A Comparison of Bicyclists' Performance Characteristics at Urban, Suburban, and Dedicated Path Intersections in Oregon

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Introduction

When stopped at a red light, and then proceeding through the intersection…
- Motorist behavior and performance is consistent and well-known
- Cyclist behavior and performance varies significantly and has not been well quantified

Outdated signal timing for bikes could result in:
- Inefficient Use of Green Time
- Unsafe Scenarios
Research Objectives

• To develop engineering guidelines for the design of bicycle-specific traffic signals.

• To develop operational guidelines for timing and phasing of bicycle-specific traffic signals or modifications that can be made to existing signals to better accommodate bicycles.
Performance characteristics were observed to better quantify cyclists’ behavior starting from a standstill and traveling through an entire intersection.

Performance Characteristics Of This Research:

- Perception/Reaction Time
- Acceleration Rates
- Cruising Speeds
- Queue Discharge Rates (separate methodology)
Data Assembly

Temporary video units were placed near intersections to obtain video footage used for analysis:
Data Assembly

Data collection is often…fun?
Performance Methodology

- Video units placed on nearby signal poles
- Footage was reviewed at a later date

Source Image: NACTO Urban Bikeway Design Guide
Performance Methodology

- Perception/Reaction Time easily observed
- Marks strategically painted on pavement allowed time observations to be made when cyclists crossed the lines.

Using previously developed research\(^1\), calculations could then be made for:
  - Acceleration Rates
  - Cruising Speeds (\& the location this was obtained)

\(^1\)Figliozzi, Miguel, et al. "A Methodology to Estimate Bicyclists’ Acceleration and Speed Distributions at Signalized Intersections."
Performance Methodology

• Of all the cyclists observed, only the following cyclists were analyzed:
  – Those that came to a complete stop at one of the reference lines,
  – were the first cyclist in line,
  – had at least one foot placed on the ground, and
  – utilized the bike lane before and after the intersection.
Queue Discharge Methodology

Goal: to compare the discharge rates of cyclists at a traditional bike lane vs. bike lane + bike box

Utilizing the same video units as before, a different methodology was applied to obtain discharge rates.

Source Images: NACTO Urban Bikeway Design Guide
Queue Discharge Methodology

Bike Lane:

• Time Measurements Recorded:
  – Beginning of Red Indication
  – First Bike to Enter Intersection
  – Last Bike to Enter Intersection
  – Last Bike to Clear Intersection

• Due to cyclists lining up, analysis closely followed HCM methods for determining headways of a queue of cars.
  – Headway for 1st Cyclist: \( h_1 = \frac{(Ref_1 - Red)}{fps} - 1 \)s
  – Headway for Subsequent Cyclists: \( h_n = \frac{(Ref_n - Ref_{n-1})}{fps} \)

• Irregular queues were not included (e.g. cyclists stopped within intx, bus merging through bike lane, etc.)
Queue Discharge Methodology

- Bike Lane + Bike Box:
- Time Measurements Recorded:
  - Beginning of Red Indication
  - First Bike to Enter Intersection
  - Last Bike to Enter Intersection
  - Last Bike to Clear Intersection
- Due to cyclists forming a group, HCM methods for determining headways was not possible.
- Cyclists split into three groups, those stopped:
  - within the bike box,
  - beyond the bike box, and
  - in front of the bike box. (Not Included in Analysis)
Queue Discharge Methodology

• Bike Lane + Bike Box Visual:

Source Image: NACTO Urban Bikeway Design Guide
In addition to the video footage that we collected, similar video footage from previous research was also used:

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Portland State University</th>
<th>City of Portland</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At Intersections (Our Footage)</td>
<td>At Intersections (Previous Footage)</td>
</tr>
<tr>
<td>Video (Hours)</td>
<td>79</td>
<td>~12</td>
</tr>
<tr>
<td>Performance (# of Observations)</td>
<td>335</td>
<td>418</td>
</tr>
<tr>
<td>Queue Discharge (# of Observations)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Intersections Analyzed

- Overall, a variety of intersections were observed:
  - Location: Urban / Suburban / Dedicated Path / Bike Box (Before & After)
  - Type of Signal: Regular / Bike Signal
  - Crossing Width: Short / Wide
  - Grade: Flat / Uphill

<table>
<thead>
<tr>
<th>Approach</th>
<th>Signal</th>
<th>Width (ft.)</th>
<th>Grade</th>
<th>Date</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>(EUG) SB Pearl St. at E 18th Ave.</td>
<td>RS</td>
<td>61</td>
<td>Flat</td>
<td>10/12</td>
<td>CLR</td>
</tr>
<tr>
<td>(EUG) WB E 18th Ave. at Pearl St.</td>
<td>RS</td>
<td>65</td>
<td>Flat</td>
<td>10/12</td>
<td>CLR</td>
</tr>
<tr>
<td>(COR) SB NW 9th St. at NW Buchanan Ave.</td>
<td>RS</td>
<td>63</td>
<td>Flat</td>
<td>10/12</td>
<td>CO</td>
</tr>
<tr>
<td>(COR) EB NW Buchanan Ave. at NW 9th St.</td>
<td>RS</td>
<td>80</td>
<td>Flat</td>
<td>10/12</td>
<td>CO/F</td>
</tr>
<tr>
<td>(BEA) EB SW 5th St. at SW Lombard Ave.</td>
<td>RS</td>
<td>55</td>
<td>Flat</td>
<td>10/12</td>
<td>CLR/CO</td>
</tr>
<tr>
<td>(BEA) WB SW 5th St. at SW Lombard Ave.</td>
<td>RS</td>
<td>55</td>
<td>Flat</td>
<td>10/12</td>
<td>CLR/CO</td>
</tr>
<tr>
<td>(CC) SE Johnson Creek Blvd. and SE Bell Ave.</td>
<td>BS</td>
<td>75</td>
<td>Flat</td>
<td>9/12</td>
<td>CLR</td>
</tr>
<tr>
<td>(PDX) WB SE Madison St. at SE Grand Ave. (bike lane)</td>
<td>RS</td>
<td>61</td>
<td>Flat</td>
<td>7/08 &amp; 9/10</td>
<td>CO</td>
</tr>
<tr>
<td>(PDX) WB SE Madison St. at SE Grand Ave. (bike box)</td>
<td>RS</td>
<td>61</td>
<td>Flat</td>
<td>2/12</td>
<td>R/CO</td>
</tr>
<tr>
<td>(PDX) EB N Weidler at N Vancouver Ave.</td>
<td>RS</td>
<td>70</td>
<td>Up</td>
<td>7/08 &amp; 12/08</td>
<td>CLR/CO</td>
</tr>
</tbody>
</table>
Suburban Intersection

Beaverton – SW 5th Street & SW Lombard Avenue (EB & WB)
Urban Intersection

Corvallis – NW 9th Street & NW Buchanan Avenue (SB & EB)
Urban Intersection

Eugene – Pearl Street & E 18\textsuperscript{th} Avenue (SB & WB)

Left-hand Bike Lane
Urban Intersection

Portland – N Weidler Street & N Vancouver Avenue (EB)

Uphill Bike Lane
Dedicated Path Intersection

Clackamas County – Springwater Trail & SE Johnson Creek Blvd (EB) / SE Bell Avenue

Bike Signal
Bike Box Intersection (Before)

Portland – SE Grand Avenue & SE Madison Street (WB)

Before Bike Box
Bike Box Intersection (After)

Portland – SE Grand Avenue & SE Madison Street (WB)
Categorical Summary by Intersection

**Time of Day**

- AM-Peak
- Off-Peak
- PM-Peak

**Weekday/Weekend**

- Weekday
- Weekend

**Alone or Group**

- Alone
- Group
Summary of Observed Accelerations

15th Percentile  Median

Long  Short  No Grade  Grade  Group  Alone  Recreational  Commuter  Case 3  Case 2  Case 1  All Cyclists

Accelinations (ft/sec2)

AASHTO

= Statistically Significant
Density Plot of Observed Accelerations

Density of Accelerations (All Cyclists)

AASHTO’s default acceleration values are clearly conservative for most everyone observed.
Summary of Observed Cruising Speed

![Graph showing cruising speeds for different categories: Long, Short, No Grade, Grade, Group, Alone, Recreational, Commuter, Case 3, Case 2, Case 1, All Cyclists. The graph indicates 15th Percentile and Median speeds. There is a vertical line at 15 ft/sec labeled AASHTO.]

- Long
- Short
- No Grade
- Grade
- Group
- Alone
- Recreational
- Commuter
- Case 3
- Case 2
- Case 1
- All Cyclists

AASHTO = Statistically Significant
Density Plot of Observed Cruising Speed

AASHTO’s default velocity values assume higher cruising speeds than most people attained.
Summary of Observed Reaction Times

<table>
<thead>
<tr>
<th>Category</th>
<th>Reaction Time (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long</td>
<td></td>
</tr>
<tr>
<td>Short</td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td></td>
</tr>
<tr>
<td>Alone</td>
<td></td>
</tr>
<tr>
<td>Recreational</td>
<td></td>
</tr>
<tr>
<td>Commuter</td>
<td></td>
</tr>
<tr>
<td>Case 3</td>
<td></td>
</tr>
<tr>
<td>Case 2</td>
<td></td>
</tr>
<tr>
<td>Case 1</td>
<td></td>
</tr>
<tr>
<td>All Cyclists</td>
<td></td>
</tr>
</tbody>
</table>

- 85th Percentile
- Median

AASHTO = Statistically Significant
Cyclists riding in groups, recreationally, or at wide intersections experienced longer reaction times than AASHTO’s default value.
## Overall Performance Summary

<table>
<thead>
<tr>
<th>Value</th>
<th>AASHTO</th>
<th>All Cyclists Observed</th>
<th>AASHTO Percentile (Estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Percentile (Values)</td>
<td></td>
</tr>
<tr>
<td>Acceleration (ft./sec²)</td>
<td>1.5</td>
<td>4.09</td>
<td>15&lt;sup&gt;th&lt;/sup&gt; (2.86)</td>
</tr>
<tr>
<td>Cruising Speed (ft./sec)</td>
<td>14.7</td>
<td>14.29</td>
<td>15&lt;sup&gt;th&lt;/sup&gt; (11.99)</td>
</tr>
<tr>
<td>Perception Reaction Time (sec)</td>
<td>1.0</td>
<td>1.11</td>
<td>85&lt;sup&gt;th&lt;/sup&gt; (1.91)</td>
</tr>
<tr>
<td>BMG + Y + AR for a 60 ft. intersection (sec)</td>
<td>10.39</td>
<td>7.48</td>
<td>85&lt;sup&gt;th&lt;/sup&gt; (9.51)</td>
</tr>
</tbody>
</table>

\[
BMG + Y + R_{clear} = PRT + \frac{V}{2a} + \frac{(W + L)}{V}
\]
Observed Crossing Times by Width

Calculated crossing time from standing start with AASHTO defaults = \( V/(2a) + (W + L)/V \), where:
- \( V \) = Bicycle Crossing Speed (14.7 feet/sec);
- \( a \) = Bicycle Acceleration (1.5 feet/sec\(^2\));
- \( W \) = Intersection Width (feet);
- \( L \) = Typical Bicycle Length (6 feet).

\[ BMG + Y + R_{clear} = P \times T + \frac{V}{2a} + \frac{(W + L)}{V} \]
Observed Queue Discharge Headways by Position in Queue

 Starts converging on 1 second headways
Queue Discharge Time by Queue Size

- Reduction
Queue Clearance Time by Queue Size

![Graph showing the relationship between queue size and clearance time for different types of intersections.](image-url)
Intersection Clearance Time by Queue Size

More Data of Larger Queue Sizes in Bike Boxes Needed (in progress)
Conclusions (Performance)

- The AASHTO defaults seem to be conservative for acceleration, fairly accurate for cruising speed, and liberal for perception-reaction times.

- The combination of AASHTO defaults in the clearance formula, hence, produces timing values that are sufficient for most riders in most locations (more care should be put into wider intersections though).

- Statistically significant differences were found between alone and group, recreational and commuter, and grade or no grade in each of the performance categories.
Conclusions (Queue Discharge)

• The average cyclist headway was found to be 0.997 seconds (5\textsuperscript{th} or higher in queue).

• The addition of a bicycle box decreases the discharge time.

• The decrease in discharge time between bike boxes and bike lanes becomes more evident with larger queue sizes.

• Cyclists utilizing a bike box appear to have longer clearance times for smaller queue sizes.
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  - Sam R. Thompson
Thank You! Questions/Comments?

e-mail: pkirk@pdx.edu

…&…

Find the interim report here: http://bit.ly/SxRrZd