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THE EFFECT OF THE BICYCLE DETECTOR SYMBOL AND R10-22 SIGN ON CYCLIST
QUEUING POSITION AT SIGNALIZED INTERSECTIONS

BY

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A thesis submitted in partial fulfillment
of the requirement for the degree of

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The Effect of the Bicycle Detector Symbol and R10-22 Sign on Cyclist Queuing Position at Signalized Intersections

ABSTRACT

The Manual of Traffic Control Devices (MUTCD) includes a roadway marking and accompanying explanatory sign which may be installed on public roads to help guide cyclists position themselves over detection at actuated traffic signals. While adopted into the MUTCD in 2003, little research is available on the effectiveness of the marking and sign. This study evaluates the influence that the roadway marking, roadway marking installed in conjunction with the explanatory sign, and an alternative detector marking comprised of the MUTCD marking installed over a one foot by two feet green rectangle, have on cyclist queuing position at actuated, signalized intersections. Over 300 hours of before and after video data, resulting in 688 observations, indicate that while all three marking options influence cyclist stopping position, only 23.5% of cyclists wait over the MUTCD roadway marking when installed alone. This improves to 34.8% with the addition of the explanatory sign and 48.4% when the marking is applied over the green rectangle.

An accompanying survey of 227 cyclists indicates that 45.4% of cyclists understand the roadway marking is meant to show where cyclist should wait in order to be detected. An additional 11.5% understand that the marking indicates the recommended waiting location for cyclist but not that it is for the purpose of detection. Survey respondents who said they preferred to wait closer to the curb (a position which usually prevents them from being over detection) stated that they chose to do so primarily for concerns about safety/visibility and to stay out of the way of motorized vehicle traffic.

INTRODUCTION

Low stress routes for cyclists consist of slower speed and low volume collector streets that provide a more comfortable and safe environment for riding a bike (1). Where these routes cross busier arterials, signalized traffic control may be required. Due to lower vehicle volumes on the intersecting collector, these intersections often employ actuated signal timing with vehicle detection used to place calls to the signal controller for the minor approach. One common form of this detection is an inductive loop placed in the pavement at, and upstream of, the stop bar.

Inductive loop detectors (often referred to as loops) take a variety of shapes and sizes but are most commonly square, rectangular, or circular in geometry. Circular loops are formed with six foot diameters, square loops with six foot long sides, and rectangular loops are usually six feet wide and vary in length depending on the needed detection zone (2). Loops are typically centered in the motorized vehicle travel lane and the detection zone roughly spans the area enclosed by the loop (3).

Large vehicles such as cars and trucks are usually detected by loops; however, cyclists are more difficult to detect (2). This is due the higher level of sensitivity needed to detect the smaller mass of bicycles and that bike riders positioned in the middle of the loop may not be sensed (2). Also, the installation of loops in the center of the vehicle lane often does not coincide with the path of travel taken by cyclists (2). This may be in part due to vehicle code in some states (including Oregon where this study was conducted) that requires cyclists to travel as close to the right curb as is reasonably safe (Oregon Revised Statute 814.430).

To facilitate cyclists' stopping in locations where they will be detected, the Manual on Traffic Control Devices (MUTCD) includes a road marking (see Figure 1a) that may be placed over the loop where cyclists will be consistently detected. Also included in the MUTCD is an explanatory sign that may be installed at intersections with the road marking (see Figure 1b).

a) 9C-05 Bicycle Detector Symbol

b) R10-22 Sign

FIGURE 1: MUTCD Approved Marking and Sign

As municipalities seek to increase the number of cyclists on the road and states adopt complete street policies, it is necessary to determine if the existing loop marking and sign are understood and utilized by cyclists. While increasing the number of cyclists involves many elements, one influence on a person's decision to ride a bike is the time it takes them to reach his destination (4). Failure to receive a green indication due to improper positioning over loops can add to this travel time and may discourage cycling. In California, determining how to best serve cyclists takes on even greater importance. This is due to legislation requiring that the road network provide equal service to motorized and non-motorized vehicles (5).

This study evaluates cyclists' understanding and use of the bicycle detector symbol and R10-22 sign as described in the MUTCD. An alternative marking option, comprised of the MUTCD road marking installed over a rectangular green background, is also examined. Three installations were tested: the MUTCD bicycle detector symbol installed alone, the MUTCD bicycle detector symbol installed with an accompanying R10-22 sign, and the MUTCD bicycle detector symbol installed over a one foot by two foot green rectangle. The evaluation of each installation includes approximately 100 hours of before and after video data with a minimum of 102 observations of cyclists' stopping positions. A total of 688 before and after observations of stopping position were logged across all three test installations. Video data are supplemented with a survey completed by 227 cyclists. Survey questions include comprehension of the bicycle detection symbol, self-reported stopping position at signalized intersections, reasons for choosing the reported stopping position and demographic information.

While this study is limited to one field test per installation, it includes a larger number of observations and incorporates both objective video data and self-reported survey data from cyclists. The combination of quantitative and qualitative data provides a more complete understanding of cyclist comprehension and use of the bicycle detector symbol by providing context to why cyclists choose to wait at specific locations at signalized intersections. There is minimal existing research on this topic. The remainder of this paper begins with a presentation of prior research followed by a description of the study sites, discussions on the data collection methodologies utilized, results and a concluding summary. Both the

methodologies and results sections are broken into two subcategories; one for video data and another for survey data.

PRIOR RESEARCH

The bicycle detector symbol and R10-22 sign are believed to have been developed by the California Department of Transportation (Caltrans) in the late 1990's (Richard Moeur, unpublished data, personal communication, May 30, 2013). They were first recommended for use by the American Association of State Highway Officials' (AASHTO) 1999 guide for roadway design and adopted into the 2003 edition of the MUTCD. Adoption of both the road marking and sign into the MUTCD was based on recommendations by the National Committee on Uniform Traffic Control Devices (NCUTCD) and the Federal Highway Administration did not require a formal experiment for adoption (Kevin Dunn, unpublished data, personal communication, May 31, 2013). While a human-factors experiment was conducted to determine which sign design was most effective, no research was found on the effectiveness of the roadway marking prior to 2013 (Ron Van Houten, unpublished data, personal communication, May 31, 2013).

A September 2013 report written by Department of Psychology at Florida State University for the Florida Department of Transportation evaluated comprehension of 17 of bicycle related signs and roadway markings, including the bicycle detector symbol (6). Participants were recruited from the Tallahassee FL area, 17 of which were identified as cyclists (6). The study identified a cyclist as someone who rode a bicycle five or more miles a week. Of the 68 participants in the study, none correctly identified the meaning of the bike detector roadway symbol (6). While comprehension of the bicycle detector symbol was low, study authors acknowledge that this may in part be due to its infrequent use in the Tallahassee area and the lack of context given during the sign knowledge test (6).

Precedence exists for the evaluation of roadway signs and markings through before and after studies and surveys of roadway users (7). A 2008 pooled fund study evaluating driver comprehension of experimental sign symbols included an intercept survey of drivers at a local shopping mall (7). While the pooled funds study focused on determining sign recognition distance and road user comprehension, this study tests cyclist comprehension and the effect the bicycle detector symbol has on cyclists' queuing position.

STUDY SITES

Three study sites in Portland, OR were chosen from a preliminary inventory of approaches at 27 signalized intersections. All approaches initially considered operated with actuated-based signal timing, used inductive loops for vehicle detection, were absent of any road markings or signage to indicate where cyclists should wait over the loop in order to receive a green indication and were popular bike routes. From this inventory, the three approaches with the most similar lane configuration, loop type, and distance from the curb to the edge of the loop were selected. These were the westbound approach of NE Dekum St. at NE Martin Luther King Blvd., the eastbound approach of NE Ainsworth St. at NE Martin Luther King Blvd., and the westbound approach of NE U.S. Grant Pl. at NE 33rd Ave.

All three approaches have a single vehicle travel lane with permissive left turns and utilize six-foot diameter inductive loop detectors. The approaches selected for the intersections of NE Dekum St. at NE MLK Blvd. and NE U.S. Grant Pl. at NE 33rd Ave both permit curbside parking, are 20-feet wide from the curb to centerline and have a distance of 10-feet between the curb and the edge of the loop detector. Curbside parking is prohibited along the approach selected for the intersection of NE Ainsworth St. at NE MLK Blvd., is 14-feet wide from the curb to centerline, and there are 4-feet between the curb and edge of the loop detector. Roadway characteristics of each site are summarized in Table 1.

TABLE 1: Characteristics of Study Sites

Variable	NE Dekum St. at NE MLK Blvd. - WB Approach	NE Ainsworth at NE MLK Blvd. - EB Approach	NE U.S. Grant Place at NE 33 rd Ave - WB Approach
Distance from Curb to Centerline	20'	14'	20'
Number of Travel Lanes	1	1	1
Movements Allowed	Thru, Left, Right	Thru, Left, Right	Thru, Left Right
Loop Type	6' Diameter Circle	6' Diameter Circle	6' Diameter Circle
Distance from Curb to Edge of Loop (ft)	10'	4'	10'

METHODOLOGY

Data were collected through two methods; recorded video of cyclists' behavior at actuated intersections and a survey of road users administered both in person and online.

Video Data Collection

A total of 302 hours of before and after video were recorded across the three study sites, resulting in 688 observations of cyclist queuing position during a red signal indication. Portable video equipment was installed at each intersection to collect data on cyclists using each location. Initial observations were made of each study site without roadway markings or signage present to indicate where a cyclist should wait over a loop detector in order to receive a green.

Once initial video data were recorded, modifications to each study site were made to help cyclists position themselves over the loop detector in order to receive a green indication. Each study site had a different modification made as described in Table 2 below. Photographs of each intersection after modification are included in Figure 2.

TABLE 2: Modifications Made to Study Sites After Initial Observation Period

NE Dekum St. and NE MLK Blvd. - WB Approach	NE Ainsworth and NE MLK Blvd. - EB Approach	NE U.S. Grant Place and NE 33rd Ave - WB Approach
Loop Stencil Added	Loop Stencil and R10-22 Sign Added	Loop Stencil over Green Background Added

Video observations were made over three consecutive days beginning before 7:00 AM on Sunday mornings and terminating on Tuesday evenings. Equipment was programmed to record from 5:00 AM to 11:00 PM but recording on Tuesdays terminated prior to 11:00 PM due to limitations in battery capacity. Each observation period resulted in between 46 and 51 hours of video. Days of the week and recording times were chosen to capture the broadest sample of cyclists. This may include recreational riders likely to ride on weekends to bike commuters who may be more likely to ride on week days.

Before installing video equipment, the approach being recorded was divided into stopping zones that cyclists would be placed in during video reduction. The study approaches for NE Dekum St. at NE MLK Blvd. and NE U.S. Grant Pl. at NE 33rd Ave. used the same zone configuration while zones for the study approach at NE Ainsworth St. and NE MLK Blvd. were different due to the smaller approach width. The zones for the three study locations are listed in Table 3 and further illustrated in Figure 3a which depicts a plan view of the zones for the intersection of NE Dekum St. at MLK Blvd.

TABLE 3: Zone Locations by Study Site

Zone	NE Dekum St. at NE MLK Blvd. - WB Approach	NE Ainsworth St. at NE MLK Blvd. - EB Approach	NE U.S. Grant Pl. at NE 33rd Ave. - WB Approach
1	Curb to 5-feet off the curb	Curb to edge of Loop (4-feet from curb)	Curb to 5-feet off the curb
2	5-feet from curb to edge of loop (10-feet off the curb)	Loop (6-feet in diameter)	5-feet from curb to edge of loop (10-feet off the curb)
3	Loop (6-feet in diameter)	Edge of loop to centerline of road (3-feet)	Loop (6-feet in diameter)
4	Edge of loop to centerline of road. (4-feet)	Crosswalk	Edge of loop to centerline of road. (4-feet)
5	Crosswalk	Sidewalk	Crosswalk
6	Sidewalk	Not Applicable	Sidewalk

NE Ainsworth St. and MLK Blvd. After Modification – Bicycle Detector Symbol

NE Dekum St. and MLK Blvd. After Modification – Bicycle Detector Symbol and R10-22 Sign

NE U.S. Grant Pl. and NE 33rd Ave. After Modification Bicycle Detector Symbol with Green Background

FIGURE 2: Pictures of Intersections after Installation of Tested Marking

a) Plan View of Stopping Zones for NE Dekum St. at NE MLK Blvd.

b) Example of Video Analysis

FIGURE 3: Stopping Zones for NE Dekum St. and NE MLK Blvd.

During the installation of video equipment, the stopping zones were created using a tape measure and placing masking tape on the pavement. Once the camera angle and view was finalized for the observation period, the tape was removed from the roadway.

Before beginning video data reduction, these zones were reestablished by using a dry erase marker to trace the taped regions onto a transparency placed over the monitor screen (see Figure 3b). This ensured consistent classification of stopping position throughout video reduction. The stopping zone was determined by where the wheels of the stopped bike met the pavement. The location, date, time, stopping zone, if the cyclist appeared to use the pedestrian push button, if the cyclist violated the red signal indication, the arrival of a motorized vehicle after the cyclist, group size, cyclist's travel direction and any unusual circumstances such as the presence of a dog with the cyclist were recorded.

Survey Data Collection

The objectives of the survey instrument were to assess road users' comprehension of existing signing and marking methods used to indicate where cyclist should wait over a detector, determine how and why cyclists choose where to wait for a green indication at a signalized intersection, and collect demographic information about the survey sample. The survey instrument was administered both as an in-person intercept survey and a self-administered online survey. A total of 227 surveys were completed consisting of 81 in person and 146 online responses. In-person surveys had a response rate of 94.2% (81 responses for 86 requests) while the online administered survey had a response rate of 16.1% (146 responses for 911 postcards).

The in-person survey was administered on a hand-held electronic device using the droidSURVEY mobile data collection application. Potential participants were approached by survey administrators and asked if they were willing to participate in the study. Requirements for participation included being over the age of eighteen and riding a bike at least once a year. Participants that did not meet these requirements were not administered the survey.

Questions were read to each participant by the survey administrator and recorded by the administrator using the survey data collection application on the electronic device. Answers to questions were both categorical and open ended. Categorical answers were all read to each participant and the participant

identified which category best describes his or her self. Responses to open-ended questions were recorded by survey administrators using the device's alpha numeric keypad.

Categorical questions included how often participants rode a bike, number of working bikes they owned, age range and gender. Five open-ended questions were asked. In the first, the participant was shown a laminated picture of the approach to a signalized intersection with a red signal indication displayed. The participant was then asked to use a dry erase marker to mark an X on the picture where they would stop as a cyclist to wait for a green indication. Three versions of this question were asked. In each version the same picture of an intersection was shown but the road marking and signage was different. In the first variation the only marking present was the bicycle detector symbol, in the second the bicycle detector symbol was accompanied by a RS-22 sign mounted on the side of the roadway, and in the third variation, the modified bicycle detector symbol over a green background was displayed (see Figure 4). In order to prevent participant answers from being influenced by previous questions, each survey participant was asked only one randomly chosen variation of this question.

a) Variation 1: Bicycle Detector Symbol

b) Variation 2: Bicycle Detector Symbol and R10-22 Sign

c) Variation 3: Bicycle Detector Symbol Over Green Background

FIGURE 4: Stopping Position Survey Question Variations

The participant was then asked the reason for choosing to wait at the location. Comprehension of the bicycle detector symbol was tested by showing participants a picture of the bicycle detector symbol installed over a visible inductive loop detector and asking its meaning.

The online version of the survey was self-administered using Qualtrics online survey platform. While the questions remained the same as the in-person survey, all questions were displayed on an electronic device. In the case where participants were asked to indicate their stopping position at an intersection, they were required to use a mouse and click where they would stop on the picture displayed. The variation of this question asked was chosen randomly by the survey software.

Online participants were recruited by taping flyers with a link to the survey onto bikes parked on public property. Flyers were also distributed by handing the flyer to cyclists at large bike-related events which attracted a wide range of rider types. A summary of where both in-person and online recruitment occurred is given in Table 4 below.

TABLE 4: Survey Recruitment Locations

Event/Location	Survey Type
Portland Sunday Parkways NE	In-person
Portland Farmers' Market, Downtown	In-person
Portland Sunday Parkways, N	Online
Portland Providence Bridge Pedal	Online
Portland Sunday Parkways, SE	Online
Portland State University Campus Bike Parking	Online
Portland Timbers Soccer Games at Jeld-Wen Field	Online

RESULTS

Video

A total 302 hours of before and after video were recorded resulting in 955 logged observations, 688 of which were used in analysis. Observations omitted in the analysis include instances when cars immediately followed a cyclist, groups of cyclists riding together, cyclists who violated the red indication, and unusual circumstances that may have influenced rider behavior such as the presence of a dog running next to the cyclists or the rider talking on a mobile phone.

Analysis indicates that the stencil with the green background is most effective at causing cyclists to wait over the proper location of the loop in order to place a call to the signal controller. While only 23.5% of riders waited over the stencil as designed in the MUTCD, 48.4% waited over the stencil when a green background was added. Addition of an R10-22 sign also appears to improve the number of cyclists who wait over the stencil area. Observations at NE Ainsworth St. and MLK Blvd. showed an increase from 6.5% of riders waiting over the stencil area before to 34.8% after the installation of the stencil and R10-22 sign. In all cases, over half of cyclists did not wait over the installed roadway marking. Observed before and after stopping positions for all three test cases are given in Table 5.

TABLE 5: Cyclist Queuing Position Before and After Installation of Marking

Marking Variation and Test Site	Stopping Zone	Observations Before	Observations After	% of Observations Before	% of Observations After
Stencil Only	0'-10' from Curb	24	24	47.1%	47.1%
NE Dekum St. at NE MLK Blvd.	Over Loop (Not Stencil)	8	7	15.7%	13.7%
	Over Stencil Area	6	12	11.8%	23.5%
	Elsewhere	13	8	25.5%	15.7%
	Total	51	51		
Stencil with R10-22 Sign	0'-4' from Curb	68	51	73.9%	45.5%
NE Ainsworth St. at NE MLK Blvd.	Over Loop (Not Stencil)	9	11	9.8%	9.8%
	Over Stencil Area	6	39	6.5%	34.8%
	Elsewhere	9	11	9.8%	9.8%
	Total	92	112		
"Green Backed" Stencil	0'-10' from Curb	65	65	41.4%	28.9%
NE U.S. Grant Pl. at NE 33 rd Ave.	Over Loop (Not Stencil)	37	22	23.6%	9.8%
	Over Stencil Area	36	109	22.9%	48.4%
	Elsewhere	19	29	12.1%	12.9%
	Total	157	225		

A chi square test of proportions determined that in all three cases, the change in stopping behavior could be attributed to the applied marking technique with greater than 95% certainty. Expected observations were calculated based on data collected before the marking was applied.

Survey

Out of 227 survey participants, 60% of participants identified as male, 38% as female, and 2% preferred not to answer the question. The age of participants ranged from 18 to over 74 with the majority of people surveyed falling between the ages of 26 and 65. Forty-one percent rode a bicycle five or more days a week. A full demographic summary is given in Table 6.

Across all three survey variations, 57% of participants indicated they would wait over the bicycle detector symbol for a green signal indication, 22% would wait zero to five feet from the curb, 15% would wait between five and 10-feet from the curb and the remaining 4% would wait somewhere over the loop detector but not over the roadway marking. A chi square test of proportions did not find a significant difference in self-reported stopping positions across the three variations of the survey.

TABLE 6: Survey Participant Demographics

Category		n	%
Gender	Male	135	59%
	Female	86	38%
	Prefer not to answer	4	2%
	Blank	2	1%
	Total	227	
Age	18-25	37	16%
	26-39	80	35%
	40-65	98	43%
	66-74	5	2%
	74 +	2	1%
	Blank	5	2%
	Total	227	
Cycling Frequency	Less than 1 day a month	10	4%
	1-3 days a month	27	12%
	1-2 days a week	42	19%
	3-4 days a week	54	24%
	5 or more days a week	94	41%
	Total	227	

Note: Percentages are rounded to the nearest integer.

Reasons for choosing stopping positions varied across each stopping zone. Those choosing to stop zero to five feet from the curb indicated that they did so primarily for safety/visibility or to stay out of the way of traffic. Of those who indicated they would wait five to 10-feet from the curb, 59% said they did so to stay out of the way of traffic. Within the group of participants who chose to wait over the bike detector symbol, 51% reportedly did so to trigger the signal, 31% reported they did so due to the marking but did not indicate they did so in order to be detected. Full results are displayed in Figure 5.

FIGURE 5: Stopping Position and Reason

When shown a picture of the bike detector roadway marking installed over a visible loop, 45.4% correctly identified that it was used to indicate the location a cyclist should wait in order to be detected. Of the remaining responses, 33.9% thought it indicated a bike lane, 11.5% the recommended location to wait while a red indication was shown, 6.5% did not know what it meant, 1.8% that bikes were allowed and 0.9% gave other answers.

CONCLUSION

Over half of cyclists do not understand the meaning of the bicycle detector roadway marking. When installed without the accompanying R10-22 sign, only 23.5% of riders waited over the stencil area. This improved to 34.8% when accompanied by the curbside mounted sign and 48.4% when the bicycle detector symbol was installed over a green background. All three test cases were found to produce a statistically significant change in stopping position. Reasons given for not stopping over the stencil area were dominated by concerns for safety and a desire to stay out of the way of motorized vehicle traffic.

While the stencil with R10-22 sign did produce significant results, the installation location of the sign is likely an important factor. In the case of this study, the installation was ideal. It was within 3 feet of the curb, had no obstructions, and few other signs were installed at the intersection.

Though all three marking options helped some cyclists properly position themselves over detection, none appear to do an adequate job. Poor comprehension of the bicycle detector symbol and the desire to stay

out of the motorized vehicle lane appear to be the primary reasons that cyclist do not wait over the symbol. Those cyclists who do not wait over the bicycle detector symbol are likely to have longer delays at intersections which may discourage them from riding a bike. Furthermore, the inability to place a call may lead to higher rates of cyclists violating the red signal indication.

This study may present a best case for cyclist comprehension and use of the tested roadway markings. Reasons include Portland having a large percent of regular bike riders compared to other American cities and widespread use of the bicycle detector symbol within the city. Also, the City of Portland's use of green to highlight areas of the roadway intended for cyclists may make results for the "green-backed" bicycle detector symbol higher than in places where green is not recognized as a bike-specific color. Other limitations include having only one field test per marking option and limited survey responses from infrequent bike riders.

As communities look to encourage cycling, improving traffic operations for these users takes on greater importance. Using radar or video detection, installing curbside push buttons for bikers, installing bike specific loops closer to the curb, or placing popular bike routes on recall may be a few methods to improve intersection performance for cyclists.

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REFERENCES

1. Mekuria, M. C., P. G. Furth and H. Nixon. *Low-Stress Bicycling and Network Connectivity*. Report No. CA-MTI-12-1005. California Department of Transportation and U.S. Department of Transportation, 2012.
2. Maki, P.J. and P.S. Marshall. Accommodating Bicycles at Signalized Intersections with Loop Detectors: A Case Study and Example. Presented at Institute of Transportation Engineers 67th annual Meeting, Boston, MA, 1997
3. California Manual on Uniform Traffic Control Devices, 2012 Edition. State of California Business, Transportation and Housing Agency Department of Transportation. http://www.dot.ca.gov/hq/traffops/signtech/mutcdsupp/ca_mutcd2012.htm. Accessed July 7, 2013.
4. Akar, G. and K.J. Clifton. Influence of Individual Perceptions and Bicycle Infrastructure on Decision to Bike. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2140, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 165-172
5. Shladover, S. E., Z. Kim, M. Cao, A. Sharafsaleh, I. Li and S. Johnston. Bicycle Detection and Operational Concept at Signalized Intersections Phase 2, UCB-ITS-PRR-2011-02. California PATH Program, February 2011.

6. Boot, W., N. Charness, C. Stothart, M. Fox, A. Mitchum, H. Lupton and R. Landbeck. Final Report: Aging Road User, Bicyclist, and Pedestrian Safety: Effective Bicycle Signs and Preventing Left-Turn Crashes BDK83 977-15. Prepared for the Florida Department of Transportation, September 2012
7. Katz, B.J., H.G. Hawkins, J.F. Kennedy and H.R. Howard. Traffic Control Devices Pooled Fund Study, Design and Evaluation of Selected Symbol Signs Final Report. May 2008.