluating their roadway networks. The model has been applied by the Maryland Department of Transportation (MDOT), the Virginia Department of Transportation (VDOT), the Delaware Department of Transportation (DelDOT), Florida Department of Transportation (FDOT), New York State Department of Transportation (NYDOT), Maryland Department of Transportation (MDOT) and many others. It has been applied in regions such as Anchorage AK, Baltimore MD, Birmingham AL, Buffalo NY, Gainesville FL, Houston TX, Lexington KY, Philadelphia PA, Sacramento CA, Springfield MA, Tampa FL, Richmond, VA, Northern Virginia, and Washington, DC.

Widespread application of the original form of the *Bicycle LOS Model* has provided several refinements. Application of the *Bicycle LOS Model* in the metropolitan area of Philadelphia resulted in the final definition of the three effective width cases for evaluating roadways with on-street parking. Application of the *Bicycle LOS Model* in the rural areas surrounding the greater Buffalo region resulted in refinements to the "low traffic volume roadway width adjustment". A 1997 statistical enhancement to the *Model* (during statewide application in Delaware) resulted in better quantification of the effects of high speed truck traffic [see the $SP_t(1+10.38HV)^2$ term]. As a result, *Version 2.0* has the highest correlation coefficient ($R^2 = 0.77$) of any form of the *Bicycle LOS Model*.

Version 2.0 of the *Bicycle Level of Service Model (Bicycle LOS Model)* has been employed to evaluate collector and arterial roadways within Rockville. Its form is shown below:

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[1]Landis, Bruce W. et.al. "Real-Time Human Perceptions: Toward a Bicycle Level of Service" *Transportation Research Record 1578*, Transportation Research Board, Washington, DC 1997.

Bicycle Level of Service Model Description

Bicycle LOS = $a_1 \ln(Vol_{15}/L_n) + a_2 SP_t(1+10.38HV)^2 + a_3(1/PR_5)^2 + a_4(W_e)^2 + C$

Where:

Vol_{15} = Volume of directional traffic in 15 minute time period

$Vol_{15} = (ADT \times D \times K_d) / (4 \times PHF)$

where:

- ADT = Average Daily Traffic on the segment or link
- D = Directional Factor (assumed = 0.565)
- K_d = Peak to Daily Factor (assumed = 0.1)
- PHF = Peak Hour Factor (assumed = 1.0)

L_n = Total number of directional *through* lanes

SP_t = Effective speed limit

$SP_t = 1.1199 \ln(SP_p - 20) + 0.8103$

where:

SP_p = Posted speed limit (a surrogate for average running speed)

HV = percentage of heavy vehicles (as defined in the 1994 Highway Capacity Manual)

PR_5 = FHWA's five point pavement surface condition rating

W_e = Average effective width of outside through lane:

where:

$W_e = W_v - (10 \text{ ft} \times \% \text{ OSPA})$ and $W_l = 0$

$W_e = W_v + W_l(1 - 2 \times \% \text{ OSPA})$ and $W_l > 0$ & $W_{ps} = 0$

$W_e = W_v + W_l - 2(10 \times \% \text{ OSPA})$ and $W_l > 0$ & $W_{ps} > 0$ and a bikelane exists

where:

- W_t = total width of outside lane (and shoulder) pavement
- OSPA = percentage of segment with occupied on-street parking
- W_l = width of paving between the outside lane stripe and the edge of pavement
- W_{ps} = width of pavement striped for on-street parking
- W_v = Effective width as a function of traffic volume

and:

$W_v = W_t$ if ADT > 4,000veh/day

$W_v = W_t(2-0.00025 \times ADT)$ if ADT $\leq$ 4,000veh/day, and if the street/ road is undivided and unstriped

a_1: 0.507 a_2: 0.199 a_3: 7.066 a_4: - 0.005 C: 0.760

(a_1 - a_4) are coefficients established by the multi-variate regression analysis.

Bicycle Level of Service Model Description

The Bicycle LOS score resulting from the final equation is pre-stratified into service categories "A, B, C, D, E, and F", according to the ranges shown in Table 1, reflecting users' perception of the road segments level of service for bicycle travel. This stratification is in accordance with the linear scale established during the referenced research (i.e., the research project bicycle participants' aggregate response to roadway and traffic stimuli). The *Model* is particularly responsive to the factors that are statistically significant. An example of its sensitivity to various roadway and traffic conditions is shown on the following page.

Bicycle Level-of-Service Categories

LEVEL-OF-SERVICE	Bicycle LOS Score
A	≤ 1.5
B	> 1.5 and ≤ 2.5
C	> 2.5 and ≤ 3.5
D	> 3.5 and ≤ 4.5
E	> 4.5 and ≤ 5.5
F	> 5.5

The *Bicycle LOS Model* is used by planners, engineers, and designers throughout the US and Canada in a variety of planning and design applications. Applications of the Model include:

1) Conducting a benefits comparison among proposed bikeway/roadway cross-sections
2) Identifying roadway restriping or reconfiguration opportunities to improve bicycling conditions
3) Prioritizing and programming roadway corridors for bicycle improvements
4) Creating bicycle suitability maps
5) Documenting improvements in corridor or system-wide bicycling conditions over time

Bicycle LOS Model Sensitivity Analysis

$$\text{Bicycle LOS} = a_1 \ln (Vol_{15}/Ln) + a_2 SP_t(1+10.38HV)^2 + a_3(1/PR_5)^2 + a_4 (W_e)^2 + C$$

where:	a_1: 0.507	a_2: 0.199	a_3: 7.066	a_4: -0.005	C: 0.760
T-statistics:	(5.689)	(3.844)	(4.902)	(-9.844)	

Baseline inputs:

ADT	=	12,000 vpd	% HV	=	1	L	=	2 lanes
SP_p	=	40 mph	W_e	=	12 ft	PR_5	=	4 (good pavement)

				BLOS	% Change
Baseline BLOS Score (Bicycle LOS)				3.98	N/A
Lane Width and Lane striping changes					
W_t	=	10 ft		4.20	6% increase
W_t	=	11 ft		4.09	3% increase
W_t	=	12 ft	- - (baseline average) - - - - - - -	3.98 - - - -	no change
W_t	=	13 ft		3.85	3% reduction
W_t	=	14 ft		3.72	7% reduction
W_t	=	15 ft	(W_l = 3 ft)	3.57 (3.08)	10%(23%) reduction
W_t	=	16 ft	(W_l = 4 ft)	3.42 (2.70)	14%(32%) reduction
W_t	=	17 ft	(W_l = 5 ft)	3.25 (2.28)	18%(43%) reduction
Traffic Volume (ADT) variations					
ADT	=	1,000	Very Low	2.75	31% decrease
ADT	=	5,000	Low	3.54	11% decrease
ADT	=	12,000	Average - (baseline average) - -	3.98 - - - - -	no change
ADT	=	15,000	High	4.09	3% increase
ADT	=	25,000	Very High	4.35	9% increase
Pavement Surface conditions					
PR_5	=	2	Poor	5.30	33% increase
PR_5	=	3	Fair	4.32	9% reduction
PR_5	=	4 - -	Good - (baseline average) - - -	3.98 - - - -	no change
PR_5	=	5	Very Good	3.82	4% reduction
Heavy Vehicles in percentages					
HV	=	0	No Volume	3.80	5% decrease
HV	=	1 - - -	Very Low - (baseline average) - -	3.98 - - - - - -	no change
HV	=	2	Low	4.18	5% increase
HV	=	5	Moderate	4.88	23% increase[a]
HV	=	10	High	6.42	61% increase[a]
HV	=	15	Very High	8.39	111% increase[a]

[a]Outside the variable's range (see Reference *(1)*)

Bicycle Level of Service Model Data Needs

These data items are used to compute the final Bicycle Level of Service (BLOS) score for each roadway segment. Please use the following guidelines when gathering available roadway data and making measurements and observations in the field.

Existing Data (from maps and electronic databases)

Annual Average Daily Traffic (AADT) – Enter this information into the database for each roadway segment from existing traffic count databases. If necessary, use assumed values based on surrounding land uses or taking 15 minute counts in the field. AADT is converted by the database to hourly traffic volume by lane in one direction of travel.

Percent Heavy Vehicles (% HV) – Enter this information into the database from existing traffic composition databases. Generally, a heavy vehicle is any large truck with six or more tires. If necessary, use assumed values based on surrounding land uses or taking 15 minute counts in the field.

85^{th} Percentile Speed (85^{th} %) – Enter this information from existing traffic speed databases. If these data are not available, the database is programmed to add approximately 9 m.p.h. (15 k.p.h) to the posted speed to reflect a typical 85^{th} percentile speed.

Field Data (from data collection measurements)

Direction of Survey (Dir. of Sur.) – Record the direction the data collection vehicle is traveling along the segment before data collector takes measurements (NB, SB, EB, or WB).

Number of lanes of traffic (L) - Record the total number of *through* traffic lanes, in both directions, of the road segment. The presence of continuous right-turn lanes should be noted in the comments field (they should not be counted as through lanes).

Configuration (Cnfg.) – Record the configuration of the road segment as D = Divided, U = Undivided, OW = One-Way, or S = Center Turning Lane. The programmed database will output the number of travel lanes in each direction. Note in the comments if in the other direction there is a different number of through lanes.

Posted Speed Limit (SP_p) - Record as posted in m.p.h. The database is programmed to add approximately 9 m.p.h. (15 k.p.h) to the posted speed to reflect the typical 85^{th} percentile speed, unless 85^{th} percentile speeds are available from existing sources.

Width of pavement for the outside lane and shoulder (W_t) – This measurement is taken from the center of the road (yellow stripe) to the gutter pan of the curb (or to the curb if there is no gutter present). In the case of a multilane configuration, it is measured from the outside lane stripe to the edge of pavement. **W_t does not include the gutter pan.** When there is angled parking adjacent to the outside lane, W_t is measured to the traffic-side end of the parking stall stripes.

The presence of unstriped on-street parking does not change the measurement; the measurement should still be taken from the center of the road to the gutter pan.

Width of paving between the shoulder/edge stripe and the edge of pavement (W_l) – This measurement is taken when there is additional pavement to the right of an edge stripe, such as when striped shoulders, bike lanes, or parking lanes are present. It is measured from the shoulder/edge stripe to the edge of pavement, or to the gutter pan of the curb. **W_l does not include the gutter pan.** When there is angled parking adjacent to the outside lane, W_l is measured to the traffic-side end of the parking stall stripes.

Width of pavement striped for on-street parking (W_{ps}) – **Record this measurement only if there is parking to the right of a striped bike lane.** If there is parking on two sides on a one-way, single-lane street, the combined width of striped parking is reported.

Total Pavement Width (TPW) – **Record this dimension only when the roadway has a total of three or more through lanes.** This measurement is taken from one shoulder or gutter pan of the curb to the other shoulder or gutter pan of the curb. If the roadway is divided, the width of the grass/concrete median should be included in the measurement and the width of the median itself should be listed in the comments field.

Edge Type – "CG" is recorded if there is a curb and gutter on the segment. "S" is entered if there is an open shoulder. If a segment has a **curb but no gutter (i.e. the pavement extends completely to the curb face), record "CNG".**

% Occupied On-Street Parking - This is an estimate on the percentage of the segment (excluding driveways) along which there is occupied on-street parking at the time of survey. Each side is measured in increments of 25% and is recorded separately: "N/E" is the Northbound or Eastbound side of the road and "S/W" is the Southbound or Westbound side of the road. **If the parking is allowed only during off-peak periods, this should be indicated in the comments field.** Angled parking is also reported in the comments field.

Pavement Condition:

Travel Lane (PC_t) - Pavement condition of the outside motor vehicle travel lane is evaluated according to FHWA's five-point pavement surface condition rating shown below. Unpaved travel lanes should be scored with a zero (0).
Shoulder or Bike lane (PC_l) - Pavement condition of the shoulder or bike lane is evaluated according to the FHWA's five-point pavement surface condition rating shown below. (Unpaved shoulders **do not** receive a zero score, see roadside profile condition.)

Pavement Condition Descriptions

RATING	**PAVEMENT CONDITION**
5.0 (Very Good)	Only new or nearly new pavements are likely to be smooth enough and free of cracks and patches to qualify for this category.
4.0 (Good)	Pavement, although not as smooth as described above, gives a first class ride and exhibits signs of surface deterioration.
3.0 (Fair)	Riding qualities are noticeably inferior to those above; may be barely tolerable for high-speed traffic. Defects may include rutting, map cracking, and extensive patching.
2.0 (Poor)	Pavements have deteriorated to such an extent that they affect the speed of free-flow traffic. Flexible pavement has distress over 50 percent or more of the surface. Rigid pavement distress includes joint spalling, patching, etc.
1.0 (Very Poor)	Pavements that are in an extremely deteriorated condition. Distress occurs over 75 percent or more of the surface.

Source: U.S. Department of Transportation. Highway Performance Monitoring System-Field Manual. Federal Highway Administration. Washington, DC 1987.

<u>Designated Bike Lane</u> - "Y" indicates that a bike lane is designated (by sign or pavement markings) on the segment, otherwise "N" is entered.

<u>Designated Bicycle Route</u> – "Y" indicates that the segment is marked with bicycle route (segment has green "BIKE ROUTE" signs or signs with a specific bike route letter or number), otherwise "N" is entered.

<u>Share the Road Signs</u> – "Y" indicates that the segment is marked with "Share the Road" signs (yellow bike warning sign with "Share the Road" beneath), otherwise "N" is entered.

<u>Rumble Strips</u> – "Y" indicates that the segment has shoulder rumble strips, otherwise "N" is entered. Note the approximate width of the rumble strips in the comments field and whether they are on the shoulder or travel lane.

<u>Steep Grade</u> – "Y" indicates that the segment has a steep grade. A steep grade is considered to be a grade of over 5%, as estimated by the data collection team.

<u>Number of Left Turn Bays</u> – Record the number of left turn bays within the segment **(consider both directions)**. A left turn bay is a lane designated for left turns only. If there is a lane that is designated for both straight and left-turning traffic, do not record it as a left turn bay.

<u>% of Segment with Sidewalk or Sidepath</u> - The percentage of sidewalk coverage (estimated in increments of 10%) of the segment is to be collected for both sides of the roadway. Sidepaths and trails within the roadway right-of-way should be considered to be sidewalks for the purpose of data collection. Make sure to collect information about sidewalks on bridges. Each side is

measured in increments of 10% and is recorded separately: "N/E" is the Northbound or Eastbound side of the road and "S/W" is the Southbound or Westbound side of the road.

Buffer Width (W_b) - The width of a grass or other buffer between the edge of the pavement (or curb face, which includes the top of the curb, if present) and the beginning edge of the sidewalk. If the sidewalk contains a line of trees, mailboxes, plantings, etc., the width of these obstructions should be included in the buffer width measurement. The gutter pan is not included in the buffer. If the buffer is different on each side of the road, the average width is recorded.

Tree Spacing in Buffer - The spacing of trees within a buffer measured from foot on center (length of spacing between trees). Trees can either be in a grass buffer or in a sidewalk. Trees that are not between the sidewalk and roadway should not be considered. If the tree spacing is different on each side of the road, the average spacing is recorded.

Sidewalk/Sidepath Width (W_s) - The width of the sidewalk (or sidepath), measured from the edge of the buffer to the backside of the sidewalk. If a grass buffer is not present, the width is measured from the curb face (the top of the curb is included in the measurement). Each side is measured separately: "N/E" is the Northbound or Eastbound side of the road and "S/W" is the Southbound or Westbound side of the road.

Roadside Profile Condition – **This data item will be collected only for facilities with no sidewalks (or sidepaths).** It will be used to assist in determining the condition of the lateral area available for bikeway, sidepath or sidewalk construction. This evaluation is meant to be general, and is applied to area between the outside edge of the pavement and the right-of-way line, or the 10-20 feet of space adjacent to the edge of the pavement. Roadside profiles will be rated 1, 2, or 3. Condition 1 is a generally buildable shoulder, such as a built gravel shoulder of 4'+ or 10-12 feet of clear space, free of obstructions and with a grade similar to the roadway. Condition 2 is a somewhat buildable shoulder which may be narrower, have more frequent obstructions or some areas with steeper grades. Condition 3 is for roadside conditions with severe slopes, ditches, trees or other features making it unbuildable without a major construction effort.

Notes:

The accuracy of all width measurements is 0.5 feet. Measurements should be taken from the middle of roadway stripes (or the middle between the two centerline stripes). When there is a major change in roadway cross-section within a segment (i.e. the road changes from 2 lanes to 4 lanes in the middle of the segment), the two parts of the segment should be entered on two separate lines on the data collection sheet. Minor changes, such as changes in speed limit, several feet of variation in paved shoulder width, or narrowing of lanes at a small bridge do not require resegmentation. **In these cases, the predominant cross-section characteristics should be recorded and notes regarding variations should be recorded in the comments field.** In addition, if there is any noticeable difference in the above parameters between two directions (north/south or east/west) on a roadway segment, the data describing the other direction should be recorded in the comment field of the database, along with the direction. All other special conditions and assumptions made during the data collection on the segments should be recorded in the comments field of the database.

APPENDIX D
LEVEL OF TRAFFIC STRESS
(LTS)

Level of Traffic Stress

Level of Traffic Stress 1: Mixed traffic, quiet local street

Latest LTS criteria (v. 2, June, 2017) for classifying road segments by level of traffic stress are found here.

Original (2012) criteria for classifying road segments by level of traffic stress are found here.

The chief deterrent to riding a bike in the U.S. is the high stress of riding without protection from the danger of fast traffic, or, more briefly, traffic stress. Some streets have low traffic stress, while others have high stress. Sometimes a treatment such as bike lanes is effective in eliminating most of the traffic stress; but other times even where there's a bike lane, it can be very stressful.

LTS 4: Mixed traffic on 4-lane street, 30 mph

Over the years, a few different methods have been developed for classifying streets by how comfortable or stressful it is to ride there. However, they have many weaknesses, and none is widely known or used. Common weaknesses are giving no account to protected bike lanes or cycle tracks; not accounting for how bikes have to interact with cars on intersection approaches or at crossings; and using black-box formulas that makes it impossible for anybody to know how a street should be classified without running the numbers through a calculation program.

In 2012, I developed a new method for classifying streets, publishing it in a report with coauthors Maaza Mekuria and Hilary Nixon. It classifies streets into four levels of traffic stress (LTS) using simple rules that rely on data that's either readily available or easy to acquire. The four levels of traffic stress are:

- LTS 1: Strong separation from all except low speed, low volume traffic. Simple-to-use crossings. LTS 1 indicates a facility suitable for children.

LTS 1 in both directions. Contraflow, bikes have their own space on 25 mph street; with flow, mixed traffic @ 25 mph on a street with no centerline

LTS 1: Protected bike lane.

- LTS 2: Except in low speed / low volume traffic situations, cyclists have their own place to ride that keeps them from having to interact with traffic except at formal crossings. Physical separation from higher speed and multilane traffic. Crossings that are easy for an adult to negotiate. Limits traffic stress to what the mainstream adult population can tolerate, those who are "interested but concerned" in the classification popularized by Portland, Oregon's bike program.The criteria for LTS 2 correspond to design criteria for Dutch bicycle route facilities.

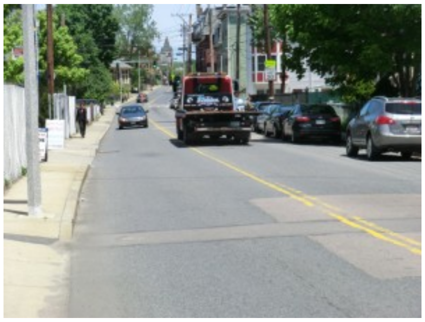
LTS 2: Bike lanes next to parking lane on 30 mph street, with space to ride outside the door zone

LTS 2: Bike lane not next to parking, 2+2 lanes with raised median, 30 mph

LTS 2: Mixed traffic on 2-lane street with centerline, 25 mph

- LTS 3: Involves interaction with moderate speed or multilane traffic, or close proximity to higher speed traffic. A level of traffic stress acceptable to the "enthused and confident."

LTS 3: Bike lane next to parking on multilane, 30 mph street, in a commercial area without enough space to ride outside the door zone. In addition, bike lane is frequently blocked, forcing cyclists into traffic



Level of Traffic Stress 3: Mixed traffic, 30 mph, 1+1 lanes with centerline

- LTS 4: Involves being forced to mix with moderate speed traffic or close proximity to high speed traffic. A level of stress acceptable only to the "strong and fearless."

LTS 4: Mixed traffic on a multilane road, 30 mph

Updated criteria (v. 2, June, 2017) for classifying road segments by level of traffic stress are found here.

Original (2012) criteria for classifying road segments by level of traffic stress are found here.

Once a city's streets have been classified by level of traffic stress, it's possible to examine the network of low-stress streets. In some cases, that network may be greatly disconnected, with "islands" of low stress streets separated from one another by high-stress barriers. See here for methods of visualizing and analyzing the connectivity of a low-stress bike network.

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Level of Traffic Stress Criteria for Road Segments, version 2.0, June, 2017

Mixed traffic criteria

Number of lanes	Effective ADT*	≤ 20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50+mph
		Prevailing Speed						
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 3	LTS 4
	1501-3000	LTS 2	LTS 2	LTS 2	LTS 3	LTS 4	LTS 4	LTS 4
	3000+	LTS 2	LTS 3	LTS 3	LTS 3	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 3	LTS 4
	1501-3000	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	3000+	LTS 3	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
2 thru lanes per direction	0-8000	LTS 3	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	8001+	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
3+ thru lanes per direction	any ADT	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4

* Effective ADT = ADT for two-way roads; Effective ADT = 1.5*ADT for one-way roads

Bike lanes and shoulders not adjacent to a parking lane

Number of lanes	Bike lane width	≤ 25 mph	30 mph	35 mph	40 mph	45 mph	50+ mph
		Prevailing Speed					
1 thru lane per direction, or unlaned	6+ ft	LTS 1	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	4 or 5 ft	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4
2 thru lanes per direction	6+ ft	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	4 or 5 ft	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	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 + Pkg lane width	≤ 25 mph	30 mph	35 mph
		Prevailing Speed		
1 lane per direction	15+ ft	LTS 1	LTS 2	LTS 3
	12-14 ft	LTS 2	LTS 2	LTS 3
2 lanes per direction (2-way)	15+ ft	LTS 2	LTS 3	LTS 3
2-3 lanes per direction (1-way)		LTS 2	LTS 3	LTS 3
other multilane		LTS 3	LTS 3	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.

APPENDIX E

LTS CRITERIA FOR ROUNDABOUTS

Level of Traffic Stress (LTS) Criteria for Roundabouts

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3/21/14

Initial draft; feedback welcome

Roundabouts can offer a relatively safe environment by virtue of forcing motor traffic to go slowly; however, they can also be a stressful environment for cyclists if cyclists are forced to mix with constantly moving traffic. The traffic stress involved in a roundabout depends on several features, of which the main two are:

- **Is there a practical cycling path outside the roundabout, or are cyclists in mixed traffic?** If cyclists have a separate path they can follow outside the roundabout, then the only traffic stress arises from crossings. If they are in mixed traffic, the road environment can present traffic stress, but there is no crossing-related stress.
- **Is it a single-lane or multi-lane roundabout?** The multilane environment is far more stressful when cycling in mixed traffic. When riding on a separate path, crossing two exit lanes poses a stressful multiple threat danger.

A. Is there a practical cycling path outside the roundabout?

Sometimes there is a clear bike path outside the roundabout.

Often, however, all that's provided is a sidewalk that bikes are allowed to share; such a shared sidewalk may or may not qualify as a cycling path. A shared sidewalk circulating around a roundabout must meet all of the following criteria to be considered a bicycling path. Unless all four criteria are met, there is no practical bicycling path outside the roundabout, and the roundabout should be evaluated assuming that bikes will be in mixed traffic.

Criteria for Whether a Sidewalk Around a Roundabout Qualifies as a Practical Cycling Path

Criterion	Support	Example*
a. 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	
b. 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.
c. 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.
d. 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.

* Illustrative example is the junction of Hutchinson Drive and Hutchinson Place in Davis, CA.

B. Level of Traffic Stress for a Path Around a Roundabout

When following a path around a roundabout, the only traffic stress arises from crossings. These criteria assume that every leg has a refuge island between crossing the exit lane and crossing the opposite direction entry lane. The crossing with the worst LTS governs.

LTS for Crossings at a Roundabout (assumes bikes on a separate 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, non-tangential	1	3
Dual exit lane, non-tangential	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

C. Level of Traffic Stress for Bikes in Mixed Traffic in a Roundabout

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 known, however, that children in the Netherlands report feeling uncomfortable riding in mixed traffic roundabouts except where traffic is light, and so the LTS 1 threshold is set at 4000 veh/day.

Dutch guidelines require a separate cycle track on any multilane roundabout. LTS for riding in multilane roundabouts is 4 because multilane roundabout always have at least one multilane exit, which gives rise to a dangerous conflict between circulating cyclists and vehicles in the inside lane that may wish to exit. This conflict can only be avoided by weaving into and later out of the inside lane.

LTS for Riding in Mixed Traffic in a Roundabout

Number of circulating lanes	ADT (Sum over all entry legs)	LTS
1	4000 or less	1
1	4001 to 6000	2
1	> 6000	3
2 or more	(any)	4

If a roundabout has 2 circulating lanes over only part of the roundabout, it should be counted as having 2 circulating lanes.

D. Where Cyclists Have a Choice

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.

APPENDIX F

LTS CRITERIA FOR INTERSECTIONS

Table 5
Criteria for Bike Lanes and Mixed Traffic on Intersection Approaches in the Presence of a Right Turn Lane

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

Note: "Bike lane" here means either a pocket bike lane (between the RT lane and a through lane), or a bike lane marked within the right turn lane. These criteria do not apply if a segregated bike lane is kept to the right of a right turn lane and provided a safe means of crossing.

Table 6
Criteria for 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	LTS 4
30 mph	LTS 1	LTS 2	LTS 4
35 mph	LTS 2	LTS 3	LTS 4
40+	LTS 3	LTS 4	LTS 4

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	LTS 3
35 mph	LTS 2	LTS 3	LTS 4
40+	LTS 3	LTS 4	LTS 4