Bicycling and Walking Performance Measures

Traditional, the new *Highway Capacity Manual*, and beyond…

*Bruce W. Landis, P.E., AICP*
A New Game....

- “Balanced” transportation....
- Multi-modal
- Complete Streets
- Livability
- Sustainable “Whatever”
- Economically-Efficient Corridors
- Community Health Metrics....

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What gets “measured” gets “done”…

- Artifacts provide the evidence:
  - Federal Reporting by States (HPMS, etc.)
  - AASHTO (Roadway Geometric Design) Manuals
  - *Highway Capacity Manual*
  - Congestion Measures
Livable, or Not Livable?
How Livable, or Complete?
LOS A
Pedestrian Space > 60 ft²/p  Flow Rate ≤ 5 p/min/ft
At a sidewalk LOS A, pedestrians move in desired paths
without altering their movements in response to others.
Pedestrian speeds are freely selected, and conflicts
between pedestrians are unlikely.

LOS B
Pedestrian Space > 40-60 ft²/p  Flow Rate > 5-7 p/min/ft
At LOS B, there is sufficient space for pedestrians to select
walking speeds freely, to bypass other pedestrians, and to avoid
crossing conflicts. At this level, pedestrians begin to be aware
of other pedestrians, and to respond to their presence when
selecting a walking path.

LOS C
Pedestrian Space > 24-40 ft²/p  Flow Rate > 7-10 p/min/ft
At LOS C, space is sufficient for normal walking speeds, and
for bypassing other pedestrians in primarily unidirectional streams.
Reverse-direction or crossing movements cause minor
conflicts, and speeds and flow rate are somewhat lower.

LOS D
Pedestrian Space > 15-24 ft²/p  Flow Rate > 10-15 p/min/ft
At LOS D, freedom to select individual walking speed and to
bypass other pedestrians is restricted. Crossing or reverse-
flow movements have a high probability of conflict, requiring
frequent changes in speed and position. The LOS provides
reasonably fluid flow, but friction and interaction between
pedestrians is likely.

LOS E
Pedestrian Space > 8-15 ft²/p  Flow Rate > 15-25 p/min/ft
At LOS E, virtually all pedestrians restrict their normal walking
speed, frequently adjusting their path. At the lower ranges,
forward movement is possible only by shuffling. Space is not
sufficient for passing slower pedestrians. Cross- or reverse-
flow movements are possible only with extreme difficulties.
Design volumes approach the limit of walkway capacity, with
stoppages and interruptions to flow.

LOS F
Pedestrian Space ≤ 8 ft²/p  Flow Rate varies p/min/ft
At LOS F, all walking speeds are severely restricted, and
forward progress is made only by shuffling. There is frequent,
unavoidable contact with other pedestrians. Cross- and
reverse-flow movements are virtually impossible. Flow is
sporadic and unstable. Space is more characteristic of queued
pedestrians than of moving pedestrian streams.
The Highway Capacity Manual

Insert Dowlings….

<table>
<thead>
<tr>
<th>Roadway</th>
<th>Traffic</th>
<th>Pavement</th>
<th>Sidewalk</th>
<th>Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane</td>
<td>Type</td>
<td>ADF</td>
<td>HV</td>
<td>W_1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speed</td>
<td></td>
<td>total width</td>
</tr>
<tr>
<td>Jnt.</td>
<td></td>
<td>Limit</td>
<td>Limit</td>
<td></td>
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<tr>
<td></td>
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</tr>
</tbody>
</table>

**Multi-Modal LOS Spreadsheet V 3.0**

Bruce W. Landis, P.E., AICP
Planning, Design, Investment Decisions...
Reliable Measures

- Motor Vehicle LOS
- Bicycling LOS
- Pedestrian LOS
- Transit LOS

- Fuel Savings
- Emissions / GHG
- Health Savings
- Economic Effects
San Antonio - Bexar Co. MPO

SAN ANTONIO - BEXAR COUNTY METROPOLITAN PLANNING ORGANIZATION

MOBILITY 2035
We Plan to Keep You Moving

SAN ANTONIO BIKES
Office of Environmental Policy
DOT Research Initiatives
National Cooperative Highway Research Program NCHRP 3-70

- Multi-modal LOS for Arterials
- Evaluated Bicycling & Walking Conditions Methods
- Established the Best Measures / Models
- Acknowledged Superiority of Bike/Ped Measures’ Approach to the Traditional MV LOS
- Tested then Intertwined all Modes’ Methods
- Created First Inter-translation QOS/LOS
- Established Simultaneous Reporting

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Nationwide Testing & Surveying

- Oregon
- Texas
- Illinois
- Virginia
- California
- Florida

Photo Credit: Sprinkle Consulting, Inc.

Bruce W. Landis, P.E., AICP
Austin’s NCHRP 3-70 Test Corridors

• Guadalupe (MLK to Dean Keeton)
• Manchaca (Berkeley to SH 71)
• Manor (Chestnut to Rogge)
National Cooperative Highway Research Program NCHRP 3-92

- Update of the *HCM*
- Incorporated NCHRP reports, reliable peer- and agency-reviewed methods
- Places Bike, Ped, Transit QOS/LOS measures on par with MV measures
- Acknowledges the “new” approach of asking “customers” for performance measures
Chapters 16 & 17  Urban Arterials
a.k.a. “Multi-modal LOS”
Highway System Structure

- Points
- Segments
- Facilities
- Corridors
- Areas
Arterial Bicycle LOS Model

Bicycle LOS = \( a_1(Seg) + a_2(\exp(Int)) + a_3(Cflt) \)

Where

- \( Seg \) = length weighted avg. *Segment Bicycle LOS Model*
- \( \exp \) = exponential function
- \( Int \) = average *Intersection Bicycle LOS Model*
- \( Cflt \) = number of conflicts per mile (e.g., driveways, unsig. Int.)
- \( a_1, a_2, a_3 \) = coefficients
Segment Bicycle LOS Model

\[ \text{Seg} = 0.507 \ln \left( \frac{V}{(4 \times \text{PHF} \times L)} \right) + 0.199 \times \text{ST} \times (1 + 10.38 \times HV)^2 + 7.066 \left( \frac{1}{\text{PC}} \right)^2 - 0.005 (W_e)^2 + 0.760 \]
Effective Pavement Width Effects....
MV Volume Effects....
Pavement Condition Effects....
Arterial Bicycle LOS Model

Bicycle LOS = \( a_1(Seg) + a_2(\exp(Int)) + a_3(Cflt) \)

Where

- **Seg** = length weighted avg.  \textit{Segment Bicycle LOS Model}
- **exp** = exponential function
- **Int** = average \textit{Intersection Bicycle LOS Model}
- **Cflt** = number of conflicts per mile (e.g., driveways, unsig. Int.)
- **a_1, a_2, a_3** = coefficients
Intersection Bicycle LOS

\[
\text{IntBLOS} = -0.2144 \, W_t + 0.0153 \, CD + 0.0066 \left( \frac{\text{Vol}_{15}}{L} \right) + 4.1324
\]

- \( W_t \) = total width of outside through lane and shoulder / bike lane (if present)
- \( CD \) = crossing distance, the width of the side street (including auxiliary lanes and median)
- \( \text{Vol}_{15} \) = volume of directional traffic during a 15-minute time period
- \( L \) = total number of through lanes on the approach to the intersection
Establishing Target Level(s) of Service
<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Through Traffic</th>
<th>Sign per Mile</th>
<th>ADT (VFD)</th>
<th>Speed Limit</th>
<th>Pavement Type</th>
<th>Bike Lane</th>
<th>Pedestrian</th>
<th>Bicycle Level of Service</th>
<th>Pedestrian Level of Service</th>
<th>Motor Vehicle Level of Service</th>
<th>Transit Level of Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR 1</td>
<td>20,000</td>
<td>30</td>
<td>2</td>
<td>1.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.16</td>
<td>D</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>SR 2</td>
<td>40,000</td>
<td>40</td>
<td>4</td>
<td>4.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.43</td>
<td>C</td>
<td>3.69</td>
<td>C</td>
</tr>
<tr>
<td>SR 3</td>
<td>60,000</td>
<td>60</td>
<td>6</td>
<td>6.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.15</td>
<td>D</td>
<td>3.47</td>
<td>C</td>
</tr>
<tr>
<td>NR</td>
<td>10,000</td>
<td>10</td>
<td>1</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2.72</td>
<td>C</td>
<td>3.67</td>
<td>C</td>
</tr>
</tbody>
</table>
**Pedestrian LOS Model**

= Worse of (Density LOS, Roadway Environ. LOS)

**Density LOS**
= letter grade of LOS for “crowding” density of sidewalks, walkways and street corners

**Roadway-Ped LOS**
= letter grade of LOS for urban street based on ped. safety / comfort factors reflecting interaction with motor vehicles
**Pedestrian Density LOS Model**

From Chapter 18 of the 2000 *HCM*

<table>
<thead>
<tr>
<th>LOS</th>
<th>Min. Ped Space per Person (SF)</th>
<th>Equivalent Max Flow Rate per Unit Width of Sidewalk (peds/hr/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&gt; 60</td>
<td>≤ 300</td>
</tr>
<tr>
<td>B</td>
<td>&gt;40</td>
<td>≤ 420</td>
</tr>
<tr>
<td>C</td>
<td>&gt;24</td>
<td>≤ 600</td>
</tr>
<tr>
<td>D</td>
<td>&gt;15</td>
<td>≤ 900</td>
</tr>
<tr>
<td>E</td>
<td>&gt;8</td>
<td>≤ 1380</td>
</tr>
<tr>
<td>F</td>
<td>≤ 8</td>
<td>&gt;1380</td>
</tr>
</tbody>
</table>

At LOS A, all walking speeds are severely restricted, and forward progress is made only by "shuffling." There is frequent, unavoidable contact with other pedestrians. Cross- and reverse-flow movements are virtually impossible. Flow is sporadic and unstable. Space is more characteristic of queued pedestrians than of moving pedestrian streams.
**Pedestrian LOS Model**

Two Roadway Environment models...modified by...

PedLOS = (\(a_1 P_{\text{Segment}} + a_2 P_{\text{Int}} + c\)) (RCDF)

- **PSeg** = *Segment Pedestrian LOS value*
- **PInt** = *Intersection Pedestrian LOS value*
- **RCDF** = *Roadway Crossing Difficulty Factor*
- **a_1, a_2** = coefficients
- **c** = constant
Segment Pedestrian LOS

Seg LOS = -1.2276 \ln (W_t + f_p \times \%OSP + f_b \times W_b + f_{sw} \times W_s) + 0.0091(Vol_{15}/L) + 0.0004 SPD^2 + 6.0468

Where:

\[
\begin{align*}
\text{Ped Seg LOS} & = \text{Pedestrian level of service score for a segment} \\
\ln & = \text{Natural log} \\
W_t & = \text{Width of outside lane plus shoulder / bike lane} \\
f_p & = \text{On-street parking effect coefficient (= 0.20)} \\
\%OSP & = \text{Percent of segment with on-street parking} \\
f_b & = \text{Buffer area coefficient (= 5.37 for trees spaced 20 feet on center)} \\
W_b & = \text{Buffer width (distance between edge of pavement and sidewalk, in feet)} \\
f_{sw} & = \text{Sidewalk presence coefficient (= 6 - 0.3Ws)} \\
W_s & = \text{Width of sidewalk} \\
Vol_{15} & = \text{Volume of motorized vehicles in the peak 15 minute period} \\
L & = \text{Total number of directional through lanes} \\
SPD & = \text{Average running speed of motorized vehicle traffic (mi/h)}
\end{align*}
\]
Intersection Pedestrian LOS

Ped Int LOS (Signal) = 0.00569 (RTOR+PermLefts) + 0.00013 (crossingTrafVol x TrafSpeed) + 0.0681 (# LanesCrossed^{0.514}) + 0.0401\ln(PedDelay) – RTCI (0.0027PerpTrafVol – 0.1946) + 1.7806

Where
RTOR+PermLefts = right-turn-on-red vehicles plus number of motorists making a permitted left turn in a 15 minute period

PerpTrafVol*PerpTrafSpeed = Product of the traffic in the outside through lane of the street being crossed and the midblock 85th percentile speed of traffic on the street being crossed in a 15 minute period

LanesCrossed = The number of lanes being crossed by the pedestrian

PedDelay = Average number of seconds the pedestrian is delayed before being able to cross the intersection

RTCI = Number of right turn channelization islands on

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Sprinkle Consulting
Roadway Crossing Difficulty Factor

RCDF = Max[0.80, Min{[(XLOS#-NXLOS#)/7.5 + 1.00],1.20}]

Where
RCDF = Roadway crossing difficulty factor
XLOS# = Roadway crossing difficulty LOS Number
NXLOS# = Non-crossing Pedestrian LOS number
   = (0.318 PSeg + 0.220 PInt + 1.606)
Pseg  = Ped. Segment LOS number (computed per equation #20)
Pint  = Ped. Intersection LOS number (computed per equation #21)
# Pedestrian Level of Service

<table>
<thead>
<tr>
<th>Level of Service</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≤ 1.5</td>
</tr>
<tr>
<td>B</td>
<td>&gt; 1.5 and ≤ 2.5</td>
</tr>
<tr>
<td>C</td>
<td>&gt; 2.5 and ≤ 3.5</td>
</tr>
<tr>
<td>D</td>
<td>&gt; 3.5 and ≤ 4.5</td>
</tr>
<tr>
<td>E</td>
<td>&gt; 4.5 and ≤ 5.5</td>
</tr>
<tr>
<td>F</td>
<td>&gt; 5.5</td>
</tr>
</tbody>
</table>
Chapters 16 & 17  Urban Arterials
a.k.a. Multi-modal or Complete Streets
LOS
Reliable Measures

- Motor Vehicle LOS
- Bicycling LOS
- Pedestrian LOS
- Transit LOS

- Fuel Savings
- Emissions / GHG
- Health Savings
- Economic Effects
Active Transportation Corridors
Advanced Tools for Livability Benefits…
Report Output for Corridor Investments

Societal benefits:

- Fuel Savings
- CO$_2$ Emissions Savings
- Health Cost Savings
Performance Metrics

Effective Mid-block Crossings

- Make motorists and pedestrians **aware of the crossing**
- Communicate the obligations
- Enable the motorists and the pedestrians to **fulfill their obligations**
Performance Metrics “Buffered” Bike, or Comfort Lanes
Your Resources…

• Highway Capacity Manual

• NCHRP Report 616

• FDOT’s Q/LOS Handbook
  http://www.dot.state.fl.us/planning/systems/sm/los/pdfs

• www.sprinkleconsulting.com

• 888 - 462 - 3514  Peyton McLeod or Bruce Landis

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