11-8-2013

Why Doesn't That Traffic Signal Ever Turn Green? An Evaluation of Roadway Markings for Cyclists

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Peter Koonce  
Portland Bureau of Transportation

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Why Doesn’t That Traffic Signal Ever Turn Green?
An evaluation of roadway markings for cyclists

Presenter: Stefan Bussey
Coauthors: Dr. Christopher M. Monsere, Portland State University
Peter Koonce, Portland Bureau of Transportation
Portland State University Transportation Seminar
November 8, 2013
Presentation Overview

• The Basics of Vehicle Detection
• Issues Related to Detection and Bicycles
• History of the Stencil and Sign
• Research Question
• Existing Research
• Study Design
• Results
Where would you wait if driving a car? How about if riding a bike?
How Signalized Intersections with Detection Work

(a) Schematic design of loop detector design

(b) Physical representation of loop detectors
Inductive Loop Detectors and Bicycles

Bicycle Detection

Detection Positions

- **Poor Detector** (one rim = 1x)
- **OK Detector** (two rims = 2x)
- **Better Detection** (narrow 4x & 2x strips)
- **Best Detection** (broad + uniform ~ 2x)

Rim Detection Areas AKA “Sweet Spots”

Types of Loops:
- Type E Circular Loop (Dipole)
- Type A Square Loop (Dipole)
- Type Q Loop (Standard Quadrupole)
- Type D Loop (Diagonal Quadrupole)

Undetectable Positions

Source: [www.cyclistview.com/signaldetection/slide04.htm](http://www.cyclistview.com/signaldetection/slide04.htm)
Current Marking and Sign for Loop Detectors
History of Sign and Stencil
Sources: Richard Moeur and Ron Van Houten

Human Factors Research for R10-22 Sign

- No research found on roadway marking
- Both first recommended for use in the 1999 AASHTO’s guide for roadway design
- Adopted into the 2003 edition of the MUTCD
- No formal experimentation was required
Research Question:
Are the existing marking techniques specified in the MUTCD effective and is there a more effective alternative?
Existing Research


• No correct responses on the meaning of the bicycle detector symbol

• 68 participants
  ▪ 20 cyclists (Identified as a cyclist if reported riding more than 5 miles per week)
  ▪ 48 non-cyclists
Study Design

- In-Person and On-line Survey of Cyclists
- Observational Data Recorded by Cameras Before and After Markings Applied
- Three Test Cases

Case 1: Stencil Only
Case 2: Stencil and Sign
Case 3: “Green Backed” Stencil
Survey – Data Collection

- 227 Complete Responses
  - 81 in person, 94.2% response rate
    - 13.6% did not meet requirements to participate
  - 146 on-line, 16.1% response rate
- Distribution
  - High-density bike parking (on-line)
  - Portland Timbers games (on-line)
  - Providence Bridge Pedal (on-line)
  - Sunday Parkways (in person and on-line)
  - Portland’s Downtown Farmers’ Market (in person)
- An average of 4 minutes to complete

In Person

On-line

Please Help Us Better Understand How Intersection Design Affects Cyclists’ Behavior

This survey is part of a study on how intersection design affects cyclists’ behavior. The study is being conducted by an undergraduate Civil Engineering student at PSU. The survey takes about 2 minutes to complete. Your help is greatly appreciated.

Survey link: http://tinyurl.com/gonbike

QR Code for handheld devices (survey may not display correctly for some devices)

For more information contact Stefan Bussey at sibussey@pdx.edu

We are asking for your help with a study to understand how intersection design affects cyclists’ behavior. The project is being carried out by Portland State University (PSU).

The survey should only take 1–2 minutes to complete. You don’t have to participate, and you can skip any questions you don’t want to answer. Your responses will be kept completely confidential, and it won’t be possible to tell who said what in any reports. If you have any questions about the study, please contact Stefan Bussey (sibussey@pdx.edu).

This study has been reviewed and approved by PSU’s Human Subjects Research Review Committee. If you have any questions about your rights as a participant in this study, you may contact the Office of Research and Strategic Partnerships, Market Center Building Suite 620, Portland State University, (503) 725–4206.

This research can only be successful with the generous help of people like you. We hope you will enjoy the questionnaire and look forward to receiving your responses.

Do you agree to participate in the study?

- Yes
- No
Survey – Questions

- Demographic Information
- Stopping Position at Signalized Intersections (Randomly selected marking variation)
- Reason for Choosing Stopping Position
- Interpretation of Detector Symbol
- Interpretation of Blue Indicator Light (Research in Progress)
Video – Data Collection

- 302 hours of video recorded and reviewed
- 955 observations logged
  - 688 used in analysis
- Only questioned once by the police

Site Selection
- No existing marking or signage
- Visible loops
- Semi actuated signal operation
- Similar geometry and lane configurations
- Popular bike route

Collection Period
- Sunday – Tuesday
- 5:00 AM – 11:00 PM
# Video – Data Collection

<table>
<thead>
<tr>
<th>Variable</th>
<th>NE Dekum St. and NE MLK Blvd.- WB Approach</th>
<th>NE Ainsworth and NE MLK Blvd. - EB Approach</th>
<th>NE U.S. Grant Place and NE 33rd Ave, WB Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Width (ft)</td>
<td>20</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>Number of Travel Lanes</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Movements Allowed</td>
<td>Thru, Left, Right</td>
<td>Thru, Left, Right</td>
<td>Thru, Left Right</td>
</tr>
<tr>
<td>Loop Type</td>
<td>6’ Diameter Circle</td>
<td>6’ Diameter Circle</td>
<td>6’ Diameter Circle</td>
</tr>
<tr>
<td>Distance from Curb to Edge of Loop (ft)</td>
<td>10</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>
Video – Data Collection

Establishing Zones for Analysis

Example of Analysis in Progress

Plan View of Study Site
Survey – Results

“How Often Do You Ride a Bike?” N=227

4% Less Than 1 Day a Month
12% 1-3 Days a Month
19% 1-2 Days a Week
24% 3-4 Days a Week
41% 5 or More Days a Week

S. Bussey – 11/08/2013
Survey – Results

What is Your Age? N=225

18-25: 16%
26-39: 36%
40-65: 44%
66-74: 2%
Over 74: 1%
Survey – Results

“What Gender Do You Most Identify With?” N=225

- Male: 60%
- Female: 38%
- Prefer Not to Answer: 2%
Survey – Results

“You are approaching this intersection with a red light. Where would you stop your bike to wait for a green light to cross?” N=227
“Why Do You Wait There?” N=211

- To be Able to Step on the Curb
- Stay Out of the Way of Traffic
- Safety/Visibility
- Marked Spot
- Trigger the Signal
- Out of the Crosswalk
- In-line with Intended Direction of Travel

0'-5' From Curb, N=48
- 56%
- 40%

5'-10' From Curb, N=29
- 59%
- 17%
- 10%

10'-16' from Curb (Over Loop), N=9
- 22%
- 22%
- 22%
- 2%

Over Stencil, N=125
- 51%
- 6%
- 2%
- 1%
“Why Do You Wait There?” N=211

- Stay Out of the Way of Traffic
- Safety/Visibility

<table>
<thead>
<tr>
<th>Distance from Curb</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0'-5' From Curb, N=48</td>
<td>56%</td>
</tr>
<tr>
<td>5'-10' From Curb, N=29</td>
<td>59%</td>
</tr>
<tr>
<td>10'-16' from Curb (Over Loop), N=9</td>
<td>22%</td>
</tr>
<tr>
<td>Over Stencil, N=125</td>
<td>9%</td>
</tr>
</tbody>
</table>

Stay Out of the Way of Traffic

Safety/Visibility
“Why Do You Wait There?” N=211

- To be Able to Step on the Curb
- Out of the Crosswalk
- In-line with Intended Direction of Travel

- 0'-5' From Curb, N=48
- 5'-10' From Curb, N=29
- 10'-16' from Curb (Over Loop), N=9
- Over Stencil, N=125
“Why Do You Wait There?” N=211

- Marked Spot
- Trigger the Signal

<table>
<thead>
<tr>
<th>Distance from Curb</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0'-5' From Curb</td>
<td>48</td>
<td>17%</td>
</tr>
<tr>
<td>5'-10' From Curb</td>
<td>29</td>
<td>7%</td>
</tr>
<tr>
<td>10'-16' from Curb</td>
<td>9</td>
<td>11%</td>
</tr>
<tr>
<td>Over Stencil</td>
<td>125</td>
<td>31%</td>
</tr>
</tbody>
</table>
Survey – Results

53.2%  Stencil Only

58.7%  Stencil and Sign

58.3%  “Green Backed” Stencil

No significant difference in queuing position between three test cases
Survey – Results

45.4% - Wait Here to Trigger the Signal
33.9% - Bike Lane/Bike Route
11.5% - Recommended Waiting Location
6.5% - Don’t Know or No Answer
1.8% - Bikes Allowed Here
0.9% - Other

“As a cyclist, what does the symbol in the above picture mean?”
Video – Results

Analysis excludes observations in which:
• A vehicle arrives immediately after the cyclist
• The cyclist is riding with one or more other cyclists
• The cyclist violates the red indication
• The cyclist is riding on the sidewalk
• Other unusual circumstances

Example of an Excluded Observation
## Video – Results

Table 1: Percent of Cyclists Waiting Over Loop Detector Before and After Marking(s) Installed

<table>
<thead>
<tr>
<th></th>
<th>Stencil ( N_B = 51, N_A = 51 )</th>
<th>Stencil and Sign ( N_B = 92, N_A = 112 )</th>
<th>“Green Backed” Stencil ( N_B = 157, N_A = 225 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Stopping Over Loop Before</td>
<td>27.5%</td>
<td>16.3%</td>
<td>46.5%</td>
</tr>
<tr>
<td>% Stopping Over Loop After</td>
<td>37.3%</td>
<td>44.6%</td>
<td>58.2%</td>
</tr>
<tr>
<td>( \chi^2 )</td>
<td>3.71</td>
<td>67.37</td>
<td>15.28</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>0.157</td>
<td>0.000</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

\( N_B \) = Observations Before
\( N_A \) = Observations After
## Video – Results

Table 2: Percent of Cyclists Waiting Over Stencil Region Before and After Marking(s) Installed

(Only Includes Observations of Cyclists who Waited Over the Loop)

<table>
<thead>
<tr>
<th></th>
<th>Stencil, N_B = 14, N_A = 19</th>
<th>Stencil and Sign N_B = 15, N_A = 50</th>
<th>“Green Backed” Stencil, N_B = 73, N_A = 131</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Stopping Over Stencil Region Before</td>
<td>42.9%</td>
<td>40.0%</td>
<td>50.7%</td>
</tr>
<tr>
<td>% Stopping Over Stencil Region After</td>
<td>62.3%</td>
<td>78.0%</td>
<td>83.2%</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>3.20</td>
<td>30.08</td>
<td>55.43</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.074</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

N_B = Observations Before
N_A = Observations After
Survey Results vs. Video Results

Survey Results

• Self reported preferences
• May represent a best case for stencil use
• Highlight the importance placed on safety

Video Results

Stencil with R10-22 sign and “Green Backed” stencil produce a significant effect
Limitations of Study

- Only one field test for each case
- Intersections not uniform in stripping configuration
- “Green Backed” stencil installed in field did not match original design
- High number of regular cyclist in Portland may skew results
What You Can Do

- Read about the City of Portland’s Policy on bikes and detection: http://www.portlandoregon.gov/transportation/article/145110
- Call 503-823-SAFE or 823-CYCL
- Use the PDX Reporter App: http://www.portlandoregon.gov/bts/article/419527
- Share your knowledge!
Acknowledgements

Rob Burchfield
Rodger Geller
Mark Haines

Steve Cohn

Ron Van Houten

Richard Moeur
Questions?
Supplemental Slide – Installed Sign and Stencil
Supplemental Slide – Installed “Green Backed” Stencil
# Supplemental Slide – Site Selection

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Intersection</th>
<th>Approach</th>
<th>Comments</th>
<th>Edge of Loop to Curb (estimated)</th>
<th>Thru Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Prescott St and MLK Blvd</td>
<td>WB</td>
<td>No stencil, loops visible. T intersection</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>NE</td>
<td>47th Ave and Sandy Blvd</td>
<td>NB</td>
<td>Stencil illegible and badly worn. Loops are visible.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Ainsworth St and MLK Blvd</td>
<td>WB</td>
<td>No stencil, loops visible</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Vancouver Ave and Columbia Blvd</td>
<td>SB</td>
<td>No stencil, loops visible. Bike lane has no loop but extends to the stop bar.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>SW</td>
<td>30th Ave and B-H Hwy</td>
<td>SB</td>
<td>No stencil, loops visible</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Vancouver Ave and Rosa Parks Way</td>
<td>SB</td>
<td>No stencil, loops visible, bike lane with no loop. Push button nearby, no bike sign.</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>NE</td>
<td>47th Ave and Sandy Blvd</td>
<td>SB</td>
<td>No stencil, loops visible</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>30th Ave and Hawthorne Blvd</td>
<td>NB</td>
<td>No stencil, loops visible</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>27th Ave and Hawthorne Blvd</td>
<td>NB</td>
<td>No stencil, loops visible. Stencil on SB approach</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>SW</td>
<td>Sunset and Capitol Hwy</td>
<td>EB</td>
<td>No stencil, loops visible</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>69th Ave and Powell Blvd</td>
<td>NB</td>
<td>No stencil, loops visible</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>69th Ave and Powell Blvd</td>
<td>SB</td>
<td>No stencil, loops visible</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Killingsworth St and MLK Blvd</td>
<td>WB</td>
<td>No stencil, loops visible</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>52nd Ave and Powell Blvd</td>
<td>NB</td>
<td>No stencil, loops visible</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>112th Ave and Division St</td>
<td>NB</td>
<td>No stencil, loops visible</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>52nd Ave and Flavel St</td>
<td>WB</td>
<td>No stencil, loops visible. T intersection</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>30th Ave and Hawthorne Blvd</td>
<td>SB</td>
<td>No stencil, no loops visible</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>SW</td>
<td>35th Ave and Multnomah Blvd</td>
<td>NB</td>
<td>No stencil, loops visible. Stencil on SB approach</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>
### Supplemental Slide – Chi Squared Analysis

#### Chi Square Test of Proportions Using Filtered Observations, All Zones - 33rd and Grant (Alternative Stencil)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Observations After</th>
<th>Observations Before</th>
<th>Percent of Observations After</th>
<th>Percent of Observations Before</th>
<th>Expected Value After</th>
<th>Chi Squared Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+2</td>
<td>65</td>
<td>65</td>
<td>28.9%</td>
<td>41.4%</td>
<td>93.2</td>
<td>8.51</td>
</tr>
<tr>
<td>3</td>
<td>131</td>
<td>73</td>
<td>58.2%</td>
<td>46.5%</td>
<td>104.6</td>
<td>6.65</td>
</tr>
<tr>
<td>4+5+6</td>
<td>29</td>
<td>19</td>
<td>12.9%</td>
<td>12.1%</td>
<td>27.2</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>225</td>
<td>157</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Chi Squared Value</td>
<td></td>
<td></td>
<td></td>
<td>15.28</td>
<td></td>
</tr>
</tbody>
</table>

*α, df=2*

#### Chi Square Test of Proportions Using Filtered Observations, Loop Zone Only - 33rd and Grant (Alternative Stencil)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Observations After</th>
<th>Observations Before</th>
<th>Percent of Observations After</th>
<th>Percent of Observations Before</th>
<th>Expected Value After</th>
<th>Chi Squared Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>109</td>
<td>37</td>
<td>83.2%</td>
<td>50.7%</td>
<td>66.40</td>
<td>27.34</td>
</tr>
<tr>
<td>3.2+3.3</td>
<td>22</td>
<td>36</td>
<td>16.8%</td>
<td>49.3%</td>
<td>64.60</td>
<td>28.09</td>
</tr>
<tr>
<td></td>
<td>131</td>
<td>73</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Chi Squared Value</td>
<td></td>
<td></td>
<td></td>
<td>55.43</td>
<td></td>
</tr>
</tbody>
</table>

*α, df=1*

*0.00000*
### Supplemental Slide – Chi Squared Analysis

#### Chi Square Test of Proportions Using Filtered Observations, All Zones - Ainsworth and MLK (Stencil and Sign)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Observations After</th>
<th>Observations Before</th>
<th>Percent of Observations After</th>
<th>Percent of Observations Before</th>
<th>Expected Value After</th>
<th>Chi Squared Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>51</td>
<td>68</td>
<td>45.5%</td>
<td>73.9%</td>
<td>82.8</td>
<td>12.20</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>15</td>
<td>44.6%</td>
<td>16.3%</td>
<td>18.3</td>
<td>55.17</td>
</tr>
<tr>
<td>4+5</td>
<td>11</td>
<td>9</td>
<td>9.8%</td>
<td>9.8%</td>
<td>11.0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>112</td>
<td>92</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Chi Squared Value 67.37
\( \alpha, df=2 \)

#### Chi Square Test of Proportions Using Filtered Observations, Loop Zone Only - Ainsworth and MLK (Stencil and Sign)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Observations After</th>
<th>Observations Before</th>
<th>Percent of Observations After</th>
<th>Percent of Observations Before</th>
<th>Expected Value After</th>
<th>Chi Squared Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>39</td>
<td>6</td>
<td>78.0%</td>
<td>40.0%</td>
<td>20.00</td>
<td>18.05</td>
</tr>
<tr>
<td>2.2+2.3</td>
<td>11</td>
<td>9</td>
<td>22.0%</td>
<td>60.0%</td>
<td>30.00</td>
<td>12.03</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>15</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Chi Squared Value 30.08
\( \alpha, df=1 \)

\( \text{Chi Squared Value} = 67.37 \) at \( \alpha, df=2 \)

\( \text{Chi Squared Value} = 30.08 \) at \( \alpha, df=1 \)
## Supplemental Slide – Chi Squared Analysis

### Chi Square Test of Proportions Using Filtered Observations, All Zones - Dekum and MLK (Stencil Only)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Observations After</th>
<th>Observations Before</th>
<th>Percent of Observations After</th>
<th>Percent of Observations Before</th>
<th>Expected Value After</th>
<th>Chi Squared Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+2</td>
<td>24</td>
<td>24</td>
<td>47.1%</td>
<td>47.1%</td>
<td>24.0</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>14</td>
<td>37.3%</td>
<td>27.5%</td>
<td>14.0</td>
<td>1.79</td>
</tr>
<tr>
<td>4+5+6</td>
<td>8</td>
<td>13</td>
<td>15.7%</td>
<td>25.5%</td>
<td>13.0</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>51</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Chi Squared Value**: 3.71

\( \alpha, df=2 \)

\( 0.157 \)

### Chi Square Test of Proportions Using Filtered Observations, Loop Zone Only - Dekum and MLK (Stencil Only)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Observations After</th>
<th>Observations Before</th>
<th>Percent of Observations After</th>
<th>Percent of Observations Before</th>
<th>Expected Value After</th>
<th>Chi Squared Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>12</td>
<td>6</td>
<td>63.2%</td>
<td>42.9%</td>
<td>8.14</td>
<td>1.83</td>
</tr>
<tr>
<td>3.2+3.3</td>
<td>7</td>
<td>8</td>
<td>36.8%</td>
<td>57.1%</td>
<td>10.86</td>
<td>1.37</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>14</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Chi Squared Value**: 3.20

\( \alpha, df=1 \)

\( 0.074 \)