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

Kirk Paulsen
Portland State University

Christopher M. Monsere
Portland State University, monsere@pdx.edu

Sam R. Thompson
Portland State University

Miguel A. Figliozzi
Portland State University, figliozzi@pdx.edu

Let us know how access to this document benefits you.

Follow this and additional works at: https://pdxscholar.library.pdx.edu/cengin_fac

Part of the Civil and Environmental Engineering Commons, and the Urban Studies and Planning Commons

Citation Details
Paulsen, Kirk; Monsere, Christopher M.; Thompson, Sam R.; and Figliozzi, Miguel A., 'A Comparison of Bicyclists' Performance Characteristics at Urban, Suburban, and Dedicated Path Intersections in Oregon' (2013). Civil and Environmental Engineering Faculty Publications and Presentations. 72.
https://pdxscholar.library.pdx.edu/cengin_fac/72

This Presentation is brought to you for free and open access. It has been accepted for inclusion in Civil and Environmental Engineering Faculty Publications and Presentations by an authorized administrator of PDXScholar. For more information, please contact pdxscholar@pdx.edu.
A Comparison of Bicyclists' Performance Characteristics at Urban, Suburban, and Dedicated Path Intersections in Oregon

2013 ITE Western District Annual Meeting – July 16, 2013

Presented by: Kirk Paulsen – Graduate Research Assistant

Research Team:
Sam R. Thompson – Graduate Research Assistant
Christopher Monsere – Associate Professor
Miguel Figliozzi – Associate Professor

Department of Civil & Environmental Engineering
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Outdated signal timing for bikes could result in: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: \( h_1 = \frac{(Ref_1-Red)}{fps} - 1s \)
  - 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

Removed from Analysis
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>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>987</td>
<td>987</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 18th 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)

After Bike Box
Summary of Observed Accelerations

<table>
<thead>
<tr>
<th>15th Percentile</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long</td>
<td></td>
</tr>
<tr>
<td>Short</td>
<td></td>
</tr>
<tr>
<td>No Grade</td>
<td></td>
</tr>
<tr>
<td>Grade</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>

Accelerations (ft/sec²)

=AASHTO

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

- 15th Percentile
- Median

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

= Statistically Significant
Density Plot of Observed Cruising Speed

Density of Velocities (All Cyclists)

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>85th Percentile</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreational</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commuter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Cyclists</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*All Cyclists* = 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><strong>Acceleration (ft./sec²)</strong></td>
<td>1.5</td>
<td>4.09</td>
<td>15&lt;sup&gt;th&lt;/sup&gt; (2.86)</td>
</tr>
<tr>
<td><strong>Cruising Speed (ft./sec)</strong></td>
<td>14.7</td>
<td>14.29</td>
<td>15&lt;sup&gt;th&lt;/sup&gt; (11.99)</td>
</tr>
<tr>
<td><strong>Perception Reaction Time (sec)</strong></td>
<td>1.0</td>
<td>1.11</td>
<td>85&lt;sup&gt;th&lt;/sup&gt; (1.91)</td>
</tr>
<tr>
<td><strong>BMG + Y + AR for a 60 ft. intersection (sec)</strong></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 = \( \frac{V}{2a} + \frac{(W + L)}{V} \), 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).

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

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

![Graph showing the relationship between queue size and discharge time for bike lanes and bike boxes.](image-url)
Queue Clearance Time by Queue Size
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**.
Acknowledgements

• OTREC
• Oregon DOT
• Research Project TAC
  – Gary Obery (ODOT)
  – Peter Koonce (PBOT)
  – Scott Beaird (Kittelson and Associates, Inc.)
  – Nick Fortey (FHWA)
  – Mark Joerger (ODOT)
• Project Team
  – Dr. Christopher Monsere
  – Dr. Miguel Figlioizzi
  – Sam R. Thompson
Thank You! Questions/Comments?

e-mail: pkirk@pdx.edu

...&...

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