AN ASSESSMENT OF BICYCLIST BEHAVIOR AT TRAFFIC SIGNALS WITH A DETECTOR CONFIRMATION FEEDBACK DEVICE

Jesse Boudart, E.I.*
Kittelson & Associates, Inc.
610 SW Alder Street, Suite 700
Portland, OR 97205
Email: jboudart@kittelson.com

Ryan Liu
Kittelson & Associates, Inc.
610 SW Alder Street, Suite 700
Portland, OR 97205
Email: rliu@kittelson.com

Peter Koonce, P. E.
Portland Bureau of Transportation
1120 SW 5th Avenue, Room 800
Portland, OR 97204
Email: peter.koonce@portlandoregon.gov

Lisa Okimoto
Portland Bureau of Transportation
1120 SW 5th Avenue, Room 800
Portland, OR 97204
Email: lisa.okimoto@portlandoregon.gov

July 31, 2014

Submitted for Presentation:
95th Annual Meeting of the Transportation Research Board
Washington, DC
January 11-15, 2015

Word Count: 3,471 + 2 Tables (500 Words) + 5 Figures (1,250 Words) = 5,221 Words
Abstract: 249 Words

* Corresponding Author
ABSTRACT

Bicycling is increasing in North America and therefore intersections have been modified to better accommodate these new cyclists. However, the increasing demand of cycling is outpacing the supply of high quality cycling markings, signing, signals, and general infrastructure at intersections. For example, recent research indicates more than 50% of bicyclists do not understand that the 9C-7 bicycle stencil symbol indicates the optimal waiting position for a cyclist to call a green light. Subsequently, people on bikes may run red lights because they do not understand the feedback of a 9C-7 pavement marking. This cycling infrastructure shortcoming illustrates the need to study how new roadway information may impact user behavior and traffic signal compliance. This research documents the impacts of an active feedback device on cyclist behavior in an effort to improve the cycling experience for the increasing number of cyclists.

A blue light feedback device was installed at a signalized intersection approach and its impact on bicyclist behavior, indicating that a statistically significant increase of people on bikes used the 9C-7 marking instead of the existing bicycle push button after installation of the blue light feedback device and especially after a sandwich board sign was installed describing the purpose of the blue light. These results indicate a blue light feedback device (accompanied with bicycle detection and the standard marking) could be used effectively in lieu of bicycle push buttons. Also, the impact of the blue light feedback device on bicyclist compliance with traffic signals (red light runners) was negligible.

INTRODUCTION AND MOTIVATION

Bicycling rates in North America have been increasing (I) and have become an area of interest for traffic engineering practitioners. To further encourage this growth in cycling, bicycle specific facilities have been constructed. Also, intersections have been retrofitted to better accommodate cyclists, such as changing the sensitivity of the inductive loop detectors to detect small metal objects such as bicycles. Since cyclists can be detected at intersections like automobiles, the location of the loop detectors may be in the middle of the road contrary to the cyclists path which is typically curb tight (2, 3). This detection location is problematic for cyclists because positioning the bicycle and the person in the middle of the road may be uncomfortable for inexperienced cyclists. Therefore, if these cyclists do not position themselves to become detected, they may not get a green light, and will either have to wait until a vehicle calls a green light, or may run the red light because of the realization that they will not get a green light. So to better accommodate cyclists at intersections, traffic engineering practitioners have been testing tools providing better information for roadway users.

For example, bicycle-specific traffic signals have been introduced to specifically control cyclists' movements. These bicycle traffic signals are one such tool to accommodate the increasing rates of cycling in the United States. However, bicycle signals cannot be installed everywhere due to resource constraints. Without a bicycle signal, bicyclists have to share the typical traffic signals to get a green light. While there are pavement markings and signs indicating how to get a green light (becoming detected), they may not be entirely understood.

One contributing factor to cyclists’ misunderstanding of traffic signal detection is the lack of consistency of application of marking and signage that is used. The City of Portland and many other agencies utilize the standard Manual on Uniform Traffic Control Devices (MUTCD) 9C-7 bicycle detector symbol, but not consistently. Recent research suggests approximately half of the
roadway users do not understand how to be detected on a bicycle (4). The MUTCD R10-22 sign helps explain the purpose of the 9C-7 marking, but when the markings are worn away, the sign becomes meaningless to the cyclist. Figure 1 provides illustrations of the 9C-7 pavement marking and R10-22 sign. Therefore, these new cyclists on the road are lacking basic information on how to receive a green indication and could be discouraged from cycling or may disregard the traffic control device entirely.

LITERATURE REVIEW

The bicyclist intersection experience is likely related to the geometric design of the intersection itself. Danila and Fink discussed how a large range of users should be accommodated including utilitarian cyclists, not simply recreational cyclists (5). North American researchers have also adequately studied the impact of bicycle improvements on people’s behavior. Researchers have studied the impact of bike boxes (6, 7, 8), which illustrates an improved perception of safety by people on bikes. Furth et al., has performed research on mitigating the “right hook” conflict at signalized intersections to improve the intersection
experience (and safety) of people on bikes through intersections (9). Steinman et al., studied
signalized intersection characteristics and their relationship to bicycle delay (10). This subject is
particularly important to research in this study, as bicycle delay is related to the intersection
delay experience. The CROW manual documents the importance of bicycle delay to an intersection
operating sufficiently for bicyclists (11).

While traffic signals have been in use for over a century in North America, bicycle
specific traffic signals are relatively new (12). Therefore, people on bikes may not understand
their operations completely which is why the 9C-7 pavement marking and R10-22 sign has been
recently introduced in the Manual on Uniform Traffic Control Devices (MUTCD). Bussey et al.,
has performed research on people’s understanding of how to be detected at intersections,
people’s understanding of the 9C-7 pavement marking, and other user behavior at signalized
intersections (4). His research indicates more than half of the roadway users do not understand
the 9C-7 pavement marking sign, which could lead toward poor intersection operations and
ultimately traffic signal non-compliance by people on bikes.

Bicycle compliance of traffic signals has been studied, but there is sparse research on the
subject. Washington DC has studied their recently installed protected bicycle lanes and bicycle
compliance of signalized intersections (13), which is an auxiliary research motivation of this
study. Other research on bicycle signal compliance related to the user’s perception of risk has
also been studied (14, 15). However, there has been no research on bicycle traffic signal
feedback devices on the bicycle experience, signalized intersections, and traffic signal
compliance.
METHODOLOGY & VIDEO DATA COLLECTION

To evaluate the impact of the feedback device and sign, three different time periods of video data were collected at the study intersection of SW Moody Avenue/SW Sheridan Street in Portland, Oregon. Table 1 illustrates the type of device or sign installed, the date of video data collection, weather conditions, and the Hawthorne bridge bicycle counts, which is included as a bicycle count index.

Table 1: Dates of Video Data Collection, Weather Conditions, and Hawthorne Bridge Bicycle Counts

<table>
<thead>
<tr>
<th>Information</th>
<th>Before</th>
<th>After Blue Light Feedback Device</th>
<th>After Blue Light Informational Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Device Installed</td>
<td>-</td>
<td>May 13, 2014</td>
<td>June 9, 2014</td>
</tr>
<tr>
<td>Date of Video Data Collected</td>
<td>May 1, 2014</td>
<td>May 21, 2014</td>
<td>June 12, 2014</td>
</tr>
<tr>
<td>Weather (Conditions/Precipitation, Minimum Temperature, Maximum Temperature)</td>
<td>Sunny, 53°F, 89°F</td>
<td>Sunny, 51°F, 73°F</td>
<td>Rainy (0.02 inches of precipitation), 57°F, 66°F</td>
</tr>
<tr>
<td>Hawthorne Bicycle Counts <a href="http://portland-hawthorne-bridge.visio-tools.com/">http://portland-hawthorne-bridge.visio-tools.com/</a></td>
<td>7,788</td>
<td>7,721</td>
<td>5,759</td>
</tr>
</tbody>
</table>

Video data was collected from 7:30 a.m. to 6:00 p.m. on all days. The blue light feedback device was installed on May 13th, to allow a week-long “learning period” for bicyclists to notice and understand the detector feedback blue light. The informational sign was installed on June 9th to allow bicyclists to read and understand the information for how to use the traffic signal and call for green indication.

Figure 2 illustrates an overhead view of the study intersection of SW Moody Avenue/SW Sheridan Street in Portland, Oregon. The SW Moody Avenue/SW Sheridan Street intersection traffic signal operates uncoordinated and in ‘free’ mode, meaning the demand of vehicles, pedestrians, bicycles, and street cars ultimately determine the length of green for all movements with maximum parameters.

The northbound (NB) cyclists utilize the bicycle signal on a dedicated bicycle phase and diagonally cross the intersection in the northeast direction. The NB cyclists originate from a bi-directional cycle path on the west side of SW Moody Avenue and then arrive at the bicycle signal. Figure 3 also illustrates other key activity areas of the SW Moody Avenue/SW Sheridan Street intersection including: the bicycle push button, bicycle stencil and the NB bicycle signal. Note that there was no accompanying R10-22 sign to control for the effectiveness of the blue light feedback device. NB bicyclists can call a green phase for the dedicated bicycle signal movement in two ways: either utilizing the bicycle push button or placing their bicycle over the bicycle stencil, where a loop detector is embedded in the pavement underneath and calls the green bicycle signal phase. Importantly, a bicyclist will not actuate the loop detector if standing next to the bicycle push button. Therefore, the bicyclist has a choice to decide whether to actuate their green phase either by the bicyclist push button, the bicycle stencil, or both.
Figure 2: Overhead View of SW Moody Avenue/SW Sheridan Street
NB bicyclist behaviors were observed, recorded and organized specifically according to the first bicyclist’s behavior. Other behaviors by the second bicyclist were disregarded, except for bicycle non-compliance (running the red light), which was assumed to be an independent decision. Only the first bicyclist’s behavior was noted to minimize bias which may occur when cyclists arrive in groups as their behaviors may not be independent behavioral decisions. The quantity, percentage, and statistical significance of the detector feedback blue light are described in the findings section.

The blue light feedback device used in this instance is a blue light installed next to the red bicycle signal face, shown in Figure 4. As shown in Figure 4, the blue light turns on when a person positions their bicycle on top of the bicycle stencil (9C-7 Marking) on the pavement, which calls a green light. It should be noted this intersection does not include a supplemental R10-22 sign. Figure 5 illustrates the location of the blue light information sign installed next to the 9C-7 marking and also includes the information provided on the back side of the sign.
Figure 4: Blue light Feedback Device
FINDINGS

Based on the three days of video data and quantified behaviors, Table 2 illustrates the quantity and relative proportions of behaviors from ‘before’ condition, ‘after’ the blue light installation and ‘after’ the blue light informational sign was installed.
Table 2: Bicyclist Behavior Observations from 7:30 a.m. to 6:00 p.m

<table>
<thead>
<tr>
<th>Observation Type</th>
<th>Before Blue Light Installation</th>
<th>Percentage of Behavior Observations</th>
<th>After Blue Light Installation</th>
<th>Percentage of Behavior Observations</th>
<th>After Blue Light Informational Sign Installation</th>
<th>Percentage of Behavior Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Count of NB People on Bikes</td>
<td>694</td>
<td>-</td>
<td>658</td>
<td>-</td>
<td>454</td>
<td>-</td>
</tr>
<tr>
<td>Total Number of Behavior Observations</td>
<td>369</td>
<td>-</td>
<td>332</td>
<td>-</td>
<td>260</td>
<td>-</td>
</tr>
<tr>
<td>User Pushes Button Only and Wait Next to Button</td>
<td>251</td>
<td>68%</td>
<td>200</td>
<td>60%</td>
<td>107</td>
<td>41%</td>
</tr>
<tr>
<td>User Pushes Button and Moves to Stencil</td>
<td>13</td>
<td>4%</td>
<td>17</td>
<td>5%</td>
<td>13</td>
<td>5%</td>
</tr>
<tr>
<td>User Waits on Stencil Only</td>
<td>54</td>
<td>15%</td>
<td>68</td>
<td>20%</td>
<td>127</td>
<td>49%</td>
</tr>
<tr>
<td>Number of People who Did Not Comply with Bike Signal (Ran Red Light)</td>
<td>51</td>
<td>13.8%</td>
<td>47</td>
<td>14.2%</td>
<td>37</td>
<td>14.2%</td>
</tr>
<tr>
<td>Number of People who Did Not Comply with Bike Signal (Ran Red Light), out of total NB cyclists</td>
<td>51</td>
<td>7.3%</td>
<td>47</td>
<td>7.1%</td>
<td>37</td>
<td>8.1%</td>
</tr>
</tbody>
</table>

As shown in Table 2, the majority of NB bicycle traffic used the push button for the first two video data collections. The percentage of red light runners was illustrated in two different ways: one with the percentage of behavior observations and the other as a measure of total NB bicyclists, which is a more common way to evaluate traffic signal compliance. In total, over 91.9% of total NB cyclists complied with the bicycle signal.

A chi squared test with three degrees of freedom was used to test the statistical significance of the blue light feedback device’s effect on bicyclist behavior at this intersection. When comparing the ‘before’ and ‘after blue light feedback device’ datasets with three degrees of freedom (all variables), the change of behavior was statistically significant with an 89.5% confidence interval. These results indicate the blue light feedback device had an impact on how people on bikes prefer to become detected, but not a statistically strong impact.

When the ‘after blue light installation’ and ‘after the blue light informational sign’ datasets are compared, results indicate the change of behavior is statistically significant with a 100.0% confidence interval. The proportion of people on bikes ‘waiting on the stencil only’ increased significantly while the number of people pushing the button has decreased. The installation of the blue light as well as the blue light informational sign has significantly changed the behavior of users from pushing the button to only waiting on the 9C-7 marking.

An auxiliary motivation of this study was to understand whether red light compliance would change from increased user feedback; however, results indicate no statistically significant difference in the number of people on bikes running red lights.

CONCLUSION

Before installation of the blue light feedback device at SW Moody Road/SW Sheridan Street, people on bikes primarily used the push button to receive a green light. However, the installation of the detector feedback blue light and blue light informational sign had a statistically significant impact to decrease the use of a push button to call a green light. With a wider use of the blue light feedback device at other signalized intersections, the feedback device could be used to potentially forgo the installation of a bicycle push button and instead to use a loop detector and 9C-7 marking. Omitting a bicycle push button could reduce costs and allow for more flexible intersection design while maintaining optimal bicycle intersection operations. Also, the amount of total time for a single person to cross the street could be reduced because bicycle
push buttons are often connected with the pedestrian signals, which are timed for a slower moving pedestrian. In summary, providing another option of feedback to become detected at an intersection by way of a blue light feedback device, the intersection experience may be improved for people on bikes.

FURTHER STUDY

To determine whether people had a better intersection experience because of a blue light feedback device, an intercept study on perceptions would be very useful. As indicated in prior research with pavement markings, many users did not understand the meaning of the 9C-7 marking. Therefore, conducting a bicyclist intercept survey for intersections with blue light feedback devices would be helpful to determine what users perceive of the device.

Bicyclist compliance with the traffic signals at this study intersection was over 92.7% of all NB bicyclists with the detector feedback blue light having negligible impact on compliance at the study intersection. The authors postulate that information on detection is still not as clear as possible which may be impacting bicycle compliance with signalized intersections. Therefore, there are a number of different studies which can be performed to understand why bicyclists do not comply with traffic signals. 1) a general behavioral intercept or mail-in study on why bicyclists do not comply with traffic signals can be conducted. 2) The available pavement markings and signs may not provide the roadway user enough confidence that they will become detected. Therefore, variations in the 9C-7 marking and R10-22 signs can be designed and tested to enhance user understanding of detection signs. 3) Variations on the blue light feedback device could be tested. For example, if the blue light device had a timer until a green light, then the enhanced feedback information may encourage a roadway user to wait, thereby increasing traffic signal compliance.

Also, bicycle compliance may be a function of a number of different intersection and environmental factors such as intersection size (crossing distance), intersection complexity, sight distance, cross traffic volume, average waiting time, etc. Comparing SW Moody Avenue/SW Sheridan Street to other relatively high bicycle volume intersections in Portland may reveal the bicyclist signal compliance depending on intersection characteristics. With more research on bicycle signal compliance and intersection geometry, intersections could be designed better to increase bicyclist compliance of traffic control devices.

ACKNOWLEDGEMENTS

The authors would like to extend thanks to Ryan Liu and Lisa Okimoto who reduced the observational video data for installations of the blue light feedback device.
REFERENCES