# Maryland Department of Transportation
# Level of Traffic Stress (LTS) Data Development

## Level of Traffic Street (LTS)

The Maryland Department of Transportation is transitioning from using the Bicycle Level of Comfort (BLOC) to using the Level of Traffic Stress (LTS) for measuring the "bikeability" of the roadway network. This transition is in coordination with the implementation of MDOT SHA's Context Driven Design Guidelines and other national and departmental initiatives. LTS is preferred over BLOC as it provides a better indication of how suitable the infrastructure may be to a variety of user-types. In addition, LTS requires fewer variables to calculate including:

- Presence and type of bicycle facility
- Speed Limit
- Number of Through Lanes/Traffic Volume

Traditionally, the Level of Traffic Stress (LTS) uses these criteria to produce ratings of roadway segments (scale "1" to "4") that reflect their relative suitability for bicyclists of varying levels of skill and experience. The lower the LTS score, the more inviting the bicycle facility is for more audiences.

## LTS Methodology

MDOT's LTS methodology is based on the metrics established by the Mineta Transportation Institute (MTI) Report 11-19 "Low-Stress Bicycling and Network Connectivity (May 2012), additional criteria refined by Dr. Peter G. Furth (June 2017) below and Montgomery County's Revised Level of Traffic Stress.

### Mixed Traffic Criteria

| Number of Lanes | Effective ADT | Prevailing Speed | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | <20mph | 25mph | 30mph | 35mph | 40mph | 45mph | 50+mph |
| Unlaned 2-way street (No centerline) | 0-750 | 1 | 1 | 2 | 2 | 3 | 3 | 3 |
| | 751-1500 | 1 | 1 | 2 | 3 | 3 | 3 | 4 |
| | 1501-3000 | 2 | 2 | 2 | 3 | 4 | 4 | 4 |
| | 3000+ | 2 | 3 | 3 | 3 | 4 | 4 | 4 |
| 1 thru lane per direction (1-way, 1 lane street or 2-way street with centerline | 0-750 | 1 | 1 | 2 | 2 | 3 | 3 | 3 |
| | 751-1500 | 2 | 2 | 2 | 3 | 3 | 3 | 4 |
| | 1501-3000 | 2 | 3 | 3 | 3 | 4 | 4 | 4 |
| | 3000+ | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
| 2 thru lanes per direction | 0-8000 | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
| | 8001+ | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| 3+ thru lanes per direction | Any | 3 | 3 | 4 | 4 | 4 | 4 | 4 |

Effective ADT = ADT for two-way roads. Effective ADT – 1.5' ADT for one-way roads

## Bike Lanes and Shoulders Not Adjacent to Parking

| Number of Lanes | Bike Lane Width | 25mph | 30mph | 35mph | 40mph | 45mph | 50+mph |
|---|---|---|---|---|---|---|---|
| 1-thru lane per direction or unlaned | 6'+ | 1 | 2 | 2 | 3 | 3 | 3 |
| | 4'-5' | 2 | 2 | 2 | 3 | 3 | 4 |
| 2 thru lanes per direction | 6'+ | 2 | 2 | 2 | 3 | 3 | 3 |
| | 4'-5' | 2 | 2 | 2 | 3 | 3 | 4 |
| 3+ thru lanes per direction | Any | 3 | 3 | 3 | 4 | 4 | 4 |

Notes:

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

## Bike Lanes Adjacent to Parking

| Number of Lanes | Bike Lane Reach = Bike + Parking Lane Width | 25mph | 30mph | 35mph |
|---|---|---|---|---|
| 1 lane per direction | 15'+ | 1 | 2 | 3 |
| | 12'-14' | 2 | 2 | 3 |
| 2 lanes per direction (2-way)<br>2-3 lanes per direction (1-way) | 15'+ | 2 | 3 | 3 |
| Other multilanes | | 3 | 3 | 3 |

Notes:

1. If bike lane/shoulder is frequently blocked, use mixed traffic criteria.
2. Qualifying bike lane reach must be at least 12'
3. Bike lane width includes any marked buffer next to the bike lane.

MDOT's LTS rating includes two additional scores: "0" to represent shared-use paths and similar facilities that are suitable for people of all ages and abilities to bicycle and "5" to represent roadways where bicycle access is prohibited. The below chart describes the LTS score in terms of facility types and the corresponding target bicycling audience that might be expected to use them.

| LTS | Target Audience | Bicycle Facility Types |
|---|---|---|
| 0 | All ages and abilities | Rail-trails, shared-use paths |
| 1 | Almost everyone | Protected bikeways, sidepaths |
| 2 | Interested but concerned | Bike lanes, bike boulevards |
| 3 | Enthused and confident | Bike lanes, shared lanes, shoulders |
| 4 | Strong and fearless | No bike facility or bike lane on a major roadway |
| 5 | Bicycle Access Prohibited | Bicycle access is prohibited by managing roadway agency |

## One Maryland One Centerline (OMOC)

MDOT's initial LTS efforts were included in a nationwide Open Street Map-based (OSM) study conducted by the University of Minnesota. As this dataset was crowdsourced, data reliability varied and did not allow MDOT to measure improvements over time. To manage data and conduct analysis more accurately, MDOT used the State Highway Administration's (MDOT SHA's) One Maryland One Centerline (OMOC) linear referencing system to implement LTS. OMOC was developed to manage roadway

inventory and data reporting to the Federal Highway Administration (FHWA) and includes a variety of roadway variables including speed limits, the number of through lanes on a roadway segment, functional classification, shoulder presence and width, lighting, signs, pavement markings and signals. OMOC can produce a variety of reports using geoanalytical tools and allows for the integration of a broad range of the geospatial data across the state. This makes OMOC the preferred platform to develop, measure and track LTS. Data within OMOC is more accurate on state roadways as speed limits for most local roadways were not captured in OMOC. To estimate the speed limit for local roadways, the roadway's functional classification was used to determine the speed limit as:

- Local – 25 mph
- Minor collector – 30 mph
- Major collector – 35 mph
- Minor arterial – 35 mph
- Principal Arterial (other) – 40 mph
- Principal Arterial (other Freeways and Expressways) – 50 mph
- Interstate – 55 mph

An additional assumption for roadway records addresses the use of number of through lanes and traffic volumes. The number of through lanes is available for all roadway records in OMOC. Traffic volumes are derived from MDOT State Highway Administration's Traffic Monitoring System, the clearinghouse for all traffic volume records. Since the number of through lanes on a roadway is based on the current and projected traffic volumes, both values can be used interchangeably. Where available, the traffic volume for roadway records was used to determine a more accurate LTS score. Where traffic volumes are not available, the number of through lanes is used to determine LTS.

## Shared-use Path Data Development

The transition from BLOC to LTS included developing two new datasets within OMOC. The first dataset is an inventory of all shared-use paths open to public, two-way bicycle access which contribute to the bicycle transportation network. Shared-use paths and sidepaths were assigned an LTS score of "0" to indicate minimal interaction with motor vehicle traffic. Many paved loop trails entirely within parks which had no connection to the adjacent roadway network were not included but may be included in future iterations.

Sidepaths, where shared-use paths runs parallel to adjacent roadways, are included in the shared-use path dataset. Sidepaths however are generally not as inviting for bicycling as shared-use paths on independent alignments due to the relative proximity of motor vehicle traffic in addition to increased exposure to potential conflicts at intersections with more roadways and driveways. Future iterations of the LTS will assign an LTS score of "1" to sidepaths.

## On-street Bicycle Facility Data Development

The second dataset is an inventory of all on-road bicycle facilities which have a designated roadway space for bicycle travel including bike lanes and protected bike lanes. Marked shared lanes in which bicycle and motor vehicle traffic share travel lanes were not included. Shared lanes, whether sharrows, bike boulevards or signed routes were inventoried but treated as mixed traffic for LTS analysis. The bicycle facilities included in the analysis include:

- Standard Bike Lanes – A roadway lane designated for bicycle travel at least 5-feet-wide. Bike lanes may be located against the curb or between a parking lane and a motor vehicle travel lane. Buffered bike lanes without vertical separation from motor vehicle traffic are included in this category. Following AASHTO and MDOT SHA design standards, bike lanes are assumed to be at least 5-feet-wide even through some existing bike lanes are less than 5-feet-wide.
- Protected Bike Lanes – Bike lanes located within the street but are separated from motor vehicle travel lanes by a vertical buffer, whether by a row of parked cars, flex posts or concrete planters.
- Shoulders – Roadway shoulders are commonly used by bicycle traffic. As such, roadways with shoulders open to bicycle traffic were identified and rated for LTS in relation to adjacent traffic speeds and volumes as well as the shoulder width. Shoulders less than 5-feet-wide, the standard bike lane width, were excluded from analysis and these roadway segments were treated as mixed traffic.

The Office of Highway Development at MDOT SHA provided the on-street bicycle facility inventory data for state roadways. The shared-use path inventory and on-street bicycle facility inventory was compiled from local jurisdiction's open-source download or shared form the GIS/IT departments. Before integrating into OMOC, these datasets were verified by conducting desktop surveys and site visits, and by consulting with local officials and residents.

## Bicycle Infrastructure Specifics

In addition to identifying protected bike lanes and standard bike lanes, additional metrics were collected with the initial analysis. These metrics were identified to enable network analysis once the initial analysis was performed. These metrics include:

- Side of roadway – Not all bike lanes are on both sides of the roadway, therefore the bike lane was assigned whether it is on the left, right or both sides of the street based on the cardinality of the route. This metric is applied to better calculate LTS in addition to bike lane miles per side of the roadway.
- Traffic flow – Each on-street bike facility was assigned whether is it allows for one or two-way travel. This metric is applied to allow for contraflow bicycle lanes and bi-directional cycletracks in addition to allowing future network analysis and routing.
- Vertical Separation – The presence of a vertical separator provides a physical barrier between bicycle and motor vehicle traffic. This separation reduces the likelihood and severity of crashes between motor vehicles and bikes, thus creating a more inviting bicycle experience. While Montgomery County's methodology distinguishes between the types of barriers such as flex posts and parked cars, MDOT's methodology only identifies if there is a vertical delineator within the buffer.

Several factors which help further define LTS were unavailable during the initial analysis. These factors include bike lane width, width of buffers between bike lanes and parking or travel lanes, bike lane reach and the presence of on-street parking. Due to the lack of data on existing bicycle facilities, all bike lanes are assumed to be at least 5' wide and not adjacent to on-street parking. Shoulder width data is available on most roadway records which helped produce more accurate LTS results. For roadways with a bikeable shoulder, but not marked as a bike lane, the shoulder width was used to calculate the LTS. As MDOT continues to expand data collection for OMOC, these additional factors will be included to refine LTS scores. See the following charts for the bike facility LTS recommendations.

### Standard Bike Lanes

| Number of Lanes | Vertical Separation | ≤25mph | 30mph | 35mph | 40mph | 45mph | 50+mph |
|---|---|---|---|---|---|---|---|
| 1-thru lane per direction or unlaned | No | 1 | 2 | 3 | 3 | 4 | 4 |
| 2 thru lanes per direction | No | 2 | 3 | 3 | 3 | 4 | 4 |
| 3+ thru lanes per direction | No | 3 | 3 | 4 | 4 | 4 | 4 |

### Protected Bike Lanes

| Number of Lanes | Vertical Separation | ≤25mph | 30mph | 35mph | 40mph | 45mph | 50+mph |
|---|---|---|---|---|---|---|---|
| 1 | Yes | 1 | 1 | 1 | 1 | 2 | 3 |
| 2 | Yes | 1 | 1 | 1 | 2 | 3 | 3 |
| 3+ | Yes | 1 | 1 | 2 | 2 | 3 | 4 |

### Roadways With Bikeable Shoulders

| Number of Lanes | Shoulder Width | 25mph | 30mph | 35mph | 40mph | 45mph | 50+mph |
|---|---|---|---|---|---|---|---|
| 1-thru lane per direction or unlaned | 6'+ | 1 | 2 | 2 | 3 | 3 | 3 |
| | 4'-5' | 2 | 2 | 2 | 3 | 3 | 4 |
| 2 thru lanes per direction | 6'+ | 2 | 2 | 2 | 3 | 3 | 3 |
| | 4'-5' | 2 | 2 | 2 | 3 | 3 | 4 |
| 3+ thru lanes per direction | Any | 3 | 3 | 3 | 4 | 4 | 4 |

## Prohibited Routes

Bicycles are prohibited from using all interstates and most limited-access roadways in the State of Maryland. A list of prohibited routes is available on MDOT SHA's website. In addition to these routes, MDOT SHA District Offices have designated additional roadways prohibited for bicycle access, typically on higher speed roadways without shoulders. All state and district-designated prohibited routes were identified with an LTS score of 5.

## Bicycle Nomenclature Subcategory

A bicycle facility subcategory is also provided in the on-street dataset. The facility subcategory is provided to account for the various names of bicycle facilities used by Maryland jurisdictions. The subcategory designation will also enable easier data maintenance when receiving data from local jurisdictions. Protected bike lanes are also referred to as cycletracks, protected cycletracks, and buffered bike lanes. Standard bike lanes include subcategories such as bike lanes, buffered bike lanes without vertical separation and contraflow bike lanes. The subcategory also allows bicycle infrastructure to be catalogued where bicycle and motor vehicle traffic share a travel lane, such as shared lanes (sharrows), bike boulevards and signed bike routes. The following tables includes the Bicycle Facility and Subcategory Types:

| Bicycle Facility Type | Subcategory | Vertical Separation | LTS Score |
|---|---|---|---|
| Shared-use Path | transportation trail | Yes | **LTS 0** |
| | multi-use trail | | |
| | sidepath | | |
| | gravel path | | |
| Protected Bike Lane | cycletrack | Yes | **LTS 1 – 4** See Protected Bike Lanes Chart for Criteria |
| | separated bike Lane | | |
| | buffered bike lane | | |
| | parking protected bike lane | | |
| | protected contraflow bike lane | | |
| Standard Bike Lane | separated bike Lane | No | **LTS 1 – 4** See Standard Bike Lanes Chart for Criteria |
| | buffered bike lane | | |
| | bike lane | | |
| | contraflow bike lane | | |
| | pocket bike lane | | |
| All Other On-Street Bicycle Infrastructure With By Both Bicycle and Motor Vehicle Traffic | bicycle boulevard | No | **LTS 1 – 4** See chart for Mixed Traffic for Criteria |
| | neighborhood greenway | | |
| | sharrow | | |
| | shared lane | | |
| | share the road | | |
| | shared street | | |
| | shared bus and bike lane | | |
| | signed bike route | | |
| Roadways Where Bicycle Traffic Uses The Shoulder | shoulder | No | **LTS 1 – 4** See Roadways with Bikeable Shoulders for Criteria |
| Roadways Prohibited to Bicycle Traffic | All roadways | No | **LTS 5** |

## On-street Parking

On-street parking presence is a variable in the LTS rating of bike lanes. Bike lanes which are located between motor vehicle travel lanes and on-street parallel parking are less inviting than bike lanes without adjacent parking. Parked cars create a less predictable travel experience for bicyclists as parked car doors may be opened into the bike lanes or parked cars may pull into the bike lane to merge into traffic.

On-street parking is not maintained in OMOC, therefore bike lane LTS rating were applied assuming the existence of on-street parking. This assumption may artificially increase LTS for some bike lanes but future iterations will be refined as parking data is created in OMOC. Shoulder information is maintained in OMOC, however, and was used for scoring. The on-street parking inventory was developed from geodata information shared by local and regional departments of transportation, public works and information technology.

## Secondary (Non-Inventory) Routes

OMOC was established for roadway asset inventory and management. All roadways follow a single direction for inventorying roadway assets such as signs, guardrails, streetlights. Where roadways are physically divided, a secondary route of the same roadway is established in OMOC with an inverse mileage. These secondary routes are established to illustrate divided roadways, but the secondary routes are not used to inventory assets. Because the primary routes contain the inventoried information, such as speed limit, through lanes and other metrics, secondary routes do not have these associated metrics to determine LTS. To address such data gaps, metrics associated with primary routes were applied to secondary routes to inform the assignment of an LTS score. In most cases, such divided roadways were on major arterial roadways with an LTS score of 4.

## Preliminary Analysis and Quality Control

With LTS metrics established, an algorithm was developed to run the model through Roads & Highways Segment Analyzer GIS program. The LTS model included all combinations of roadways with and without bicycle facilities, traffic volumes or through lanes and speed limits. The model was then expanded to accommodate exception cases, such as MD 650 (New Hampshire Avenue) in White Oak where a six-lane roadway had standard bike lanes on each side of the roadway. The combination of traffic volumes and the 40-mph speed limit assigned the roadway segment an LTS 4. Additional revisions were made until most roadway records were assigned an LTS score.

## Data Uses

The 2021 LTS data produced through this process can be used in a variety of planning exercises. The consistent metrics applied across the state will help inform bicycle mobility and accessibility decisions at state and local levels. Primarily, the LTS analysis illustrates how bikeable Maryland roads are where the greatest barriers lie. While most roads in the state are and LTS 1, the main roadways which link residential areas with community services are typically LTS 4. In the coming months, MDOT will use the LTS in variety of way including:

- Conducting a bicycle network analysis to develop accessibility measures and potential performance metrics.
- Cross referencing with state crash location data;
- Performing gap analysis to help inform project prioritization.

## Data Limitations

As a principle of data governance MDOT strives to provide the best possible data products. While the initial LTS analysis of Maryland's bicycle network has many uses, it should be used with a clear understanding of the current limitations the data presents.

1. **Assumptions** – As noted earlier in this document, some of the metrics used to determine LTS score were estimated. Speed limits for many local roadways were not included in the original data and were assigned based on the functional classification of the roadway. Speed limits are also based on the posted speed limit, not the prevailing operating vehicle speeds which can vary greatly. Such discrepancies between actual and assumed conditions could introduce margins of error in some cases. As data quality improves with future iterations, the LTS scoring accuracy will also improve.

2. **Generalization** – MDOT's LTS methodology follows industry standards but needs to account for varying roadway conditions and data reliability from various sources. The LTS methodology aims to accurately capture Maryland's bicycle conditions and infrastructure but must consider data maintenance requirements. To limit data maintenance generalizations were made in the methodology so that a score could be assigned. Specifically, factors such as intersections, intersection approaches and bike lane blockages are not included in this initial analysis. LTS scores may be adjusted in the future based on MDOT review, updated industry standards, and additional LTS metrics being included in OMOC such as parking and buffer widths.
3. **Timestamped** - As the LTS score is derived from a dynamic linear referencing system (LRS), any LTS analysis performed reflects the data available in OMOC. Each analysis must be considered 'timestamped' and becoming less reliable with age. As variables within OMOC change, whether through documented roadway construction, bikeway improvements or a speed limit reduction, LTS scores will also change. Fortunately, as this data is updated in the linear referencing system, the data becomes more reliable and LTS scores become more accurate.