# Appendix B:  Bicycle Level of Service Definitions

## ***<u>Bicycle Level of Service Model Description</u>***

The Bicycle LOS Model is a "supply-side" criterion.  It is an evaluation of bicyclists' perceived safety with respect to motor vehicle traffic.  It identifies the quality of service for bicyclists that currently exists within the roadway environment.  Following the model description, the data requirements, data collection and compilation guidelines, and results of the evaluation are documented.

The statistically calibrated mathematical equation entitled the *Bicycle Level of Service (Bicycle LOS)*[1] *Model (Version 2.0)* was used for the evaluation of bicycling conditions. This model is the most accurate method of evaluating the bicycling conditions of 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 conditions, 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 100,000 miles of evaluated urban, suburban, and rural roads and streets across North America. Many urbanized area planning agencies and state highway departments are using this established method of evaluating their roadway networks. These include Anchorage AK, Baltimore MD, Birmingham AL, Buffalo NY, Gainesville FL, Houston TX, Philadelphia PA, Lexington KY, Sacramento CA, Springfield MA, Tampa FL, as well as 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.

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

[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

$SP_t(1+10.38HV)^2$ term]. As a result, *Version 2.0* has the highest correlation coefficient ($R^2$ = 0.77) of any form of the *Bicycle LOS Model*[2].

Version 2.0 of the *Bicycle Level of Service Model (Bicycle LOS Model)* was employed to evaluate the roads and streets within the First Coast MPO region. Its form is shown below:

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

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:

| | |
|---|---|
| $W_e = W_v - (10\text{ ft} \times \%\ OSPA)$ | and $W_l = 0$ |
| $W_e = W_v + W_l(1 - 2 \times \%\ OSPA)$ | and $W_l > 0$ & $W_{ps} = 0$ |
| $W_e = W_v + W_l - 2(10 \times \%\ OSPA)$ | 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 ≤ 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.

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 in Figure 2.

**TABLE 1 Bicycle Level-of-Service Categories**

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

*The* Bicycle LOS Model *is used by planners and engineers throughout the US and Canada in a variety of planning and design applications. This can be used to conduct a benefits comparison among proposed bikeway/roadway cross-sections, identify roadway restriping or reconfiguration candidates for bicycle improvements, and to prioritize and program roadways for bicycle improvements.*

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## FIGURE 1 Bicycle LOS Model Sensitivity Analysis

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

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

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 (T-statistic = 9.844)

| | | | | | |
|---|---|---|---|---|---|
| $W_t$ | = | 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 (T-statistic = 5.689)

| | | | | | |
|---|---|---|---|---|---|
| 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 (T-statistic = 4.902)

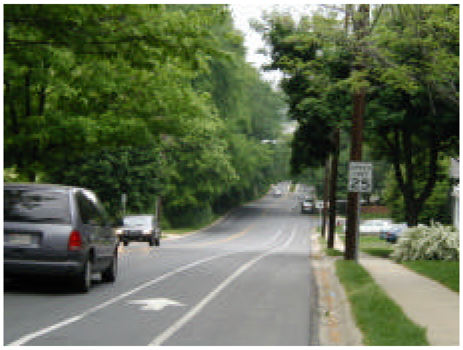
| | | | | | |
|---|---|---|---|---|---|
| $PR_5$ | = | 2 | Poor | 5.30 | 33% increase |
| $PR_5$ | = | 3 | Fair | 4.32 | 9% reduction |
| $PR_5$ | = | 4 - - | Good - (baseline average) - - - | 3.98 - - - - | no change |
| $PR_5$ | = | 5 | Very Good | 3.82 | 4% reduction |

Heavy Vehicles in percentages (Combined speed and heavy vehicles T-statistic = 3.844)

| | | | | | |
|---|---|---|---|---|---|
| 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)*)

The BLOS Model provides a grading system (A-F) for rating bicycle riding conditions on each roadway segment.  Level A reflects the best conditions for bicyclists; level F represents the worst conditions. The photos provided show examples of real world locations that depict the existing conditions, which generate the various Level of Service grades.



BLOS A

BLOS B

BLOS C

BLOS D

BLOS E


BLOS F

## ***Bicycle Level of Service Model Definitions***

The following list provides a definition for each of the data fields required for computation of the *Bicycle Level of Service* scores, as well as the associated guidelines for their collection and compilation into the programmed database.

**Average Daily Traffic (ADT)** - is the average daily traffic volume on the segment or link. The programmed database will convert these volumes to $Vol_{15}$ using the Directional Factor (D), Peak to Daily Factor ($K_d$) and Peak Hour Factor (PHF) for the road segment.

***Percent Heavy Vehicles (HV)*** - is the percentage of heavy vehicles *(as defined by the 1994 Highway Capacity Manual or the Client*) on the segment or link.

***Number of lanes of traffic (L)*** - is the total number of *through* traffic lanes of the road segment and its configuration. (e.g., D = Divided, U = Undivided, OW = One-Way, S = Center Turning Lane). The programmed database will convert these lanes into directional lanes. The presence of continuous right-turn lanes should be noted in the comments field. In the other direction it will be noted in the comments if there is a different number of through lanes.

***Posted Speed Limit ($S_p$)*** - Recorded as posted.

***$W_t$ total width of pavement*** - is measured from the center of the road, yellow stripe, or (in the case of a multilane configuration) the lane separation striping to the edge of pavement or to the gutter pan of the curb. When there is angled parking adjacent to the outside lane, $W_t$ is measured to the traffic-side end of the parking stall stripes.

***$W_l$ width of paving between the outside lane stripe and the edge of pavement*** - is measured from the outside lane stripe to the edge of pavement or to the gutter pan of the curb. When there is angled parking adjacent to the outside lane, $W_l$ is measured to the traffic-side end of the parking stall stripes.

***$W_l$ width of pavement striped for on-street parking*** - Record this factor 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, report the combined width of the striped parking.

***Total Pavement Width (TPW)*** - is measured from the center of the road or yellow stripe to the edge of pavement or to traffic side of the gutter pan of the curb. Record this dimension only when the roadway has four or more thru lanes and has no striped paved shoulder or bike lane.

***OSPA %*** - estimated percentage (measured in increments of 25%) of the segment (excluding driveways) along which there is occupied on-street parking at the time of survey. Each side should be recorded separately. If parking is allowed only during off-peak periods and parking restrictions change widths and laneage, indicate the geometric changes in the comments field.  Note:  Indicate any "angled parking" in the comments field.

***Travel Lane ($PC_t$)*** - Evaluate the pavement condition of the motor vehicle travel lane according to the FHWA's five-point pavement surface condition rating shown below

***Shoulder or Bike lane ($PC_l$)*** - Evaluate the pavement condition of the shoulder or bike lane according to the FHWA's five-point pavement surface condition rating.

**PAVEMENT SURFACE CONDITION RATING**

**5.0** - 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** - Pavement, although not as smooth as described above, gives a first class ride and exhibits signs of surface deterioration.

**3.0** - 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** - 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*** *- Pavements that are in an extremely deteriorated condition.  Distress occurs over 75 percent or more of the surface.*