Bicyclists' Stopping Behaviors:
An Observational Study of Bicyclists' Patterns and Practices

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Abstract

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This thesis presents an observational research describing the stopping behaviors used by bicyclists at intersections controlled by stop signs and/or flashing beacons in the City of Seattle. The primary intent is to identify whether it is more common for bicyclist to roll through intersections or to come to a "complete stop," as is required by Washington State Legislature. This is done through the development of a pilot study for observing bicyclists' behaviors, based on a foundation of methodological and theoretical research as well as a review of domestic bicycle traffic accident data. During a three-day count period in November 2014, a pilot study documented bicyclists' stopping behavior, collecting data on a total of 2,616 bicyclists at six count locations. Results from this study find that approximately 55% of all bicyclists used rolling stops and/or track stands, 25% failing to stop and only 19% coming to a complete stop. Perhaps the most significant finding emerging from this research is the lack of truly significant findings. Despite this high degree of non-compliance with the stopping law, no reliable evidence was found exhibiting decreased safety resulting from the use of rolling stops by bicyclists at stop signs.

Acknowledgements

With my whole heart, I dedicate my master thesis to Edward Dionisio Silva, my late father. From listening to books on tape in the bicycle trailer, to riding the backseat of our tandem, a childhood of weekend bicycle rides on the Burke-Gilman Trail nurtured my love of bicycling and shaped my interests in transportation planning. My mother, Susan Elizabeth Caverly, also deserves her due credit for supporting me through my every academic and personal pursuit.

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INTRODUCTION

THE STOPPING BEHAVIORS OF BICYCLISTS

PURPOSE OF RESEARCH

The rolling stop was introduced to the American bicyclist in 1982 when the Idaho State Legislature adopted a law allowing alternative stopping behaviors at the signalized and stop sign controlled intersections. This law allowed for bicyclists to treat stop signs as yield signs and red lights as stop signs, with the requirement that bicyclists always yield the right-of-way appropriately before entering a roadway crossing (Idaho State Legislature 1988). Although no other U.S. states have embraced identical stopping laws, several have enacted laws allowing for variable stopping behaviors—including South Carolina, Utah, and Wisconsin (South Carolina Legislature 2008; Utah State Legislature 2014; Wisconsin State Legislature 2009). In Washington State, the law requires that bicyclist come to a "complete stop at stop signs and obey all traffic control device in the same manner as users of other modes of transportation (Washington State Legislature 2010b; Washington State Legislature 1975).

The fundamental purpose of this thesis is to investigate the stopping behaviors used by bicyclists in the City of Seattle, with a specific interest in assessing the prevalence of rolling stop practices. A preference for this behavioral practice is perennially expressed in research studies and news articles aiming to rationalize the efficacy of the rolling stop as a policy option for other states and local jurisdictions. Rolling stops are upheld as a highly efficient practice which allows bicyclists to conserve their energy at roadway crossings (Fajans and Curry 2001, 31). Opposition to the rolling stop is equally prevalent, with American road users frequently expressing a concern for decreased traffic safety resulting from the use of this less predictable stopping behavior by bicyclists (Salmon 2012). Both sides of this debate, however, lack strong creditability, as limited resources exist which are adequate to inform a comprehensive evaluation of the effectiveness and value of rolling stops.

Beyond moving the rolling stop debate forward in the context of Washington State, this research is distinctly focus on establishing a quantitative dataset for describing the behavioral practices of bicyclists. In order to do so, a pilot study was designed and implemented during the initial phase of this research. The methodological approach was inspired by the framework established through the National Bicycle and Pedestrian Documentation Project and annual counts performed in Washington Sate, as well as academic studies reviewed during the course of this research. Over the course of a three-day data collection period, behavioral data was collected on a total of 2,616 bicyclists located at six locations in the City of Seattle.

RESEARCH QUESTIONS

Reflective of the purpose and potential application of this research, the following four questions guided the development of this pilot study and use of the data collected:

(1) Do bicyclists in the City of Seattle use rolling stops or track stands at intersections controlled by stop signs and/or flashing beacons?

(2) Are bicyclists capable of accurately perceiving where conditions afford the safe use of rolling stops or track stands, rather than coming to a full stop and bringing at least one foot to the ground?

(3) What methods should be used to document bicyclists' stopping behaviors?

Based on the findings of these descriptive questions, one additional normative research question is explored as a means of summarizing the possible application of this study. The final research question this thesis attempts to answer is:

(4) Should the Washington State Legislature consider adjusting bicycle traffic laws, transportation design guidelines, or other policies based on the findings of this study?

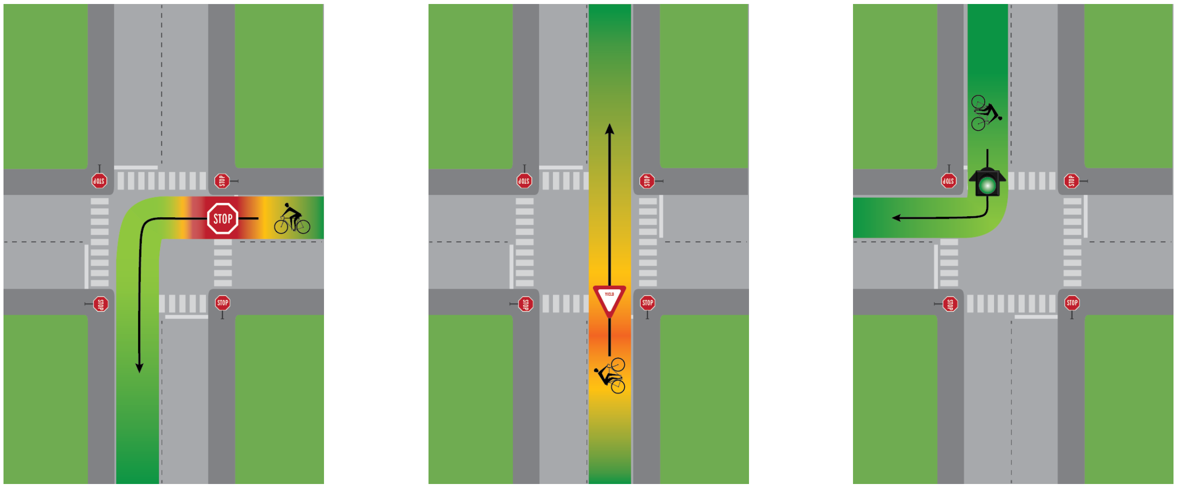
DEFINING STOPPING BEHAVIOR

In order to explore these research questions, this thesis identified the types of stopping behaviors used by bicyclists at roadway intersections, which are as follows:

(1) Full and Complete Stops;
(2) Rolling Stop and/or Track Stands; and
(3) A Failure to Stop or Yield.

The establishment of these three categories is reflective of a review of current state law in Washington and a comparison to the traffic laws practiced in other U.S. states. In Chapter 6 "Pilot Study Data Collection Methods", Figure 25 provides an overview of each type of stopping behavior together with a discussion of the use of this variable in the pilot study. Obviating further discussion here, while still providing context for each stooping type, Figure 1 presents a conceptual diagram visualizing the definition assigned to each stopping behavior examined through this research.

FIG. 1: Diagrams of Bicyclists' Stopping Behaviors



BICYCLISTS' STOPPING BEHAVIORS:
Conceptual Diagrams of Bicyclists Stopping Behaviors at Stop Sign Controlled Intersections

FULL AND COMPLETE STOP

ROLLING STOP AND/OR TRACK STAND

NO STOP OR YIELD

THESIS STRUCTURE

This thesis is organized into eleven chapters that collectively aim to respond to each of the research questions identified. Following this introduction, Chapter 1 presents a overview of bicycle stopping requirements in the United States, bicycle safety records, and the national rhetoric surrounding the topic of bicyclists' stopping behavior. The Chapter 2 presents a theoretical framework for considering how human perception might influence a bicyclist's decision regarding how, or whether, to stop at a crossing. In order to inform the design of the observational pilot study, the Chapter 3 provides a descriptive review of methodological case examples of related research.

Chapters four through seven describe the methods and design of the pilot study. This includes an explanation of criteria used to select count locations and schedule the observation periods as well as summary of data collection guidelines and in depth introduction to each variable included in the study. The observational pilot study's preliminary descriptive results on bicyclists' stopping behaviors are presented in Chapter 8. Extending the investigation pilot study results, Chapters 9 and 10 introduce two linear regression models designed to predict stopping behavior. Finally, Chapter 11 provides a synopsis of these descriptive and analytical results, with a focus on presenting key findings and responding to the four defined research questions.

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CHAPTER 1:

BACKGROUND RESEARCH

BICYCLE TRAFFIC LAWS IN THE UNITED STATES

WASHINGTON STATE'S "DEAD READ" LAW

In Washington State, the law requires that bicyclists come to a stop at all intersections controlled by traffic signals, with an active red light, and with a stop sign and/or flashing red beacon. This is principally enforced through the Revised Code of Washington (RCW) 46.61.050 which mandates that (Washington State Legislature 1975):

> "[the] driver of any vehicle, every bicyclist, and every pedestrian shall obey the instructions of any official traffic control device applicable thereto placed in accordance with the provisions of this chapter, unless otherwise directed by a traffic or police officer, subject to the exception granted the driver of an authorized emergency vehicle".

It is further and unambiguously required that, through RCW 47.36.110, all persons must come to a "complete stop" at stop signs before turning onto or crossing any designated arterial highways statewide (Washington State Legislature 2010b). This law also provides traffic engineers with the authority to install yield signs at intersections where traffic studies show "vehicles may safely enter the major arterials without stopping" (Washington State Legislature 2010b).

No authority is expressly given to engineers by law, however, to investigate whether bicyclists, specifically, can safely turn onto or cross a given road without stopping.

Rather, Washington State's traffic regulations generally do not consider the specific needs of bicyclists. RCW 46.61.775 instructs bicyclists to adhere to traffic laws applying to vehicles when traveling on the road and follow laws pedestrians must follow when riding on a sidewalk— with the exception of those laws that have no applicability to bicyclists by the nature of the law (Washington State Legislature 2000). According to RCW 46.61.755, bicyclists violating any regulation controlling how bicyclists, vehicles, and/or pedestrians may use the public right-of-way (including off-street paths) are equally liable to be ticketed and fined (Washington State Legislature 1982, 2).

With regard to traffic control devices, the most notable way in which bicycles are treated as an independent mode of transportation is in the requirement that traffic control equipment "routinely and reliably detect motorcycles and bicycles" at signalized intersections (Washington State Legislature 2009). Mandated through RCW 47.36.025, This practice aims to raise the level of service provided to bicyclists and motorcyclists to the same standards expected by drivers of vehicles. Although this law is not directly applicable to this current study, it is highlighted to show that Washington State presently elects to enhance bicycle mobility by improving how traffic control devices may respond to bicyclists. No provisions exist in the state, however, to enable bicyclists to respond to traffic control devices in a manner different than that of any other road users.

IDAHO STATE'S "ROLLING STOP" LAW

An alternative approach is taken in the State of Idaho, where statewide regulations elevate the level of service for bicyclists by adjusting the laws for how bicyclists should respond to traffic control devices. As of 1982, bicyclists in Idaho hold the legal right to treat stop signs as yield signs and, under some circumstances, red lights as stop signs.

Under Idaho Code 49-720, bicyclists may slowly approach an intersection controlled by stop signs, yield the right-of-way to approaching vehicles to avoid any hazards, and continue through the intersection without coming to a full and complete stop (Idaho State Legislature 1988, a). This code further allows bicyclists approaching a red solid light to yield, if turning right, or to come to a stop and then to yield the right-of-way before continuing straight or left through the solid red light (Idaho State Legislature 1988, b). This stop-as-yield method, permitted at intersections controlled by stop signs, is commonly known as an “Idaho stop”, or a rolling stop.

BICYCLE STOPPING LAWS NATIONWIDE

This long-standing Idaho law has been the subject of much debate across the nation as different states have enacted different variations on the “Idaho stop” law. For example, in South Carolina and Virginia, bicyclists can proceed through a solid red signal after first coming to a full and complete stop and then waiting for a minimum of 120 seconds (South Carolina Legislature 2008, 5; Virginia General Assembly 2013, B). Bicyclists in Utah are afforded the same rights; however, they may wait only 90 seconds before continuing through a red light (Utah State Legislature 2014, 7). In Wisconsin, it is legal for bicyclists to proceed through a red light after only 45 seconds, under the condition that no other vehicles are present (Wisconsin State Legislature 2009, 1). The State of Minnesota allows bicyclists to ride through a solid red light if it is on for an “unreasonable” period of time or if the signal is clearly and “apparently malfunctioning” (Minnesota State Legislature 2014, 9). Laws in each state further include the requirement that bicyclists exercise caution as they move into an intersection and/or avoid hazardous situations with other road users.

In recent years, these types of stopping laws have continued to be the subject of debate around the country. For example, the Bicycle Transportation Alliance—a non-profit bicycle advocacy organization in Oregon—proposed House Bill 2690 to the Oregon State Legislature in 2009. This law would have allowed “Idaho stops” at stop signs, but not including the allowance for rolling stops at traffic signals (Bicycle Transportation Alliance 2009). Unfortunately, the bill failed to make it to the House Transportation Committee for a vote, as the organization was unable to “conform support for the bill from at least 31 House members (the number of votes it would need to pass)” (Maus 2009b). While this law was not adopted in Oregon, more recently, the City of Aspen made legal a similar stopping law. The Municipal Code in this city now allows bicyclists to use rolling stops at all intersections controlled by stop signs, except at crossings with Highway 82 (City of Aspen 2014).

These many domestic cases, which do not represent an exhaustive list, set precedence for supporting traffic laws enabling bicyclists to treat traffic control devices in a different way than vehicular drivers may—under a defined set of circumstances. With this in mind, this research, in part, investigates whether or not any variation of the “Idaho Stop” law might be a beneficial or rational policy option in Washington State.

THE ROLLING STOP DEBATE

As is the case in the State of Washington, most places in the United States require bicyclists to come to a complete stop at stop signs. Nevertheless, Idaho and the several other states mentioned above allow bicyclists varying degrees of flexibility in legal stopping behaviors. Proponents of rolling stop laws often imply that this behavior is already ubiquitous, as “[even] well intentioned, well-trained, and conscious cyclists rarely come to a *complete* stop at stop signs" (MacRhodes 2009). Those who oppose such laws, on the other hand, regard bicyclists as scofflaws and do not believe laws should not be adjusted to accommodate the wants of bicycle riders. For example, findings from several focus groups with non-bicyclists as participants, conducted by Rebecca Sanders as part of her dissertation research at the University of California Berkeley, show that almost half of the 19 total participants are frustrated with and concerned about bicyclists violating traffic laws (Sanders 2013, 31). The rationale behind these cited concerns is the fear that bicyclists are "endangering themselves and others" when disregarding stop signs or red lights (Sanders 2013, 33).

In 2009, a graduate student, also from the University of California Berkeley, researched the legitimacy of the "Idaho Stop" law and the practice of rolling stops in general. This work concludes that, among a variety of factors discussed, the "Idaho stop" law is safer for bicyclists than "dead red" laws; the law also benefits human health and encourages a mode-shift to bicycling (Meggs 2010). Proponents of rolling stop laws commonly cite this research, as Meggs' research provides quantitative data to reference in support of arguments for this behavior. An individual formerly serving as the Idaho Transportation Bicycle and Pedestrian Coordinator since 1996, furthermore, referred to this research as "an excellent paper on Idaho's unique stop sign law for bicyclists" (McNeese 2009). At issue, however, is the fact that this research, produced in 2009, was labeled by Meggs as a draft and does not contain citations or appendices firmly evidencing many of the key arguments he presents; the application of this research is, therefore, not given weight in this thesis. Unfortunately, however, little other research exists which directly addresses the rolling stop debate, leaving arguments on both sides of the debate with little other than conjecture, politics, and personal bias. This thesis intends to introduce new quantitative data to potentially advance the discourse around the use of rolling stops by bicyclists.

Two questions frequently brought up in debates regarding rolling stop laws are presented below. Both questions will be revisited in the final chapter of this thesis, together with a final discussion on how to apply the findings of the pilot study to transportation policy decision-making.

SHOULD BICYCLISTS OBEY THE SAME TRAFFIC LAWS AS DRIVERS?

A question often asked by opponents to legislation allowing bicyclists to use rolling stops is: “Why do bikes deserve special treatment?” (Beam 2009). As data presented in the previous sub-section exhibits, a similar proportion of drivers and bicyclists disobey stopping laws. Those who advocate for rolling stop laws have argued that bicyclists are already using rolling stops and should, therefore, be legally allowed to do so. Representative Nick Kahl (D-Portland) supported House Bill 2690 on the basis of his own disobedience of the existing stopping laws in Oregon (Maus 2009a). Looking to the perception data, however, drivers of motor vehicles could make the same claim—as 30% admit to sometimes or often slowing, but not stopping, when approaching stop signs.

The Vehicular Cycling (or Effective Cycling) theory, articulated by John Forester, likewise challenges the notion of a rolling stop law. A basic principle of this theory is that “cyclists fare best when they act as drivers” and obey all rules that apply to “vehicles” (Hiles 1996). Beyond encouraging obedience to traffic laws and traffic control devices, this theory aims to prevent bicyclists from “feeling like a trespasser on roads owned by cars [;rather, the bicyclist] feels like just another driver with a slightly different vehicle, one who is participating and cooperating in the organized mutual effort to get to desired destinations with the least trouble" (Forester 1994, 3). Rather than changing rules to distinguish cycling from driving, the logic presented by Forester argues cyclists are safer when they use the roadway as do motor vehicle drivers and should respect the same set of laws regulating driver behavior (Pucher and Buehler 2012, 114).

ARE ROLLING STOPS SAFE FOR BICYCLISTS?

Rhetoric surrounding the topic of rolling stops and the "Idaho stop" law frequently includes a concern that rolling stop behavior and rolling stop laws both pose a threat to roadway safety. Making rolling stops and running stop signs and red lights are commonly referred to in articles and blogs as risky behaviors, and when the rolling stop law was considered in Oregon, one journalist made the argument that "the proposed law is not only unfair, it is dangerous" (Takemoto-Weerts 2010; Attig 2009). The trepidations toward rolling stops expressed by media are echoed by the results of research studies regarding road user perception.

A 2002 study of driver perception published by the Federal Highway Administration found that 58% of drivers indicate perceive the use of rolling stops by other road users as a major threat to their own safety. Another 40% report feeling that this behavior at stop signs is only a minor threat, with only a slight 2% seeing it as entirely non-threatening (Royal 2003, 58-59). Looking more closely at the rolling stop behaviors of bicyclists, survey results produced by Sanders exhibit that the reduction of bicyclists running red lights and stop signs is the fifth highest priority respondents want to see addressed by location transportation planners. Although results for this particular survey variable are not statistically significant, descriptively this research shows the concern regarding bicyclists' stopping behavior. This concern was shared by 21% of non-bicyclists or potential bicyclists, 16% of occasional cyclists, and only 14% of regular riders (Sanders 2013, 265). The results of Sander's research also indicate that some drivers complain that bicyclists' maneuvers at intersections are unpredictable and perceive such actions as dangerous (Sanders 2013, 33).

In regard to child safety, Representative Jim Weidner (R-Yamhill), from Oregon, opposed the "Idaho Style Stop" house bill based on a concern that it would enable bicyclists to "blow through" stop signs and a reluctance to "vote on legislation that could result in a situation where a child could die" (Maus 2009a). The Bicycle and Pedestrian Coordinator from the City of Eugene also voiced this opinion after House Bill 2690 was proposed. In the Coordinator's letter of opposition, a major concern was that "many bicyclists, especially [the City's] young riders, will misunderstand the law and blast through the stop signs with tragic results" (Shoemaker 2009). Although the City did not retract the statement that the behavior of younger bicyclists is of concern, the City of Eugene officially switched its position on the house bill to neutral within two weeks of the first statement (Blue 2009). Moreover, by 2011, the City of Eugene supported the adoption of policies allowing the "Idaho stop" (Steffen 2011, 4).

Child safety is explored further in Figure 2, presented in the following section.

AMERICAN BICYCLE TRAFFIC DATA

A principle issue faced by those involved in the rolling stop debate is a distinct lack of adequate quantitative data available to legitimately address safety concerns associated with the application of a variable stopping law for bicyclists. Unlike for vehicular traffic, a rich dataset does not exist describing the movements and patterns of American bicyclists.

FATALITY ANALYSIS REPORTING SYSTEM

At present, the National Highway Traffic Safety Administration manages the most comprehensive national database describing the experiences and actions of bicyclists on American roadways. This database is titled the Fatality Analysis Reporting System (FARS) and includes information on reported traffic accidents with the following characteristics (NHTSA 2015):

(1) Occurred on the Public Right-of-Way
(2) Involved a Motor Vehicle; and
(3) Resulted in a Fatality During or After the Crash

The inadequacies of this dataset for understanding bicyclists' behavior and traffic safety are many. To begin, this dataset expressly omits accidents that involved only non-motorized vehicles. Furthermore, any traffic accidents not resulting in a fatality are not recorded in this national database. These limiting caveats notwithstanding, the FARS database includes tens of variables of relevance to a descriptive, introductory comparison of bicyclist safety of all ages in the states identified as having varied stopping laws at stop signs and traffic signals. In order to produce the data reported on Figure 2, several steps were taken to manipulate data downloaded from the FARS online Encyclopedia article describing accidents involving bicyclists between 2010 and 2013. Of the 23,539 traffic accidents reported to the NHTSA during that four-year period, 2,908 involved bicyclists and other cyclists, representing 12.4% of all crashes.

The national database identifies twenty categories of contributing circumstances to accidents, one of which broadly captures accidents involving the disregard of a traffic sign, signal, or officer, just prior to or during the crash. Unfortunately, the database does not provide further details on the type of traffic control device, making it impossible to determine exactly how many accidents reported in the FARS database were caused by stop sign violations. Not endemic to only a study of bicyclist behavior, this is a data gap preventing analytical research that would target specific traffic control devices and their relationships to the safety of users of any mode of transportation.

Disregarding a traffic control device or officer was listed as a contributing circumstance to 1,052 bicycle crashes between 2010 and 2013, 36.2% of all accidents. Although the number occurring at stop sign controlled intersections cannot be determined, this thesis estimates a closer figure by identifying the crashes located at intersections that might reasonably feature a stop sign. Based on the typologies identified in the FARS database, analysis found that 683 bicycle accidents caused by disobeying traffic controls occurred at one of the following four types of intersections:

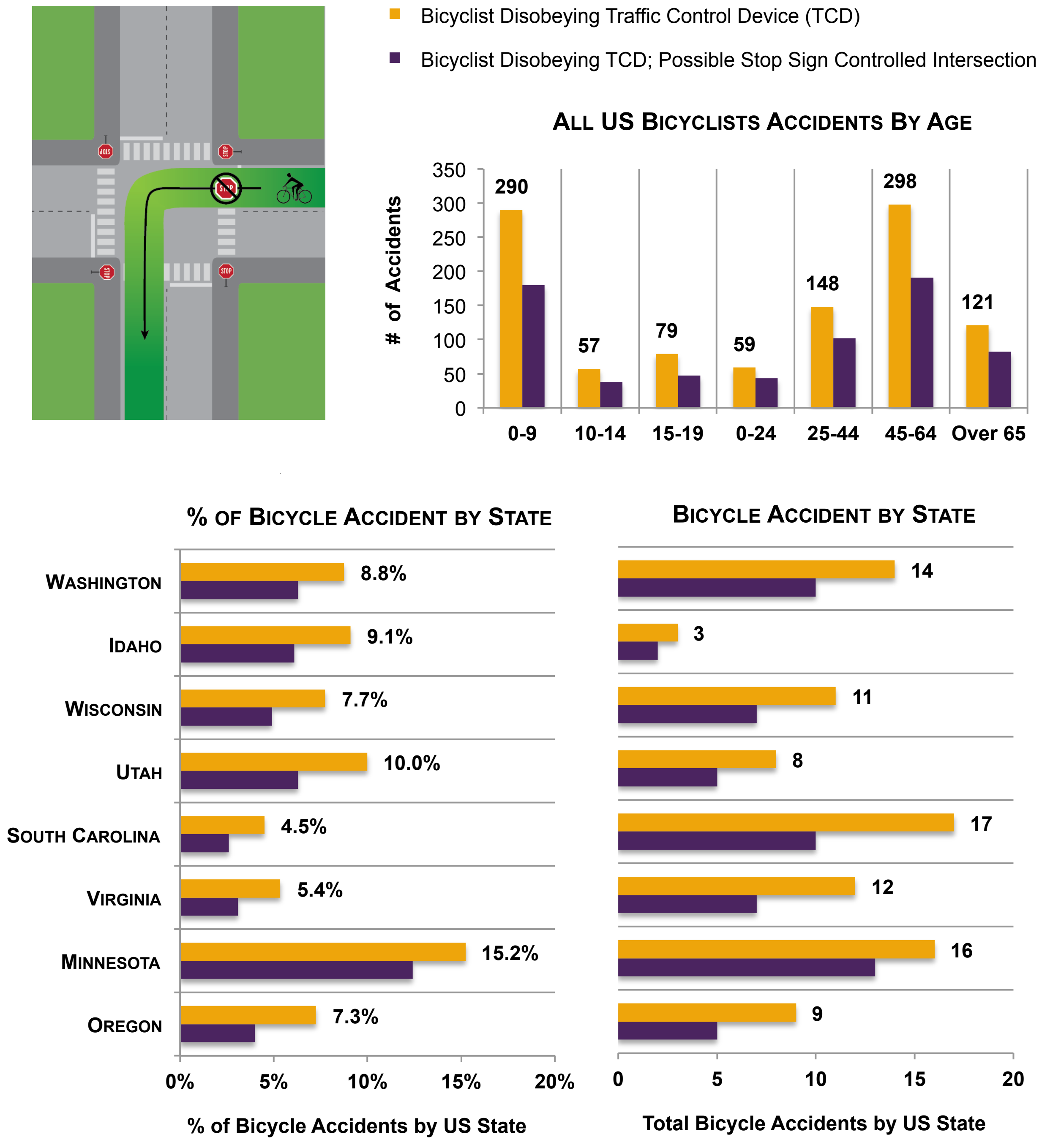
(1) Four-Way Stop
(2) T-Intersection
(3) Y-Intersection
(4) 5-Points or More

The other accidents occurred away from an intersection, or at roundabouts, traffic circles, or L-intersections where stop signs are less likely to be located. The actual number of bicycle traffic accidents happening at stop signs, however, is still unknown, as yield signs, traffic signals, or other controls may also be in place at all four types of intersections listed above. Nevertheless, this is the closest national average estimated through this research.

Figure 2 presents the descriptive results for the 1,052 accidents involving the disregard of traffic control devices and the 683 possibly taking place at stop sign controlled intersections. The chart on the top presents data related the age of the bicyclist, and the two charts at the bottom present descriptive statistics for each state identified in the discussion of bicycle stopping laws above. The age breakdown highlights that bicyclists ages 0 to 9 experience the same number of accidents as does the age cohort spanning two decades from age 45 to 64. This indicates that the younger age group experiences approximately twice as many accidents related to traffic control devices as does the older group of bicyclists. Disobeying traffic control devices was also the contributing circumstance to 113% more accidents among young children than for children and young adults between the ages of 10 and 19. Without engaging in further analysis, these results do indicate a rational foundation for concerns that children are more vulnerable than other, older, bicyclists at traffic control devices. This data is, however, inadequate to assess the cause for this potential vulnerability. For more satisfactory data to evaluate the safety concerns, further investigation or the expansion of existing research estimating the effectiveness of bicycle education programs and child compliance rates to traffic control devices is recommended.

FIG. 2: Data on Bicyclists Involving a Disregarding Traffic Control Devices from 2010 to 2013

ACCIDENTS INVOLVING A DISREGARD OF TRAFFIC SIGNS, SIGNALS, OR OFFICERS:
Bicycle Crashes Reported to the FARS Database from 2010 to 2013 (NHTSA 2010-2013)



Note: A major caveat to these figures is that state population is not considered. The interpretation and use of this data is, therefore, cautioned in further research without comprehensive review of the FARS database.

With regard to the comparison of bicycle accidents in the states defined earlier in this chapter, no clear trends were found to exhibit the safety outcome of variable stopping laws for bicyclists at controlled intersections. Data shows similarly small proportions of bicycle accidents involving traffic control devices occur in South Carolina and Virginia, which share a law requiring bicyclists to wait 120 seconds at a red light before proceeding (South Carolina Legislature 2008, 5; Virginia General Assembly 2013, B). Yet, 9-10% of all bicycle accidents in Washington, Idaho, and Utah are caused by instances of disobedience to traffic control devices, despite there being differing stopping laws in all three states. Figure 2 provides charts with the percentage of all bicycle accidents and actual total number of accidents occurring in each state between 2010 and 2013.

The most crucial piece of information missing to reliable compare bicycle safety data in different states is the actual number of bicyclists. For better or worse, no US state requires people to register as bicyclists and earn a bicyclist's license; therefore, no statewide registries of bicycle riders exist. The League of American Bicyclists uses data from the US Census to determine the number of bicycle commuters on an annual basis. At issue, however, is the fact that it is true that literally any person of nearly any age can be a rider or passenger of a bicycle and use the public right-of-way. While the bicycle commuter estimations provided by this and other groups are useful, they do not provide a complete picture of the American bicycling community. Furthermore, as the US Census defines a commuter as someone 16 years old or above, the baseline population for bicycle commuter estimations is not comparable with the entire FARS dataset.

Alternative data might be derived from annual bicycle counts conducted in many states across the country using varied frameworks based on the National Bicycle and Pedestrian Documentation Project methodology. This informal national model freely provides training and data collection materials that enable any jurisdiction to collect a reliable dataset for describing local to national bicycle volumes. The Washington State Department of Transportation, for example, deploys its own annual count project with Cascade Bicycle Club every fall, using methods mainly based on the NBPDP framework. See Chapter 3 “Methodological Case Examples” for more information on these bicycle count methods. This thesis briefly considered using bicycle volume data collected through these annual observational surveys to determine a more accurate estimate of bicycle rates in states with different stopping laws. However, the number of cities and count locations recorded in each state varies enough that these figures are also not easily compared. Despite efforts made, this thesis was unable to identify and implement methods to satisfactorily compare bicycle behaviors and safety at stop sign controlled intersections in different US states.

CONTRIBUTING CIRCUMSTANCES IN WASHINGTON STATE

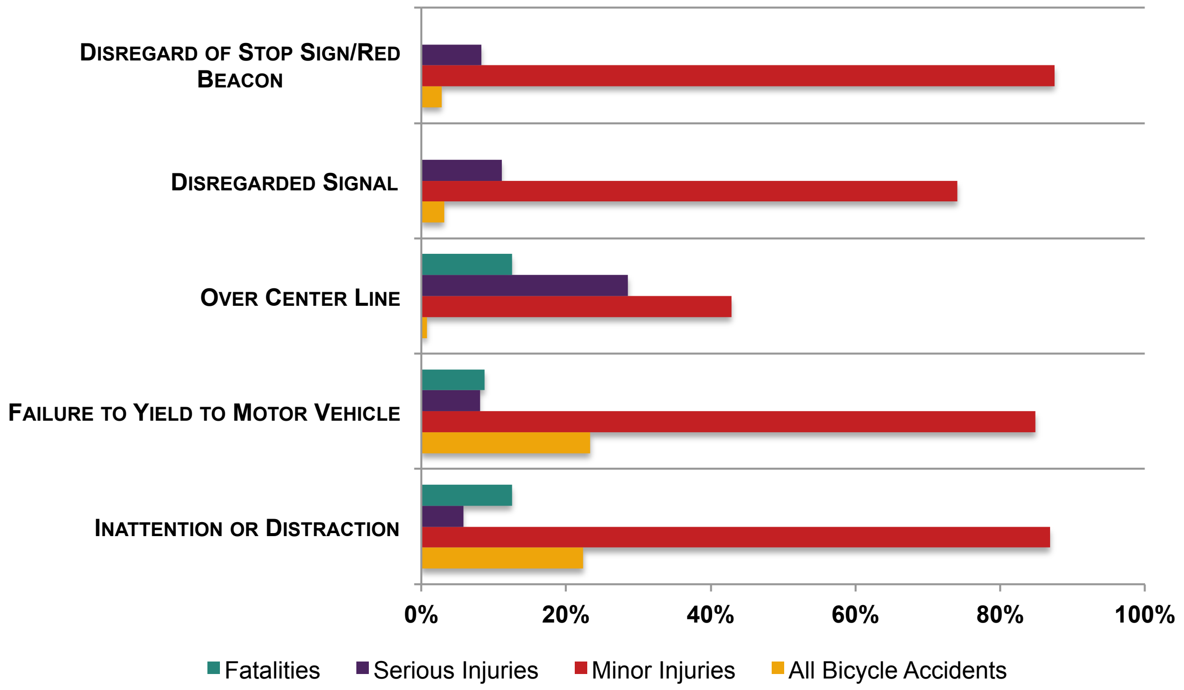
To briefly explore bicycle safety in Washington State, data reported by the State’s Department of Transportation in 2013 is reviewed in Figure 3. Unlike the data reported to the FARS database, Washington State does record if the disregard of a stop sign and/or flashing beacon, specifically, was a contributing circumstance to a given crash. The disregard of a stop sign and/or red beacon accounted for 2.83% of all bicycle accidents reported in Washington that year. No fatal injuries were caused by this behavior, and two serious injuries occurred when a bicyclist did not follow the State’s stopping law, accounting for 3.5% of serious injuries (WSDOT 2013, 15). A bicyclist's disregard of a stop sign is listed as the contributing circumstance for 87.5% of all minor injuries reported in 2013, with this the most common injury resulting from this action.

For comparison, four other contributing circumstances are reported in Figure 3. This includes the bicyclists' disregard of traffic signals (accounting for 3.18% of bicycle traffic accidents), riding over the centerline (0.82%), failure to yield the right-of-way to a motor vehicle (23.32%), and the inattention or distraction of a driver (22.38%). In 2013, a driver's distraction or inattention, as well as a bicyclist's action of riding over the center line, each caused two (12.5% of) bicycle traffic fatalities. Together with two caused by a bicyclist's failure to appropriately yield the right-of-way to a motor vehicle, these three circumstances account for 18.8% of fatalities recorded. Minor injuries are the most common outcome for each of the four circumstances. The failure to yield the right of way and driver distraction both cause the most serious injuries, with these circumstances accounting for 28.1% and 19.3% of serious injuries, respectively.

Of all eighteen contributing circumstances reported in Washington State, disregard of a stop sign is cited for the eighth most number of collisions. Disregarding stop signs was the cause of 24 bicycle traffic accidents, or 3% of all 2013 bicycle traffic accidents.

FIG. 3: Contributing Circumstances to Bicycle Traffic Accidents in 2013

CONTRIBUTING CIRCUMSTANCES TO BICYCLE ACCIDENTS IN WASHINGTON STATE:
By Percent of each Type of Contributing Circumstances in 2013 (WSDOT 2013, 15)



SEVERITY OF INJURY	Fatalities	Serious Injuries	Minor Injuries	Total Traffic Accidents
Disregard Stop Sign/Red Beacon				
Total Count	0	2	21	24
% within Disregard Stop Sign	**0%**	**8.3%**	**87.5%**	**2.83%**
% within Injury Type	0%	3.5%	2.9%	2.83%
Disregard Signal				
Total Count	0	3	2-	27
% within Disregard Signal	**0%**	**11.1%**	**74.1%**	**3.18%**
% within Injury Type	10.4%	5.3%	2.7%	3.18%
Over Center Line				
Total Count	2	2	3	7
% within Over Center Line	**1.8%**	**28.6%**	**42.9%**	**0.82%**
% within Injury Type	12.5%	3.5%	0.4%	0.82%
Failure to Yield Right-of-Way to Motor Vehicle				
Total Count	3	16	168	198
% within Failure to Yield	**0.1%**	**8.1%**	**84.8%**	**23.32%**
% within Injury Type	18.8%	28.1%	23.2%	23.32%
Inattention/Driver Distraction				
Total Count	2	11	165	190
% within Distraction	**0.1%**	**5.8%**	**86.8%**	**22.38%**
% within Injury Type	12.5%	19.3%	22.8%	22.38%

EXISTING DATA ON BICYCLISTS' STOPPING BEHAVIOR

In 2009 and 2014, researchers at Hunter College conducted observational studies of bicyclists in New York City. Both studies included the study of stopping behavior at traffic lights, but did not observe stop sign controlled intersections. The first study observed that 37% of bicyclists "did not stop at all at red lights" and another 28.7% of bicyclists "paused at a red light but then went through the light while it was still red" (Tuckel and Milczarski 2009, 7). In the more recent study, 30.4% fully stopped, 35.6% paused before proceeding through a red light, and 34% made no attempt to stop or pause at the red light (Tuckel and Milczarski 2014, 8). The pausing behavior reported in these studies is assumed to have characteristics similar to the rolling stops in this thesis. While these numbers are relevant to a discussion of rolling stops, they are more relevant to a debate of rolling stops at traffic signals than to the characterization of bicyclist behavior at intersections controlled by stop signs.

Two decades ago, the USDOT funded an observational study comparing road users' behavior in locations with bicycle lanes and wide curb lanes in California, Florida, and Texas. With the recognition that behaviors may have changed since 1995 when the study began, this past research included an investigation into the stopping behaviors of bicyclists at intersections controlled by stop signs as well as traffic signals. Findings showed that where traffic signals are in place, only 8.4% of bicyclists disobeyed the traffic signal, whereas a total of 25.3% of bicyclists were observed disobeying stop signs. This research additionally included a measure of the safety of bicyclists' maneuvers while disobeying the signals and signs. Findings show that 81.8% of bicyclists at traffic signals and 85% at stop signs were coded as using safe maneuvers as they disobeyed these traffic control devices (Hunter et al. 1999).

In an unrelated national perception survey of bicyclist attitudes and behaviors conducted by the National Highway and Traffic Safety Administration in 2012, 93% of respondents indicated knowledge of the stopping requirements (Schroeder and Wilbur 2013a, 72). These data might be used to argue the idea that most of the bicyclists observed in these three separate studies were likely aware of the legal requirement to stop at red traffic lights and stop signs. A different study, conducted by the Traffic Safety Administration in 2002, examined how drivers perceive their behavior as well as the behavior of other motorists. Similar to the findings for bicyclists, this study found that 30% of drivers "slow down but do not stop completely at [a] stop sign", with 18% using this rolling stop sometimes and 12% engaging in this stopping behavior often (Royal 2003, 48–49). That being the case, only 8% of respondents reported normally witnessing other drivers "ignoring stop signs" (Royal 2003, 56–57). The 22% difference in self-reported behaviors and frequency with which drivers see one another roll through the intersection may possibly be explained by the incidence of drivers electing to use rolling stops more when other drivers are not present.

This thesis aims to build up on these existing data sources and build a dataset adequate for analyzing the stopping behaviors used by bicyclists. A primary application of such a data set is to inform the national debate regarding bicyclists' behavior and the efficacy of alternative stopping laws for bicyclists.

CHAPTER 2:

THEORETICAL FRAMEWORK

In this chapter, three theoretical perspectives are presented to frame an academic discussion of bicyclists' stopping behavior. Collectively, the concepts and models presented below highlight the influence that physical environment, route familiarity, and personal preference have on the mobile practices of human beings. Throughout this thesis, the term 'behavioral mobility' is the term used to describe a framework defined using concepts presented through the following three bodies of work:

(1) The theory of affordances proposed by Gibson is applied to a discussion of how people in motion perceive and use their mobile environment. Following this ecological argument;

(2) Spatial Knowledge and the Decision Field Model are synthesized by Stern and Portugai to describe the influence that familiarity has on the risk avoidance deliberation process used by a person in motion; and

(3) Scollon and Scollon jointly developed the field of geosemiotics, which explores the meaning of signs as a function of their geography and how people traveling through the public realm use and interact with them.

The remainder of this chapter introduces and discusses each of these three conceptual contexts for understanding the behavioral patterns of mobility.

VISUAL PERCEPTION AND THE THEORY OF AFFORDANCES

The theory of affordances proposed by James J. Gibson, refined in his book, *The Ecological Approach to Visual Perception*, offers a theoretical basis for approaching this question. Gibson introduces this theoretical concept by suggesting that:

> "…the affordances of the environment are what it offers to the animal, what it provides or furnishes, for either good or ill" (Gibson 1979, 127).

For the purposes of this research, the public right-of-way comprises the 'environment' and the 'animal' is any person in motion on the roadway, bicyclists in particular.

Terrestrial conditions are the basis for what actions and behaviors are possible in a given environment. The theory of affordances suggests that the physical characteristics of an environment either support or inhibit the affordances of that place. Environments with horizontal, flat, and rigid surfaces which extend adequately at the human scale afford the support of human movement (Gibson 1979, 127, 131). Steep slopes and no rigid surfaces (i.e., non-solid surfaces such as water, thick mud, etc.), however, impede mobility, because such environments are more difficult for human beings to traverse without special equipment (Gibson 1979, 132). Gibson accounts these environmental requirements for the affordances of mobility on the basis of the law of gravity, and specifically on the fact that human beings are at risk of being "pulled down" if the surface does not sufficiently afford support (Gibson 1979, 223). Beyond what the physical setting makes possible or impossible for human beings to do, Gibson argues that what an environment affords or prevents must be "measured relative to the animal" (Gibson 1979, 127). Relative measurement is necessary, given that the members of each species typically share near-identical locomotion and perception characteristics and use the environment in a way that is distinct from other species.

Gibson refers to the ecological concept of the “niche” to explain that each type of animal, each type of person, utilizes the physical setting in its own unique way. The various functions, skills, position, or needs of a given animal construct its niche, which Gibson describes as a "set of affordances" (Gibson 1979, 128). The type of species an animal is influences what niche it fills and, therefore, what affordances the environment supports for that given animal. Animals with hands, for example, are afforded the ability to interact with objects and manipulate substances in an environment differently than can those without hands.

The set of affordances mankind processes as a result of the species' physical capabilities, size, and brain functions has allowed human beings to alter the environment on a larger scale than other species living on the planet (Gibson 1979, 129). The myriad alterations that mankind has made to the environment are all in the interest of augmenting the potential affordances the physical setting provides—such as the development of transportation infrastructure to afford the movement of people and goods. However, Gibson's theory underscores that the physical landscape is not the only important element in determining which affordances an environment does and does not support. Rather, it is the perception, cleverness, and ingenuity of the individual that determines what they are able to do in a given setting. Supporting this notion, Gibson finds that “behavior [is] controlled by information about the world and the self conjointly” (Gibson 1979, 233). The degree to which locomotion and other activities are possible depends on how the animal responds to a given setting (Gibson 1979, 134).

The natural response to a given setting is partially dependent on how well an individual can see and read their environment. Gibson, therefore, concludes that ambient light is a necessary component of human visual perception (Gibson 1979, 140). Thomas Edison developed the earlier invention of the incandescent light bulb and produced a street light which was unveiled in New Jersey in 1879—an example of human beings using innovation to augment the affordances of the natural environment (History.com Staff 2010). With pedestrian-scale and vehicle-scale lighting now ubiquitous with modern transportation systems, such systems are reliably able to accommodate travel during hours of astronomical twilight.

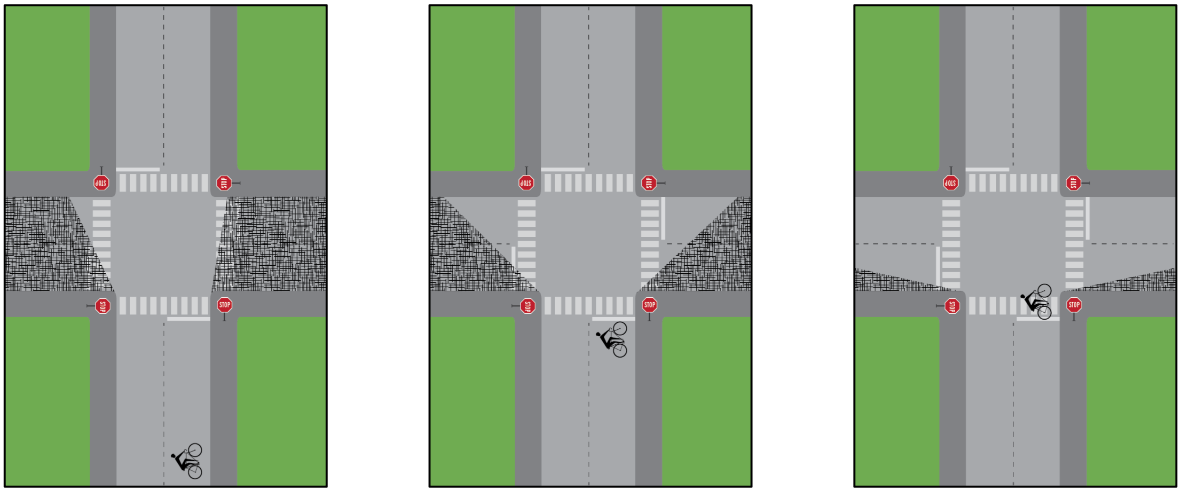
Mobile practices are furthermore dependent on how well orientated an animal is in a given environment. Animals in a stationary position will perceive and cultivate an understanding of the affordances provided by a physical setting from one point. Gibson asserts, however, that the act of locomotion results in a “path of observation” developed through repeated use of the same linear environment (Gibson 1979, 197). At each point along this path, the animal can see as far as the occluding edge created by objects, such as buildings or vegetation. Using the appropriate example of a bicyclist approaching an intersection, Figure 4 depicts the movements of this occluding edge as the bicyclist’s position changes and they reach the vista at the crossing (Gibson 1979, 198–199).

As is further exhibited through Figure 5 in the following sub-section on “Decision Field Theory and Spatial Knowledge”, the more often an individual follows the same path, the more fluent they become in traversing that particular mobile setting. Moreover, Gibson further posits that human beings can “place-learn” and gain the ability to perceive an environment uninhibited by physical structures and beyond the horizon (Gibson 1979, 198). The collection of the myriad moments of visual perception along a given route represented in Figure 4 are the foundation of an individual's perception of the path's entire physical setting as a whole. This notion is somewhat reminiscent of the theories and methods for cognitive mapping previously postured by Kevin Lynch in *Image of the City*. In the same theoretical vein, Lynch suggests the following (Lynch 1960, 131):

> "The creation of the environmental image is a two-way process between observer and observed. What he sees is based on exterior form, but how he interprets and organizes this, and how he directs his attention, in its turn affects what he sees."

FIG. 4: Line of Sight and the Opening of the Occluding Edge

CONCEPTUAL MAP OF THE OCCLUDING EDGE AT AN INTERSECTION:
(Based on: Gibson 1979, 199)



Approaching the Intersection with a Limited View of the Intersecting Roadway

At Stop Bar with Improved, but Imperfect View of the Intersecting Roadway

At Crosswalk with Near Unobstructed View of Both Intersecting Roadways

Note: The occluding edge is drawn from the sidewalk corners, rather than parcel line, to account for any potential obstructions to line-of-sight, such as street furniture, pedestrians, and parked vehicles are assumed present in at a typical crossing.

Similarly embracing the notion that all human beings shape their own perception and spatial awareness, the mapping methodology developed by Lynch explicitly recognizes that each individual has their own mental map of any given environment.

Just as an individual may have a mental map of the environment beyond the occluding edge, this thesis argues that, for human beings with experiential knowledge of a route's physical layout, it is reasonable to expect that individuals can likewise establish a mental map of where to expect human activity—which may have implications for risk assessment of stopping behaviors at roadway crossings. Lynchian maps include an identification of 'nodes,' representing important intersections a transportation system has with areas of high concentrations of activity (Lynch 1960, 73–78).

For the purposes of this research, one of the most significant conclusions made by Gibson is the following (Gibson 1979, 225):

> "Control lies in the animal-environment system. Control [of locomotion] is by the animal *in* its world, the animal itself having subsystems for perceiving the environment and concurrent for getting about in it and manipulating it. The rules that govern behavior are not like laws enforced by an authority or decisions made by a commander; behavior is regular without being regulated."

This statement emphasizes that an animal's behavioral mobility is influenced by its own perception and understanding of the environment in which it is moving. The theory of affordances suggests that particular physical settings either afford or inhibit different kinds of activities. This posits the notion that the environment itself establishes a loose set of rules for what is and is not allowed. As Gibson exhibits here, however, each animal will behave uniquely in an environment, based on their "set of affordances" and perception of a given setting. Based on this logic, the mobile behaviors an animal engages in are a function of its perceptive capabilities and personal understanding of the environment it is traversing.

Building on the concept of niches and noting the human ability to overcome physical barriers through built innovation, this thesis argues that people utilizing different modes of transportation should be considered different species of animals in the context of the Gibson's theoretical framework. Just as each species of animal enjoys distinct physical characteristics and capacities, each mode of transportation comes with a unique set of mobility affordances. Fundamentally, each mode requires the human user to position and use their body in a prescribed way in order to advance forward. Pedestrians are required to use their feet to walk, but otherwise are free to move without restriction. Drivers, on the other hand, are generally in an upright, seated position with their feet on the pedals, hands on the steering wheel, and body strapped in by the seatbelt. Bicyclists are also seated with their feet on pedals and controlling their vehicle by steering; however, unlike drivers, bicyclists must balance on the bicycle while moving their feet in a circular motion around the frame's bottom bracket.

An additional rationale for treating different modes as different animals is the simple fact that drivers travel inside of a climate-controlled vehicle and rely on their motor vehicle to travel forward, whereas non-motorized travelers are self-propelled and out of doors, more exposed to weather conditions. Regarding the animal-environment system, drivers enjoy a more neutral relationship with the environment because their vehicle extends their set of affordances and obviates physical exertion.

Pedestrians and bicyclists are both more sensitive to the geographic environment than are vehicular drivers, as uphill slopes and long-distance travel, for example, require a greater output of energy for these non-motorized travelers. This thesis posits that bicyclists are more sensitive to changes in terrain than are pedestrians, because bicyclists, for example, gain considerably more speed on downhill slopes than do pedestrians, cannot safely travel up or down steps, and are less able to traverse sand or rocky terrain than those traveling by foot. Based on these many distinctions, Gibson's theory is therefore used in this thesis research both to frame an understanding of human perception and to establish an argument supporting a differentiation in the mobile practices of the users of each mode of transportation.

DECISION FIELD THEORY AND SPATIAL KNOWLEDGE

The importance of personal knowledge and experience of a place for the purposes of mobility is established and confirmed by Eliahu Stern and Juval Portugali in their chapter titled, "Environmental Cognition and Decision Making," in *Wayfinding Behavior*. In their research on route choice and mobile navigation, these researchers found that "decision making is strongly based on the individual's level of spatial knowledge" (Stern and Portugali 1999, 101). One of the many theories discussed by Stern and Portugali is decision field theory, which was developed by Busemeyer and Townsend in 1991, in order to investigate the human behavior and the deliberation process under risky and/or uncertain conditions (Busemeyer and Townsend 1991, 432). The proposed theory uses mathematical calculations to establish a seven-step model of the deliberation process, which was inspired by psychological theories related to approach-avoidance conflict and decision-making, as well as information-processing theories related to choice probability and time (Busemeyer and Townsend 1991, 435). This thesis does not attempt to synthesize each element of this theory and instead, focuses on the conclusions of this research that are most germane to a discussion of mobility.

Of particular interest is the inclusion of time in the formula for perception. Rather than indicating that each individual's preferences are always static, the decision field theory assumes preferences are dynamic. Busemeyer and Townsend suggest that each decision is made using information gained through past relevant experiences (Busemeyer and Townsend 1991, 436). Therefore, decisions are made using increasing amounts of information, and an individual's preferences may develop over time. An element of time also exists for each decision itself, as the individual deliberates upon which action to take, based on the consequences of either action. The central notion proposed through the decision field theory is that (Busemeyer and Townsend 1991, 455):

> "the deliberation process involves an accumulation of information about the consequences of a decision, and the amount of attention allocated to the various consequences changes over time during deliberation."

This insinuates that preferences not only develop over a span of time, but they also develop during the decision-making process itself. Moreover, the development of a preference depends on the level of thought the individual dedicates to their decision. Decision field theory proposes that all decisions have time constraints, with the final deadline being the decision time. At some point during the deliberation process, the approach-avoidance theory suggests, "the consequences of an action become more salient as the preference state for that action approaches its threshold" (Busemeyer and Townsend 1991, 442). This is to imply that the impending need to make a decision will provoke action, as the consequences become more relevant or significant to the individual.

Applying this to the situation of a bicyclist approaching an intersection, a rolling stop might be interpreted as an outward exhibition of the deliberation process some bicyclists go through. When coming to a stop sign, a bicyclist might be scanning the intersection for activity on the other legs of the roadway as well as checking for potentially crossing pedestrians. This theory suggests that if other road users are present and a potential for risk exists, the bicyclist will make a firm decision to roll through the intersection or stop and yield to intersecting traffic. This theory would further suggest that a bicyclist who does not stop at an intersection also does not engage in this same deliberation process. Disregarding a consideration for potential risk and yielding the right-of-way implies that bicyclists who fail to stop make their stopping decision in advance of their immediate approach to an intersection. As may also very well be the case for the other stopping behaviors, existing circumstances at an intersection are only one aspect of the practice of decision-making as described by decision field theory.

Stern and Portugali extend their theory to suggest that the accumulation of specific knowledge of an environment influences route-choice and mobile behaviors. As is supported by the theory of affordances, the more spatial knowledge a mobile individual has about a particular setting, the better oriented with that environment the animal becomes (Gibson 1979, 198–200). To explain this relationship and the role familiarity plays in mobile practice, Stem and Portugali defined three foundational components of urban-navigation and spatial knowledge, which are as follows (Stern and Portugali 1999, 101-102):

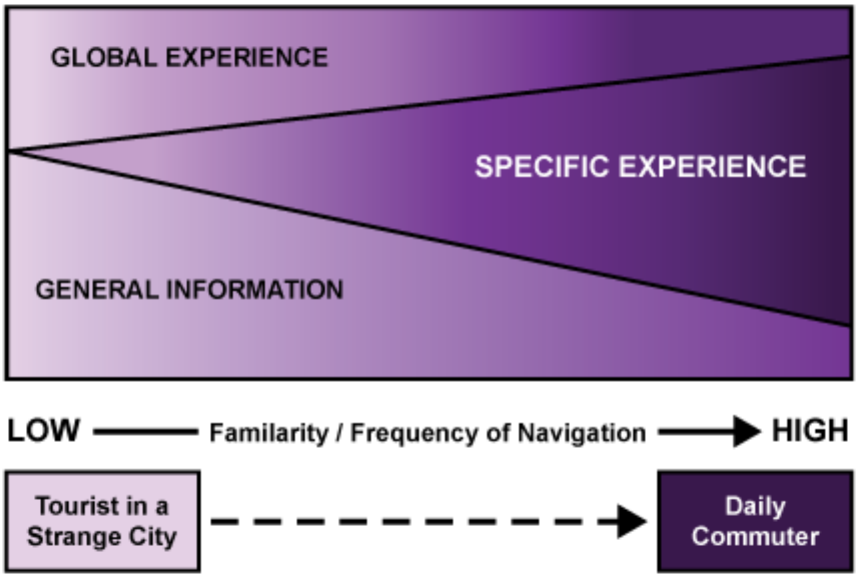
(1) Specific Knowledge – personal experience in a given transportation setting;

(2) Global Experience – basic understanding of modern transportation systems based on personal experience; and

(3) Information – indirect knowledge acquired through independent research or social contacts.

FIG. 5: Components of Spatial Knowledge and Frequency of Urban Navigation

FRAMEWORK FOR URBAN NAVIGATION AND SPATIAL KNOWLEDGE:
(Recreation of: Stern and Portugali 1999, 102)



The first two components require some level of personal familiarity with the environment and the third supplements first-hand knowledge with borrowed information (Stern and Portugali 1999, 101). As is shown in Figure 5, Stern and Portugali posit that increased frequency of use is tied to higher levels of familiarity. This association is made based on the theoretical notion that when an individual visits or moves to a new city, they will begin by learning and using the same routes and will eventually go from a inexperienced stranger to a mobile environment to becoming a knowledgeable daily commuter (Stern and Portugali 1999, 102–103). This suggests that the patterns and practices employed by a daily commuter will exhibit a more nuanced comprehension of the affordances in their mobile environment.

GEOSEMIOTICS AND DISCOURSES IN PLACES

Pulling from a blend of sociology, ethnography, and semiotics theory, the relationship between knowledge and mobile behaviors is addressed through a theoretical model suggested by Ron Scollon and Suzie Wong Scollon in their publication, *Discourse in Place: Language in the Material World*. Specifically, this book presents the framework of geosemiotics to describe the meaning of signs and the behaviors resulting from how people in motion interpret the signs they interact with in the material world. The title of this theory highlights the dual emphasis on the physical setting (‘geo’ for geography) as well as the language of sign systems and the influence signs intend to have over behavior or actions (‘semiotics’, as defined by Peirce in 1867) (Scollon and Scollon 2003, 4; Atkin 2015). Three principles serve as the foundation of geosemiotics, which are as follows (Scollon and Scollon 2003, 205):

(1) Indexicality – the placement of a sign in a given setting establishes the meaning of that sign;

(2) Dialogicality – the meaning of each sign is dependent on the presence and placement of other semiotic devices, embodied or disembodied; and

(3) Selection – the action an individual is engaging in, and the positioning of that action, determine which signs an individual directs their attention at.

The first principle, indexicality, is directly tied to the authors' assertion that all signs are indexes, which is to say, that all signs implicitly act as a point of reference to a physical object or place (Scollon and Scollon 2003, vii, 212). The meaning of each sign is linked to the index to which it is assigned, which is largely influenced by the mobile discourse regulating the physical setting. On American roadways, the Federal Highway Administration (FHA) manages this discourse through its *Manual for Uniform Traffic Control Devices* (MUTCD), which standardizes the design, placement, and meaning of all regulatory signs installed on the public right-of-way (Scollon and Scollon 2003, 190). The language system attributed to the stop sign developed when it was innovated in the City of Detroit in 1915 (Hawkins 1992, 23). Although traffic control devices are now under the purview of the FHA, the American Association of State Highway Officials (now the American Association of State Highway and Transportation Officials) developed the language defining the specifications and use for stop signs in 1927 in the nation's first formally established set of guidelines for rural transportation control devices. In the *Manual and Specifications for the Manufacture, Display, and Erection of U.S. Standard Road Markers and Signs*, the stop sign is identified as an octagonal sign with a yellow background and black text (AASHO 1927, 5–6).

These requirements were updated as of 1954 revisions to the MUTCD—which was written to regulate rural and urban roads, and which was jointly written by the AASHO and the National Conference on Street and Highway Safety (NCSHS) in 1935—changing the design to the familiar modern red sign with white text (JCUTCD 1954, 2; AASHO and NCSHS 1935). Despite this change, the index of the stop sign has remained constant since its conception. Regarding the stop sign, the original rural sign manual states that (AASHO 1927, 20):

> “This sign is used at places on a highway where traffic is required to stop. Ordinarily, such points will be at railroad grade crossings, where stops may be required by law; at the intersection of two main highways; and at the junction or intersection of a cross-road with a main highway.”

This early manual correspondingly addressed the placement of a stop sign, further establishing the indexicality for where a stop sign should be installed based on safety concerns. A range of distances from the “point of potential danger”—i.e., the intersection of roads—is provided, in addition to the following guidance (AASHO 1927, 20):

> “The Stop Sign should not be set back from the point of danger in an effort to save a sign, because the stop should be made at the point where the cause of danger is visible and the driver can see and understand the reason why he has been brought to rest.”

These placement requirements inherently reference the safety and visibility issue of the occluding edge discussed by Gibson (Gibson 1979, 199) (Fig. 3).

With a design, meaning, and location defined, Scollon and Scollon further infer that the meaning of the stop sign is abstract until it is installed at a location that corresponds to the traffic code and engineering regulations. Referring specifically to stop signs, these theorists explain that, despite germane comprehension of the meaning of a stop sign in the United States, the meaning of the sign is not truly applied until the sign is in place at its indexed location (Scollon and Scollon 2003, vii–viii). When the sign is in the fabrication shop or used as wall decoration by an interior decorator, it is abundantly clear that the symbol is not being used for the purpose it was created to fill—that is, because the sign is not installed at a roadway intersection and is not positioned to dictate the movements of traffic.

Advancing this notion, the characteristics of a given place might also attribute a somewhat different kind of abstract meaning to a given sign. The theories describing spatial knowledge and urban navigation developed by Stern and Portugali support an extension of the concept of abstract meanings, as the two imply that individuals with specific knowledge of an environment will select a route based on preference. This thesis posits that, for example, the abstract meaning of a stop sign at a high volume intersection is tied to the expectation for longer wait time or more dangerous circumstances, which, in turn, affects the route choice decision-making.

The meaning of the sign is also a function of the second principle, dialogicality. Through this principle, Scollon and Scollon emphasize the importance of the intersemiotic dialog that people in motion engage in with the aggregate of semiotic devices in place at a given location (Scollon and Scollon 2003, 193). In a comparison of daily life and social interactions at street corners in Beijing, Hong Kong, Paris, Vienna, and Washington, D.C., these theorists identified the following four categories of semiotic devices at all intersections under investigation:

(1) Regulatory Discourses: Municipal – traffic control devices regulating vehicles or pedestrians, public notices, and non-linguistic signs like curb cuts and built barriers intended to regulate mobile behaviors (Scollon and Scollon 2003, 181–185);

(2) Infrastructural Discourses: Municipal – regulated functional public notices such as plaques identifying power supply lines and sewer mains, and public labels, such as street signs, that do not serve the purpose of dictating the actions of the typical person in motion (Scollon and Scollon 2003, 185–187);

(3) Commercial Discourses – regulated permanent and temporary signs or goods in the public realm to advertise and invite potential customers to particular shops or services (Scollon and Scollon 2003, 187): and

(4) Trangressive Discourses – unregulated signs and markings including flyers posted on telephone poles or public notice boards, wanted posters in shop windows, or graffiti painted on buildings and infrastructure that are typically targeted primarily at pedestrian traffic, due to the scale and location of these signs (Scollon and Scollon 2003, 188).

Depending on the combination or configuration of these various semiotic devices, the meaning of a given sign may differ slightly. One reason this is true is the simple fact that an intensity of signs in a given place creates a complex semiotic environment that is difficult to analyze and interpret (Scollon and Scollon 2003, 194). This implies that signs in settings with a high concentration of semiotic devices will experience a reduction of their individual meaning or may be hidden or overlooked among other indexed devices.

Moreover, the semiotic aggregate is additionally influenced by the intentional relationships between different traffic control devices, as is dictated by regulatory manuals and guidelines administered by all levels of government. The original American sign manual, for example, includes the allowance for installing a slow sign in advance of a stop sign (AASHO 1927, 20). Geosemiotics describes this relationship through the assertion that (Scollon and Scollon 2003, 193):

> "[signs] operate quite independently semiotically, nevertheless, their co-presence produces a kind of dialogicality between them so that each takes part of its meaning from the co-presence of the other."

Concrete examples of this theorized intersemiotic dialogicality are presented in Figure 6, featuring two locations included in the pilot study that is developed and implemented through this thesis. The image on the left shows a situation in which the purpose of a given traffic control device is to signal the presence of another device. On the right, the second photo presents a situation where the temporary presence of one device partially supplants the actions required by another.

Important to the rolling stop debate, Scollon and Scollon further recognize that an intersemiotic dialog occurs between people in the form of gesture-based social interactions. In order to develop the principles of geosemiotics, the theories proposed by

FIG. 6: Semiotic Aggregate – Examples of Regulatory Discourse from Pilot Study Locations

EXAMPLES OF REGULATORY INTERSEMIOTIC DIALOGICALITY:
(Photo Credit: Cat Silva)

SAND POINT COUNT LOCATION:
Burke-Gilman Trail

The rumble strip prior to the stop sign is a regulatory semiotic device intending to raise the level of awareness, bringing attention to the crossing and stop sign ahead. Without the strip, unfamiliar travelers may not notice the stop sign until they are closer to the intersection.

BALLARD COUNT LOCATION:
Neighborhood Greenway

A temporary warning sign placed in front of the stop sign. This indicates to road users that they must look for a flagger regulating the patterns of movement at an intersection. The stop sign must be obeyed, in addition to following the direction of the flagger.

Erving Goffman are applied to describe human interactions in mobile situations. In *The Presentation of Self in Everyday Life*, Goffman writes that (Goffman 1956, 19):

> "…in the presence of others, the individual typically infuses his activity with signs which dramatically highlight and portray confirmatory facts that might otherwise remain unapparent or obscure. For if the individual's activity is to become significant to others, he must mobilize his activity so that it will express *during the interaction* what he wishes to convey."

Here, Goffman's theories of social interaction infer that all people in a mobile environment are embodied semiotic devices. Applying these notions to geosemiotics, the theorists write (Scollon and Scollon 2003, 56–57):

> "Not only are our discourses in place positioned to the spot on the earth in which they take place, they are positioned in relationships, both social and physical, to the other humans who are also in those spaces."

These concepts support the notion that the behaviors individuals engage in at an intersection, in part, depend on the signs that otherw sharing the same environment are giving off (Scollon and Scollon 2003, 55). Just as people will negotiate a roadway based on the disembodied traffic control devices in place, so too will mobile actions be adjusted based on the embodied signs shown by others in their presence. Both these physical and gestural signs, therefore, provide a rough roadmap of the affordances a transportation environment provides. Following this logic, this thesis suggests that the list of four sign types present at an intersection be extended to include:

(5) Embodied Devices – embodied signs that people give off or receive in a given social or mobile setting.

For the purposes of the present investigation of stop signs and rolling stops, there are two key takeaways from Goffman's theories and their functions for the theory of geosemiotics. First, the mere presence of other individuals using any mode of transportation on the public right-of-way affects the actions of a given person in motion. Second, the actual performances and behaviors of other people similarly affect the actions taken by the individual. However, as is also true for physical signage, the existence or manifestation of a semiotic device does not automatically imply that a person will respond to that device through their mobile behaviors. The argument for this is presented by the third principle of semiotics.

Building on the first and second principles, which establish the meaning of semiotic devices, individually and in aggregate, the principle of selection embraces the notion that people will direct their attention toward only a subset of the signs they might interact with. Advancing the framework developed by Goffman, geosemiotics suggests that people traveling along a path will foreground those semiotic devices they perceive as important, and will background those signs that do they do not perceive as serving a meaningful purpose for their action. (Scollon and Scollon 2003, 205). As an example, a person taking the action of walking on a sidewalk will be more interested in the content of sandwich boards and the actions of other pedestrians. They will, however, be likely to disregard traffic control devices directed only at vehicular traffic and will be less aware of the actions of drivers on the adjacent roadway. The action of walking, therefore, naturally selects the set of embodied and disembodied semiotic devices that an individual will foreground to guide their the mobile behaviors and decision-making.

Throughout their book, Scollon and Scollon serendipitously refer directly to the meaning of a stop sign and the mobile practices at stop sign controlled intersections—with the three principles of geosemiotics explained through this example. First, indexicality of a stop sign cannot be established until the location of the device and actions of the individuals are known (Scollon and Scollon 2003, 2). The framework for geosemiotics identifies the following four questions to ask in order to fully understand the indexed meaning of a given stop sign (Scollon and Scollon 2003, 3):

(1) "Who has 'uttered' this (Is it a legitimate stop sign of the municipal authority)?;

(2) Who is the viewer (it means one thing for a pedestrian and another for the driver of a car)?;

(3) What is the social situation (is the sign 'in place' or being installed or worked on)?; and

(4) Is that part of the material world relevant to such a sign (for example, is it a corner of the intersection of roads)?"

The first, third and fourth questions cooperatively define the physical setting and only second question defines the individual. Responding to these four questions, the indexicality of the geosemiotic relationship studied through this thesis identifies the general location as intersections of public rights-of-way which are controlled by legitimate, fully installed, stop signs and/or suspended flashing beacons. The viewer is anyone traveling by bicycle through the setting matching the general location. Among other things, geosemiotics underscores the important role the mode of transportation plays in selection and responses to dialogicality, through the statement that (Scollon and Scollon 2003, 183):

> "pedestrian traffic is of a rather different order than vehicular traffic, both in terms of social practice and in terms of legal enforcement of regulations."

It is correspondingly true that bicyclists engage in unique traffic patterns, when compared with users of other modes. This thesis aims to advance the theoretical and practical conversations attempting to describe the behaviors of bicyclists as distinct from the practices used by drivers, motorcyclists, or pedestrians to traverse a mobile environment.

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CHAPTER 3:

METHODOLOGICAL CASE EXAMPLES

The methodology developed for this pilot study aiming to collect and examine data on the behavior of bicyclists is strongly influenced by methods developed by several existing bicycle count documentation projects. This chapter presents a review of the four primary case studies informing the design and methodological approach for the pilot study. The list of case samples is as follows:

(A) The Annual National Bicycle and Pedestrian Documentation Project;
(B) The Annual Washington State Bicycle and Pedestrian Documentation Project;
(C) Two Behavioral Studies of Bicyclists at Hunter College in New York City; and
(D) One Study Comparing Bicycle Lanes to Wide Curb Lanes completed by the National Highway Research Center, with funding from the United States Department of Transportation Federal Highways Administration.

All four case examples are domestic studies of bicyclists using American transportation infrastructure and following American traffic laws. Each case study informing the methodological approach is focused on collecting information on bicyclists' volumes, patterns, and/or behavior. Of the bicycle documentation projects examined for this study, the third shares the most in common with the pilot study under development.

This chapter aims to be a reference guide providing a descriptive overview of the four studies and projects. Rather than engaging in a critical analysis of methods used by these studies, this chapter presents an appraisal of the methods and metrics employed in each data collection project. The practical reason in doing so is to document precisely which elements of these studies are particularly salient to the purpose of the research presented in this thesis. Beyond discussions throughout this document, this chapter acts as a reference guide describing specific details of the selected case examples.

The review for each case example covers five areas of particular interest to this research, including:

(1) **Overview of the Aims of Each Project** – The purpose of the overview is to establish an understanding of the goals each project was developed to achieve in order to best assess how relevant the project's methods are to the this pilot study.

(2) **Explanation of Count Location Selection** – In the interest of building a strong set of criteria for determining precisely where data collection should take place, the methods used by each case example are documented and considered for use in the pilot study.

(3) **Methods for Scheduling Counts** – The schedule of count periods influences the reliability and comparable nature of data collected. Each of the various count schedule models seen in the case examples is reviewed with the intention of determining whether the pilot study can follow the same schedule as an existing project.

(4) **Data Collection Methods** – Methods used in each example inform the procedures developed for the pilot study, a description of the guidelines followed before, during, and after data collection. This includes a review of the process as well as the variables collected.

(5) **Data Analysis Methods** – A brief description of how data from each study is used for analytical purposes in each study is also included. This element of each case example is reviewed in order to inspire potential methods for the pilot study.

(6) **Relevance for Pilot Study** – As the purpose of examining the case examples is to seek inspiration for the pilot study, the discussion of each study concludes by noting any relevant aspects of aspects of the given case example.

Case Example A:

NATIONAL BICYCLE AND PEDESTRIAN DOCUMENTATION PROJECT

A1 – OVERVIEW OF CASE EXAMPLE

A formalized methodology for collecting bicycle count data nationwide was established in 2003 through a joint effort by the Institute of Transportation Engineers Pedestrian and Bicycle Council together with Alta Planning + Design, a national planning firm focused on bicycle and pedestrian facilities. This methodology is titled the National Bicycle and Pedestrian Documentation Project (NBPDP) and was established with three primary goals in mind, which are to (Alta Planning + Design 2010a, preface):

(1) Produce a consistent methodology for bicycle and pedestrian counts to be used nationwide;

(2) Create a national database of comparable data gathered using one uniform methodology; and

(3) Apply collected data to a correlational analysis between bicycle and pedestrian patterns, local demographics, and land use patterns.

Beyond these goals, the NBPDP is a resource for transportation planning and engineering professionals, policy makers, and non-motorized transportation advocates. The guidelines established by the NBPDP provide direction on when to schedule counts and length of count periods as well as methods for collecting and analyzing data. Instructional and count materials are accessible for free online, supporting the ability of jurisdictions across the country to contribute to the national data set.

A2 – COUNT LOCATION SELECTION METHODS

The NBPDP provides guidance on the selection of count locations in the form of a list containing eight selection criteria. These general criteria for location selection are quoted below (Alta Planning + Design 2010a, 5):

(1) "Pedestrian and bicycle activity areas or corridors (downtowns, near schools, parks, etc.);

(2) Representative locations in urban, suburban, and rural locations;

(3) Key corridors that can be used to gauge the impacts of future improvements;

(4) Locations where counts have been conducted historically;

(5) Locations where there are on-going counts being conducted by other agencies through a variety of means, including video taping;

(6) Gaps and pinch points for bicyclists and pedestrians (potential improvement areas);

(7) Locations where bicycle and pedestrian collision numbers are high; and

(8) Select locations that meet as many of the criteria as possible."

Once a list of potential locations is established, it is recommended that the final count locations be randomly selected. Ultimately, the list of locations should be sited in areas where pedestrian and bicycle traffic volumes would be useful for the local jurisdiction.

A3 – COUNT SCHEDULING METHODS

With the objective of establishing comparable data of locations nationwide, the NBPDP recommends annual dates for bicycle and pedestrian counts. The official annual count period occurs in mid-September, as this is the peak-period of pedestrian and bicycle activity during the year. Three additional, optional annual count periods are recommended during the months of January, May, and July, in order to examine seasonal patterns (Alta Planning + Design 2010a, 1).

The NBPDP indicates that counts should be performed on at least one weekday and on the Saturday before or after the weekday count(s). Weekday counts should occur on a Tuesday, Wednesday or Thursday, under the assumption that travel patterns on these days should not be statistically significant from one another (Alta Planning + Design 2010a, 2). Lastly, no counts should be scheduled on holidays.

As of 2009, the NBPDP recommends that counts occur in 2-hour periods between 17:00-19:00 on weekdays and 12:00-14:00 on Saturdays. The count times are recommended based on historic data showing that these two periods see the highest pedestrian and bicycle traffic volumes (Alta Planning + Design 2010a, 2). Alternatively, more ambitious data collection efforts could schedule counts for 12-hour periods, from 7:00-19:00 on weekdays and Saturdays alike (Alta Planning + Design 2010a, 2). In regard to the final analysis of data collected, it is ideal for counts to occur two or three (preferred) times at each location (Alta Planning + Design March 2009a).

A4 – DATA COLLECTION METHODS

Data Collected Prior to Count Periods

Prior to all counts, the NBPDP directs jurisdictions to collect a total of sixteen pieces of descriptive data for each count location. Each piece of data collected on count locations is quantified, following a coding system established by Alta Planning + Design. The collection and quantification of these descriptive data enable thorough comparisons among different sites within the same jurisdiction and across the nation.

The following is the list of all descriptive data which the NBPDP recommends be collected before the count period (Alta Planning + Design March 2010b, 12-14):

(1) Type of Facility;

(2) Type of Setting (urban/suburban/rural);

(3) Scenic Quality;

(4) Surrounding Land Uses;

(5) Number of Destinations Nearby (parks, schools, etc);

(6) Quality of Connecting Facilities;

(7) Length of the Facility;

(8) Quality of Access;

(9) Quality of the Overall Network;

(10) Traffic Volumes (ADT) of Adjacent Roads;

(11) Posted Traffic speed of Adjacent Roads;

(12) Crossing and Intersection Traffic Volumes (ADT);

(13) Adequacy of Crossing and Intersection Protection;

(14) Condition; and

(15) Topography.

Additionally, data collectors are trained using a variety of methods. First of all, it is recommended that a Count Manager be assigned to the project who will coordinate volunteers, interns, students, or others collecting data (Alta Planning + Design 2010a, 6). A part of this coordination involves training counters, ensuring they understand the data collection forms and how to code the conditions in the field (Alta Planning + Design 2010a, 8). Training materials can be obtained on the NBPDP's official website.

Data Collected During Count Periods

At the beginning of the count period, data collectors are directed to record three pieces of data, which are as follows (Alta Planning + Design March 2010b, 15):

(1) Date of the Count;

(2) Time Period; and

(3) Weather Conditions.

For both the time period and the weather conditions, the NBPDP provides coding guidelines for quantification.

With this foundation background and situational data established, the data of primary interest to the NBPDP is collected. The total number of non-motorized travelers is recorded, noting the number of male and female subjects separately. The following list provides a brief explanation for how the counts should be recorded (Alta Planning + Design March 2010b, 3-7):

(1) Bicycles (counting the number of people, not bicycles);

(2) Pedestrians (including individuals using wheelchairs, strollers, etc.);

(3) Other (such as: individuals riding skateboards, rollerblades, horses, etc.); and

(4) Gender (male or female, by mode type).

Jurisdictions are encouraged to collect additional data on the pedestrians and bicyclists observed during counts; however, these data need not be reported to the NBPDP.

Two types of methods for recording counts might be used when following the methods of the NBPDP. Screenline counts are used for collecting data on non-motorized traffic volume and for analyzing how land use or demographics impact bicycling and walking. Alternatively, intersection counts are used for safety studies or to collect data at areas with high collision rates. The primary difference is that turning movements are recorded when using intersection counts but not when passing screenline counts. The NBPDP does not prescribe one method over the other. Rather, those following their methodological framework are encouraged to use whichever count method will provide the type of data of particular interest to that given jurisdiction (Alta Planning + Design 2010a, 6). It is recommended that every non-motorized traveler pass the screenline or crossing the intersection should be counted each time they cross that point (Alta Planning + Design 2010a, 8).

Post-Count Data Submission

Once a jurisdiction has completed a count following the NBPDP guidelines, it is asked that the count data be submitted to the NBPDP to be included in the national database. Forms can be submitted to: data@bikepeddocumentation.org

A5 – DATA ANALYSIS METHODS

In 2009, the NBPDP refined a formula for extrapolating calculated average bicycle and pedestrian volumes from hourly count totals to estimated weekly, monthly, and annual totals. This formula is tailored for the analysis of shared-use paths as well as areas with dense pedestrian activities. Although the project recognizes that it would be far more ideal that year-round data be available, this adjustment factor enables the NBPDP and local jurisdictions to make the most of the data that is collected through the annual counts (Alta Planning + Design March 2009a).

A6 – RELEVANCE FOR PILOT STUDY

The basic methodology established by the NBPDP serves as the structure of the pilot study. Most descriptive variables collected through this project were considered for inclusion in the pilot study; however, most were not used, due to the physical settings of the selected count locations. As the sites generally shared the same characteristics, the data collected for these variables was not diverse and was of little analytical use. The same is true for the categorical variable for weather conditions suggested by the NBPDP. All other variables included in this national project are included in the pilot study, as are the methods for scheduling data collection.

Case Example B:

WA STATE BICYCLE AND PEDESTRIAN DOCUMENTATION PROJECT

B1 – OVERVIEW OF CASE EXAMPLE

Washington State formally established its own bicycle and pedestrian documentation project in 2008. The project is now organized in late Autumn each year by the Washington State Department of Transportation (WSDOT) (Cascade Bicycle Club 2013, 3). The impetus of this annual tradition was an objective to “increase bicycle and pedestrian transportation choices” WSDOT’s 2009-2015 Strategic Plan (WSDOT 2008a, 30). To accomplish this objective, the plan targets to increase non-motorized connectivity and implement a statewide count. Additionally, the 2008-2027 Washington State Bicycle Facilities and Pedestrian Walkways Plan identifies bicycle and pedestrian counts as one of six performance measures for assessing how the State is meeting the objective to increase choices (WSDOT 2008b, 28).

The statewide counts are managed by the Cascade Bicycle Club (Cascade), a Seattle-based non-profit organization focused on the mission to “create a better community by bicycling” (Cascade Bicycle Club n.d.). Cascade largely coordinates the outreach effort to recruit and schedule volunteers for the many cities involved in the project. The count forms used by all cities and volunteers are produced by Cascade, in addition to instructional materials and background information on the project. Although it differs in some areas, the methodology employed in the Washington State Bicycle and Pedestrian Documentation Project (WSBPDP) is based on the data collection system established by the NBPDP (WSDOT 2014).

In 2014, over 40 cities participated in the count, including Bellevue, Bremerton, Everett, Gig Harbor, Longview, Olympia, Seattle, Spokane, and Wenatchee (WSDOT 2014).

B2 – COUNT LOCATION SELECTION METHODS

Cascade encourages use of the general criteria for selecting count locations established by the NBPDP (Cascade Bicycle Club 2014b, 5). Where the methodology in Washington differs is in a lack of emphasis on random selection. It is also recommended not to perform counts of bicycles at intersections; rather, cities should consider placing bicycle count locations mid-block and/or along trails. Cascade cites two reasons for this location criteria, which are that turning movements: (a) are difficult to track with one volunteer; and (b) not an important variable in the statewide data analysis (Cascade Bicycle Club 2014b, 6).

Another aspect of the selection location process developed by Cascade is a recommendation for each site to be visited prior to the count. During the visit, the local count coordinator should determine the best place for the data collector to stand, considering line of sight and visibility as well as the safety of the individual performing the count (Cascade Bicycle Club 2014b, 6).

To establish a list of count locations, Cascade encourages cities to begin by drafting a list of general categories of locations where pedestrian and bicycle data would be particularly useful. This may include locations along priority corridors, near landmarks, or in areas known to be unsafe to non-motorized road users. Locations might also be equitably distributed throughout areas with different demographics or areas for potential improvement. Lastly, any locations for which there exist historic count data should be included (Cascade Bicycle Club 2014b, 6).

B3 – COUNT SCHEDULING METHODS

Adhering to the NBPDP rationale that Autumn is the peak period for bicycle and pedestrian activity, the annual count in Washington State is scheduled for late-September to early-October. The documentation project records bicycle and pedestrian volumes in all cities for three days in a row. Counts are scheduled from Tuesday to Thursday and occur twice a day in 2-hour periods, from 7:00-9:00 and 16:00-18:00, on weekdays. On weekend days, counts are typically not recprded (Cascade Bicycle Club 2014b, 3).

B4 – DATA COLLECTION METHODS

Data Collected Prior to Count Periods

As the annual counts in Washington State are modeled after the NBPDP, the same fifteen pieces of data describing the setting of each count location are collected (Cascade Bicycle Club 2014a, 1-4). Correspondingly, the Cascade instructs municipalities to assign a Count Coordinator to manage the counts in each jurisdiction and train volunteers before the day of the count (Cascade Bicycle Club 2014a, 7).

Data Collected During Count Periods

The data collected on the day of the count mirrors the methodology developed by the NBPDP. This includes reporting the date, time, and weather conditions, although none of these variables is coded as it is in the national project. Furthermore, the statewide counts record the subjects’ gender as well as noting whether subjects are riding a bicycle, walking, or using some other form of non-motorized travel. In addition to the variables the national project recommends recording, the counts in Washington State also include collecting directional data—noting if subjects are traveling northbound, Southbound, Eastbound, or Westbound (Cascade Bicycle Club 2013, 7). Data collectors are directed to record the direction of travel after any turning movement (Cascade Bicycle Club 2013, 57) While this data is collected, directional patterns of bicyclists and pedestrians are not analyzed in the annual reports produced by Cascade.

Post-Count Data Submission

Volunteer data collectors are directed to return their forms to Cascade within 10 days of the count. Cities self-managing the pedestrian and bicycle counts are likewise asked to submit data to Cascade within the same time period. Data submission can be done via email, sending the completed form to the Cascade Bicycle Club Count Volunteer Coordinator (Cascade Bicycle Club 2014b, 7). Alternatively, count data can be submitted through an online form made available at: www.wsdot.wa.gov/bike/count

B5 – DATA ANALYSIS METHODS

Once all data is collected for participating cities, Cascade produces an annual report describing the aggregate results of the statewide counts. These reports typically compare the counts from participating jurisdictions and report the percent change from counts in years past. The following data is

(1) Pedestrian Count and Percent Change

(2) Bicycle Count and Percent Change

(3) Helmet Use Count and Percent Change

(4) All Variables Above are Reported by Gender

Unlike the NBPDP, Cascade does not appear to use an adjustment factor to extrapolate Autumn count data to year-round count estimates.

B6 – RELEVANCE FOR PILOT STUDY

The primary relevance of this statewide documentation project to the pilot study is the geographic location of both studies. As this study is located within Washington State and their study has roots in the NBPDP, the pilot study is designed to produce data that is directly compatible with this statewide dataset. For this thesis, a compatible dataset enables a direct comparison to particular variables investigated in both projects. Moreover, planning this project to match the Washington State dataset was serendipitous, as several members of staff at Cascade Bicycle Club became involved in this project during the count periods. The organization advertised a need for data collection volunteers, and staff collectively contributed fourteen hours of data collection to this pilot study. This research will be provided to this organization upon completion.

Based on responses to this research, this advocacy organization or others could, for example, promote the expansion of the annual data collection effort to include behavioral variables recommended through this pilot study and report. Each behavioral variable has a different, though possibly overlapping, set of policy and safety implications. Cascade, or any other agency employing these methods, could pick and choose among the recommendations, based on advocacy goals, or become inspired to investigate an unlisted behavior in which bicyclists engage.

Case Example C:

BICYCLISTS' BEHAVIORAL STUDIES IN YEW YORK

C1 – OVERVIEW OF CASE EXAMPLE

The final bicycle count methodology providing inspiration for the pilot study was developed and used for two unrelated studies conducted in New York City in 2009 and 2013. These studies were managed by Professors Peter Tuckel and William Milczarski from the Sociology and Urban Affairs and Planning departments, respectively, at Hunter College at the City University of New York. Similar to the purpose of this pilot study, the 2009 study was developed to address the lack of existing data describing the behavior of bicyclists riding in an urban setting (Tuckel and Milczarski 2009, 2). Specifically, this study was designed to establish a data set describing bicyclists' obedience to traffic laws, with primary aims to (Tuckel and Milczarski 2009, 3):

(1) Estimate the use of bicycle helmets;

(2) Measure the obedience to various selected traffic laws (two laws selected apply only to commercial bicyclists); and

(3) Investigate the use of hand-held and hands-free electronic devices while riding.

This research was continued in 2013 after a set of infrastructural improvements was made in order to augment bicycle access in New York City. That year, 573 miles of bicycle lanes were installed and a new bike share system was introduced to the city, which boasts 6,000 Citi Bikes, located across 330 bike share stations (Tuckel and Milczarski 2014, 1). Building on the research aims established in the 2009 study, the research was expanded to include an comparison of the travel behaviors exhibited by users of the new bike share program with those by commercial bicyclists and general riders. The study specifically asked (Tuckel and Milczarski 2014, 2):

(1) “How does their [Citi Bike cyclists] profile differ, it at all, from cyclists who are not bike-share riders?”; and

(2) “How does their riding behavior compare to cyclists in the city?”

Both studies were conducted with the involvement of graduate and undergraduate programs enrolled in courses instructed by Tuckel and Milczarski. Despite the slight change in focus and different geographies, the same methodological approach was used both years. Unlike the statewide counts in Washington, which were developed around the same time, the methods used in these behavioral studies are notably divergent from those used in the NBPDP. As is discussed below, the researchers at Hunter College employed unique scheduling and count location techniques in their work.

C2 – COUNT LOCATION SELECTION METHODS

In both studies, the count locations were randomly selected from all intersections located within defined study areas. The 2009 study focused on a total of 45 intersections located in Mid-Manhattan, in the area running, east to west, from 1st Avenue to 10th Avenue and, south to north, from 14th Street to 59th Street (Tuckel and Milczarski 2009, 3). Four years later, the researchers’ methodology changed to include a criterion requiring intersections to fall into one of four “strata”, or bicycle facility typologies, which are defined as follows (Tuckel and Milczarski 2014, 3):

(1) Shared roadways with no bicycle lane present (streets or avenues);

(2) Unprotected bicycle lanes (streets or avenues);

(3) Protected bicycle lanes (streets or avenues); and

(4) Bikeways located along the Hudson River and the East River.

As there are no intersections along the bikeways, count locations were placed where the "nearest street would bisect the bikeway were the street extended" (Tuckel and Milczarski 2014, 15). Using these typologies, 98 intersections were randomly selected in a study area located at the south edge of Manhattan at the Hudson River and East River, north to 86th Street (Tuckel and Milczarski 2014, 3).

C3 – COUNT SCHEDULING METHODS

The studies managed by these two faculty members record bicycle counts using widely divergent methodology from that proposed by the national and statewide projects discussed above.

In 2009, counts were scheduled seven days a week during five distinct time periods between 9:00 and 22:00, broken up as follows (Tuckel and Milczarski 2009, 4):

(1) Monday through Friday from 9:00 to 13:00 (undergraduate students);

(2) Monday through Friday from 13:01 to 18:00 (undergraduate students);

(3) Monday through Friday from 18:01 to 22:00 (graduate students);

(4) Saturday and Sunday from 9:00 to 18:00 (undergraduate students); and

(5) Saturday and Sunday from 18:01 to 22:00 (graduate students).

All counts in this first study occurred in April between the 2nd and the 28th in 2009 (Tuckel and Milczarski 2009, 5). This schedule changed in 2013. Still scheduling counts seven days a week, the time schedule shifted from 7:30 to 20:30, with each student preforming counts at given intersections for a one-hour period of time (Tuckel and

Milczarski 2014, 4). All counts occurred between June 10th and November 1st (Tuckel and Milczarski 2014, 5).

The fundamental difference between this scheduling method used by Tuckel and Milczarski and the methods used by Washington State and the NBPDP is that bicycle observations at each count location do not occur simultaneously. Additionally, it is not clear in summary reports whether intersections were counted more than a single time. While the data collected does represent the population of bicyclists at each of the 48 intersections during the given count period, it can be argued that this data is not as comparable as the data collected in the other two case examples.

C4 – DATA COLLECTION METHODS

Data Collected Prior to Count Periods

As stated, data collection in both studies was carried out by students enrolled in graduate and undergraduate level courses at Hunter College instructed by the principal investigators of the research project. In their courses, students were provided instruction in the count methodology and guidelines. Moreover, curriculum included preparation in observational research techniques before fieldwork began (Tuckel and Milczarski 2009, 4).

In regard to data collected describing the count location, the studies in 2009 and 2013 recorded a different series of attributes describing the site. The first study collected two pieces of data (Tuckel and Milczarski 2009, 5):

(1) Roadway Configuration (one-way or bi-directional); and

(2) Census-Tract Data (racial, ethnic, and household economy demographics).

Four years later, however, neither of these variables is collected. Rather, the 2013 study reports collection of the following variables, including (Tuckel and Milczarski 2014, 5):

(1) Type of Bicycle Facility (see the Methodology for Selecting Count Locations sub-section above);

(2) Calendar Date;

(3) Day of the Week; and

(4) Time Period (not formally listed as an attributed collected; it can be assumed this is collected as each student was assigned to a particular date(s)).

The report describing the results of the first study does not include any mention of these site attributes in the analysis. However, the 2013 study did include an investigation and analyses of the type of bicyclist and type of facility used as well as how particular facilities are used by different types of riders (Tuckel and Milczarski 2014, 6-7, 9).

Unlike the statewide and national methodologies, these conditions were not actually recorded prior to, but were rather reported after the completion of the counts.

Data Collected During Count Periods

On the dates students were scheduled to perform counts, they were directed to record several sets of variables describing the demographic make-up and behavior of bicyclists under observation. For example, the subjects' gender was recorded in both studies and the 2009 study recorded whether subjects were over or under the age of 14. Additionally, between the two studies, the researchers grouped bicyclists into three categories, which are (Tuckel and Milczarski 2009, 5; Tuckel and Milczarski 2014, 4):

(1) Commercial Cyclists (is or is not);

(2) Citi Bike Rider (only collected in 2013 study); or

(3) Commuter/Recreational Rider (non-commercial cyclist, non-Citi Bike user).

Beyond these identifying characteristics for the subjects themselves, both studies conducted at Hunter College required students to document bicyclists' obedience to the same seven traffic laws (Tuckel and Milczarski 2009, 5; Tuckel and Milczarski 2014, 4):

(1) Use of a Bicycle Helmet (required of adults over age 14; required by commercial cyclists);

(2) Stopping at Red Lights (required by law);

(3) Riding With or Against Traffic (required to ride with traffic);

(4) Riding on the Sidewalk (prohibited by law);

(5) Riding in the Designated Bicycle Lane (required by law);

(6) Use of Electronic Device while Riding (prohibited by law; including hand-held cell phone or other hands-free devices);

(7) Displaying Business (required by law for commercial cyclists); and

(8) Use of Lights on the Front and Back of the Bicycle in the Evening (only collected in 2009.

In addition to collecting a different set of data on bicycles than the national and Washington State projects, Professors Tuckel and Milczarski developed substantially different methodologies for taking counts. Rather than counting each pedestrian and bicyclist who passes by, in each study the students observing intersections were instructed to count using the following methods (Tuckel and Milczarski 2009, 4-5; Tuckel and Milczarski 2014, 4):

(1) Count no more than one cyclist in a given minute;

(2) Observe the bicyclists riding closest to the student, when two individuals are riding parallel with one another;

(3) Do not count a given bicyclist more than once;

(4) Do not count any bicyclists with an "intimidating presence";

(5) Only count bicyclists 14-years-old and above (collected in 2013 only); and

(6) Observe the intersection in an inconspicuous manner.

The observation method most notable is the first, which limits the size of the sample population based on a unit of time. This methodology is used in these studies in order to self-weight observations, making equal observations for intersections with varying bicycle traffic volumes (Tuckel and Milczarski 2014, 4). The guideline provided to students for adherence to this method is to count the first bicyclist passing by at the start of each new minute (Tuckel and Milczarski 2014, 15). A downside to this method is that only the weighted score is available for analysis, as opposed to a study collecting the total number of bicyclists and dividing this total by the total number of minutes of the study. However, a strong benefit of the method used is that the each given subject has an observer's full focus, ensuring the accuracy of observations made.

Inexplicably, neither study recorded information on weather conditions. This is surprising, as research has confirmed the common assumption that poor weather conditions cause a decrease in bicycle use (Gebhart and Noland 2013, 14) and may also impact how bicyclists behave on the roadway. Moreover, these short lists of site attributes are considerably less comprehensive than the list of variables collected following the methodology established by the NBPDP and used in Washington State.

C5 – DATA ANALYSIS METHODS

Following the completion of each study period, Professors Tuckel and Milczarski produce reports describing the purpose, methods, and findings of the behavioral studies. Within these reports, the results of the observations at the 45 and 98 intersections, in 2009 and 2013 respectively, are presented and variables are compared to one another. For example, the results of observations made for each traffic law studied are compared to the following two or three variables (Tuckel and Milczarski 2014, 5-10):

(1) Type of Bicyclist;

(2) Gender of Bicyclist; and

(3) Time of Day (only analyzed in 2009).

In 2013, the researchers added a comparison of the type of bicyclist to the (Tuckel and Milczarski 2014, 6-7):

(1) Type of Site; and

(2) Type of Facility (only analyzed facilities with bicycle lanes).

Another interesting comparison made in 2013 is the use of a standard, unprotected bicycle lane, observing whether each cyclist (Tuckel and Milczarski 2014, 9):

(1) “Rides only on bike lane;

(2) Rides only on street/ave; or\

(3) Rides on both bike lane and street/ave.”

C6 – RELEVANCE FOR PILOT STUDY

Of particular interest to the pilot study, the analysis of the 2013 observations of stopping at red lights included three categories under the umbrella term “stop”. These are as follows (Tuckel and Milczarski 2014, 8):

(1) “Stops fully at red light;

(2) Pauses and then goes thru red light; or

(3) Does not stop or pause when light is red.”

Approximately one-third of all subjects were observed engaging in each of the three actions, with the small proportion coming to a full and complete stop (Tuckel and Milczarski 2014, 8). That is also to say, a substantial portion of the subjects observed in New York are employing an action behavior similar to a rolling stop at signalized intersections. This finding suggests that bicyclists may behave similarly at intersections controlled by stop signs and/or suspended flashing red beacons. Furthermore, the inclusion of these three variables for describing bicyclists' actions at a red light makes these particular results of this study relevant to a broader discussion regarding a rolling stop and, therefore, relevant to the final analysis of the results of this pilot study.

Case Example D:

NHRC COMPARISON OF BICYCLE LANES TO WIDE CURB LANES

D1 – OVERVIEW OF CASE EXAMPLE

The final methodological case example is a technical report presenting a comparative analysis of bicyclists' behaviors and actions while using bicycle lanes and wide curb lanes in three cities located in California, Florida, and Texas. This study was conducted between 1995 and 1998 by a team of five researchers at the Highway Safety Research Center (NHRC) at the University of North Carolina, with support from the Federal Highway Administration. This tri-state study is targeted at meeting two primary objectives (Hunter et al. 1999, 2):

(1) Complete a comparative analysis of bicycle lanes verses wide curb lanes; and

(2) Establish a guidebook providing “current innovative bicycling activities” and countermeasures for issues identified by the analysis.

A principal issue brought up in this research is the increasing desire for bicycle facilities in American cities, coupled with a lack of rigorous evaluation data describing the effectiveness or utility of implemented facilities (Hunter et al. 1999, 1). Focusing on the debate regarding the utility of bicycle lanes verses wide curb lanes, this research was designed to address this data gap and inform the activities of bicycle advocacy groups or best practices of transportation engineers.

The study involved this observational data collection, in addition to developing a bicycle experience survey of bicyclists who were observed (Hunter et al. 1999, 15). This thesis only describes the methods for the observational data, as the experience survey is less directly relevant to the purposes of this chapter and research.

D2 – COUNT LOCATION SELECTION METHODS

The research team considered the following five key factors to determine the final list of cities included in the nationwide study (Hunter et al. 1999, 11):

(1) Type of Bicycle Facilities;

(2) Intensity/Amount of Bicycle Facility Types;

(3) Local Bicycle Volumes;

(4) Partnerships with Local Coordinators; and

(5) Opportunity for Videotaping (based on weather).

As this final factor indicates, this national study does not investigate weather and favors dry climates. Based on these criteria, Santa Barbara, California, Austin, Texas and Gainesville, Florida were selected for study

To determine the 16 count locations across the three cities, an additional list of factors was used to determine the exact data collection sites in the three selected cities, which is (Hunter et al. 1999, 12):

(1) Width of Bicycle Lane (> and < 1.5 meters)

(2) Width of Wide Curb Lane (> and < 4.3 meters)

(3) or Wide Curb Lane (wide vs. narrow);

(4) Speed Limit (low vs. high);

(5) Traffic Volume (low vs. high); and

(6) Bicycle Volume (objective of 20-30 bicyclists per hour)

Sites in Austin and Gainesville were located near the university campuses, as higher volumes of bicyclists were expected near these centers. As the University of California, Santa Barbara is located in a suburban area, however, the campus in this city was not targeted as an ideal location for bicycle count locations (Hunter et al. 1999, 14).

D3 – COUNT SCHEDULING METHODS

Dissimilar to the other three case examples, this study utilized videotape recordings exclusively to document behaviors rather than on-site data collection. Traffic cones were spaced 30.5 meters apart along the sidewalk, to afford a measure of distance and identify where actions occurred when reviewing video footage (Hunter et al. 1999, 15).

All sixteen intersections were recorded twice in two-hour intervals. Methods for scheduling the video recordings are significantly less strict than those used by the NBPDP. Each intersection was recorded twice during two-hour periods, with a general goal of recording all intersections at the same time, once during the morning and weekend. However, the researchers allowed adjustments to this schedule. For example, intersections that saw low bicycle traffic volumes on weekends were to be recorded twice during the week instead ((Hunter et al. 1999, 14–15). In addition to these 2-hour recordings, one 15-minute video was made at each location, with the camera focused on the lanes of vehicular traffic. This recording was made at a time said to “correspond to the time of the bicycle video taping” and is intended to be used to estimate the number of vehicles crossing through the intersection and, thereby, estimate how exposed to traffic bicyclists are at each location (Hunter et al. 1999, 15).

No exact schedule of video recording periods was published in the technical report.

D4 – DATA COLLECTION METHODS

Data Collected Prior to Count Periods

In addition to the data collected in the process of selecting the count locations, the research team collected several pieces of descriptive data on each location, including the following (Hunter et al. 1999, 14):

(1) Traffic Control Devices;
(2) Type of Pavement Markings (striping);
(3) Number of Lanes of Traffic;
(4) Estimated Driving Speed;
(5) Average Annual Daily Traffic;
(6) Presence of Parking; and
(7) Details on the Bicycle Lanes and Wide Curb Lanes.

Data Collected During Count Periods

With the use of video recording equipment, the research team was able to include a more expansive set of variables in the data set. As the list of variables used in this research is extensive, the variables presented in the three lists below are not an exhaustive record of variables collected, but are those of most significance to the development of this pilot study. The first group describes the characteristics of bicyclists under observation. The second two groups listed relate to the actions the bicyclists made at the intersections as well as information on the conflicts observed.

Bicyclists' Characteristics: (Hunter et al. 1999, 20)

(1) Gender;

(2) Helmet;

(3) Age; and

(4) Wrong Way Riding (on sidewalk and roadway).

Intersection Actions: (Hunter et al. 1999, 30, 32–33)

(1) Facility Bicyclist Approached Intersection Along;

(2) Change in Facility Bicyclist Approached Intersection Using Along:

(3) Obedience to Traffic Signals and Stop Signs;

(4) Safety of Maneuvers Made by Bicyclists Disobedient to Traffic Signals and Signs;

(5) Turning Movement (Straight, Left, Right);

(6) Method of Crossing Intersection When Traveling Straight;

(7) Method of Left Turns;

(8) Method of Right Turns;

(9) Walking Bicycle Through Intersection; and

(10) Tracking Movement (straight, shy right, shy left).

Conflict Type: (Hunter et al. 1999, 40)

(1) Motor Vehicle Position During Conflict;

(2) Bicyclists' Avoidance Response;

(3) Seriousness of Conflict; and

(4) Bicyclist and Motorist Action in Intersection Conflict.

D5 – DATA ANALYSIS METHODS

Results presented in this technical report are primarily descriptive in nature. These descriptive results are presented as comparison of data collected on bicycle lanes or wide curb lanes, with the statistical significance of findings noted. While statistical modeling was not done on all variables, the research team did develop linear regression models to investigate conflict data observed. The models were designed through a process of testing different sets of variables and omitting insignificant variables from the model while adding others that may be involved (Hunter et al. 1999, 25). The focus of this analysis is a comparison of the results at the two bicycle facility types under investigation. Following up the regression model results reporting, is a clinical analysis of the count locations experiencing the highest conflict rates.

D6 – RELEVANCE FOR PILOT STUDY

The purpose and objectives of this analytical study are very similar to the intention of this thesis, even including a variable directly related to the primary research question. As with the studies conducted by faculty and students at Hunter College, this late-90's study recorded the obedience to traffic signals and, furthermore, documented compliance to stop signs. Unfortunately for the goals of this research, the investigation of obedience to signs and signals are binary variables that do not address the use of rolling stops. This thesis assumes rolling stops were categorized as disobeying the stop sign, although the report does not make any indication either way.

Methodologically, this case example served as the inspiration for a qualitative variable included in the pilot study that describes the safety of bicyclist maneuvers. Rather than recording safety data only on bicyclists who disregard the stop signs, however, the pilot study records this variable for the safety of maneuvers for all bicyclists observed. This variable is extended in order to afford an investigation into the differences in safety among bicyclists using the three defined stopping behaviors. The descriptive analysis of the results for this variable in the pilot study is provided in Chapter 8 “Pilot Study Descriptive Statistics.”

CHAPTER 4:

PILOT STUDY COUNT LOCATIONS

METHODOLOGY FOR SELECTING LOCATIONS

THEORETICAL FRAMEWORK

The theoretical framework guiding this examination of the behavioral mobilities of bicyclists is founded on the following thesis:

> *Human perspective and situational circumstances play a large role in the outcome of any given mobilities scene.*

Based on this hypothesis, these methods assume that bicyclists will exhibit different behaviors or engage in different actions depending on a wide number of variables related to the:

(1) Regulations in place and the way laws are interpreted and obeyed in practice in a given place;
(2) Physical setting and weather conditions; as well as
(3) Individual bicyclists' experience levels and familiarity with the area.

While this study does not delve deeply into the third area that directly influences human perspective, the first two indirect influences on mobility are expressly explored herein. The first influence listed above is of primary focus in this study, as this is an investigation of whether, and to what degree, bicyclists obey the stop sign law. This main investigation is augmented through a careful selection process for determining the physical setting in which data is collected.

COUNT LOCATION SELECTION CRITERIA

Acknowledging that bicyclists' behavioral movements are often location-specific, the list of locational criteria for any given observational study will vary depending on the focus of the study. With this in mind, this study recommends that the task of determining the site(s) for any study observing behavioral mobilities begin by establishing a list of criteria required for the affordance of the behavior(s) under examination.

Behavior-Specific Selection Criteria

As this pilot study aims to examine how bicyclists behave at intersections controlled by stop signs, selected locations must meet the three following criteria:

(1) Must be on a public right-of-way;

(2) Must be an intersection of two roadways, a point of intersection between two off-street paths, or the intersection of an off-street path with the roadway; and

(3) Must be controlled by stop signs and/or suspended flashing beacons.

Together, these three qualities establish the environment in which a bicyclist must make a decision to stop, use a rolling stop, or not stop at all where they are legally required to do so.

Location-Specific Selection Criteria

To supplement this behavior-specific list of criteria and reflect the project's theoretical framework, the primary place-specific criterion used to determine count locations requires that a diversity of bicycle facility types are present at selected locations. This study further suggests that any data collection site selection might begin with a consideration for the guidelines proposed by the National Bicycle and Pedestrian Documentation project, which is presented in Chapter 3 "Methodological Case

Examples". These guidelines urge a consideration for recording counts along busy corridors, areas that may be in need of improvement, or locations with a high incidence of bicycle or pedestrian collisions. Additionally, the NBPDP recommends projects consider including an equal number of data collection sites in urban, suburban, and rural areas (depending on the scope), as well as locations with ongoing or historic counts (Alta Planning + Design 2010a, 5). As this project is based exclusively in an urban setting, variety in setting is achieved by requiring that no two count locations be sited within the same neighborhood and intersections at which bicycle counts regularly occur are prioritized in the selection process.

The following list represents these three place-specific criteria used to determine count locations for this pilot study:

(1) Each of the following six types of bicycle facilities must be represented by one or more of the selected intersections:
  (a) Shared Roadway;
  (b) Bicycle Lanes;
  (c) Buffered Bicycle Lane;
  (d) Greenway;
  (e) Bikeway; or
  (f) Off-Street Path.
(2) Topography and other variables describing the physical setting should be varied;
(3) No more than one count location in any one neighborhood; and
(4) Preference is given for locations where counts are regularly recorded and documented.

Of these location-specific criteria, the second played a very large role in selecting the locations to be observed. The City of Seattle systematically collects bicycle counts at fifty locations on a quarterly basis, adhering to the methods and submitting data to the NBPDP (SDOT 2014a). A portion of these intersections is, likewise, included in the annual statewide bicycle and pedestrian counts run by WSDOT and the Cascade Bicycle Club. Moreover, as of 2014, the City owns nine automatic bicycle counters, operating throughout the city along bicycle and pedestrian corridors—two of which provide data 24/7/365 and seven of which provide monthly reports (SDOT 2014b).

The process for selecting intersections began with a review of this combined list of fifty-nine locations regularly observed for the purposes of data collection on bicycle patterns and volumes. Each intersection on this list meeting the three behavior-specific criteria is considered a candidate for observation in this pilot study. Only four of the locations recorded for the NBPDP and three with automatic bicycle counters are intersections controlled by stop signs and/or suspended flashing red beacons. Two locations (B and C) included in the national and statewide projects and two of the locations (D and F) featuring automated bicycle counters yielding monthly data are included in this pilot study. The review of each these citywide count locations highlighted that most stop sign controlled intersections recorded for the quarterly NBPDP counts feature bicycle lanes or shared roadways, whereas the automatic bicycle counters are located along the city’s greenways, off-street paths, or near other important bicycle connections. This finding is reflected in the bicycle facilities in place at these four selected count locations for this pilot study.

No intersections featuring stop signs and bikeways are counted on a regular basis by the City of Seattle. Therefore, an intersection (E) along one of the City's new bikeways, featuring a stop sign, was located. For the sixth and final intersection (A), a third intersection, including both shared roadways and bicycle lanes, is included. The rationale for observing more locations with these two types of facilities is that they are substantially more common typologies than bikeways, greenways, or off-street paths.

LIST OF SELECTED COUNT LOCATIONS

Using the selection criteria established for this pilot study and introduced in this chapter, stop sign controlled intersections located in each of the following Seattle neighborhoods were selected for observation:

(A) Capitol Hill;
(B) Queen Anne;
(C) Greenlake;
(D) Ballard;
(E) University District; and
(F) Sand Point.

The remainder of this chapter provides details on each individual count location as well as a summary of the physical attributes investigated as variables in a statistical analysis of pilot study results.

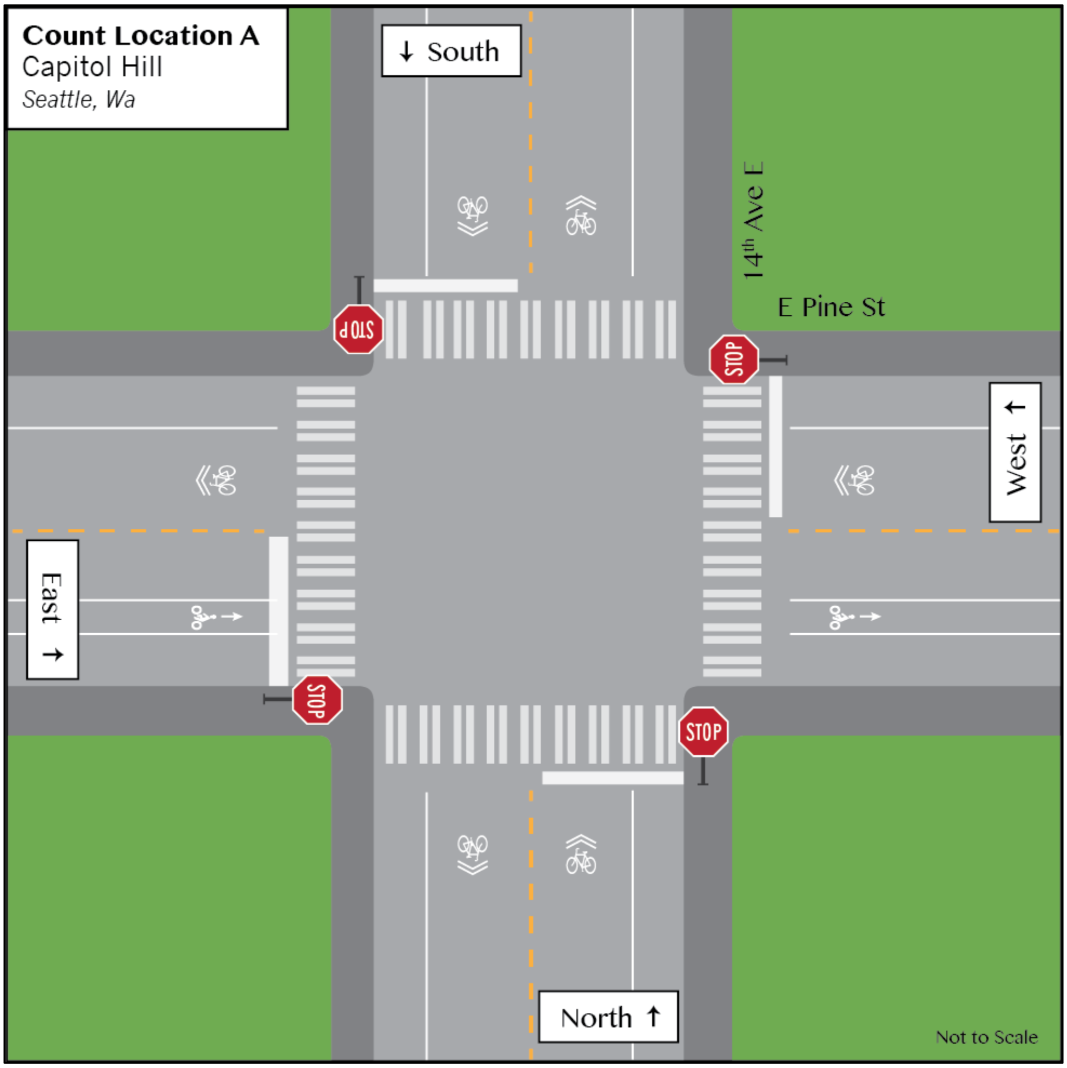
PROFILES OF SELECTED COUNT LOCATIONS

COUNT LOCATION A – CAPITOL HILL

Count Location A is at the intersection of 14th Avenue East and East Pine Street in the Capitol Hill Neighborhood. Each bicyclist entering the intersection from each cardinal direction is recorded, as all must stop at the stop signs installed.

FIG. 7: Count Location Diagram – Capitol Hill

CAPITOL HILL COUNT LOCATION:
14th Avenue East and East Pine Street



Located along the Pike-Pine corridor, this intersection primarily accommodates bicycle transportation through shared roadways. This is an area which is decidedly mixed use. This intersection, specifically, features apartments with ground floor retail and/or dining, a religious institution, and the back face of a hair salon. On both intersecting roads, traffic speeds are the standard 30 mph for arterial roads, as is true for all count locations. Stop signs are placed on each corner, above an “all way” sign blade and another blade informing road users of the restriction against parking within 30 feet of the sign. No red beacon is present. One streetlight is installed on the Northeast corner of the intersection. Curb ramps are located on each curb, and piano key crosswalks as well as stop bars are present on all sides.

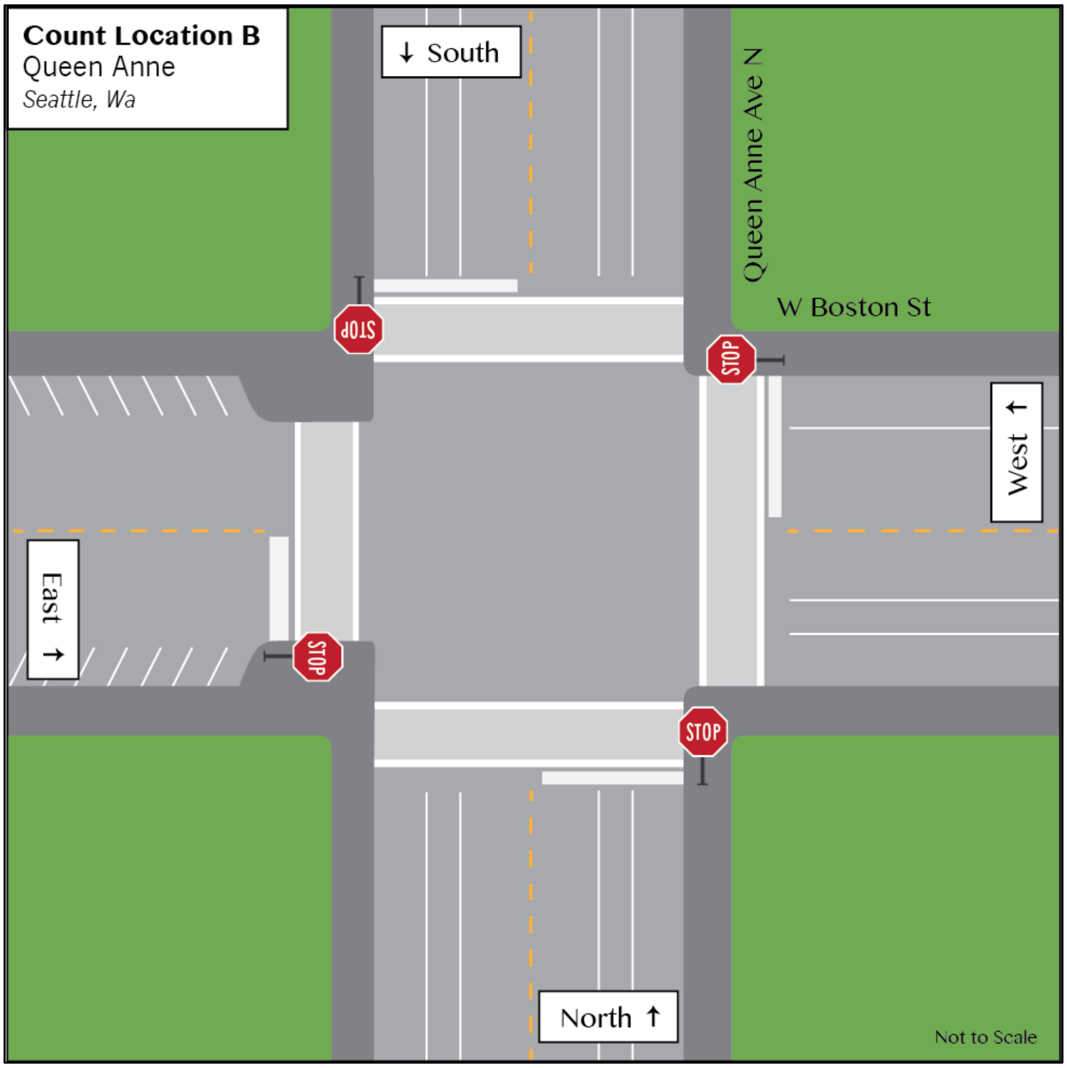
Sharrows are stamped on the roadway, just before the crosswalk, when facing the intersection. The Eastbound bicycle lane is a climbing lane, giving bicyclists traveling up E. Pine Street a dedicated space on a section of the roadway, which may be slower and more difficult for some riders. This climbing lane is paired with a shared roadway for faster, downhill moving bicyclists, a common practice in the City of Seattle.

COUNT LOCATION B – QUEEN ANNE

Count Location B is at the intersection of Queen Anne Avenue North and West Boston Street, in a part of the Queen Anne neighborhood known as Upper Queen Anne. All bicyclists entering the intersection are recorded, as directions of travel must come to a stop at stop signs located on each corner.

FIG. 8: Count Location Diagram – Queen Anne

QUEEN ANNE COUNT LOCATION:
Queen Anne Avenue North and West Boston Street



This intersection is included in the quarterly citywide counts which take place in the City of Seattle reported to the National Bicycle and Pedestrian Documentation Project. Each corner features low-rise retail, with residential units located above ground floor retail on one corner. Stop signs are installed on each corner, and traffic signals still hang above the intersection, from when the intersection was once controlled by traffic lights. A moderately high number of vehicles cross through this intersection on a daily basis. Parking is available at the curb on the north, east, and south segments of the intersection, with angle parking on the west segment. Non-motorized traffic is well catered to with wide sidewalks, bicycle racks, and street trees with planter strips. Moreover, cafes and eateries on each corner provide café seating to patrons and passers by. The crossings are celebrated with a brick pattern stamped into a light grey pavement, painted with two parallel white bars marking the width of the crosswalk.

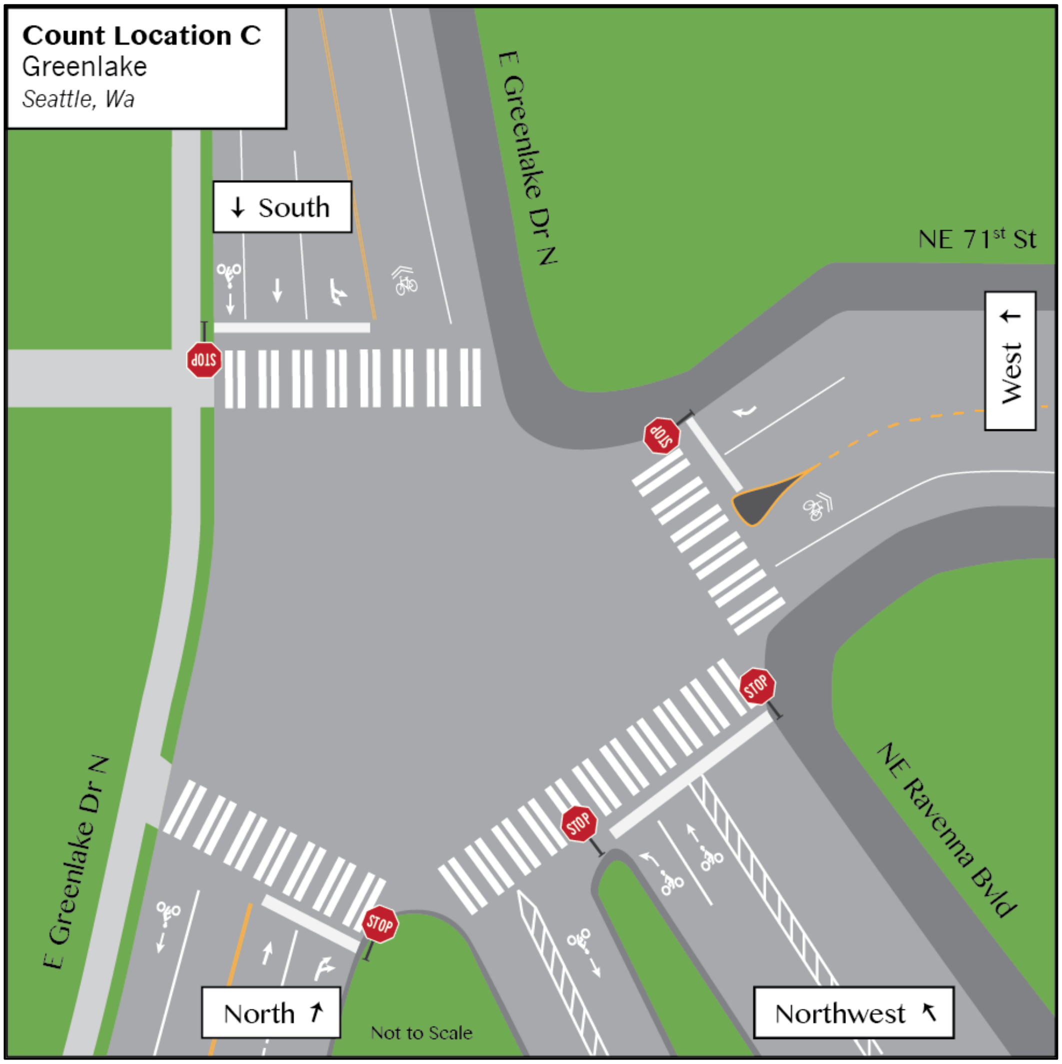
North-south moving bicyclists are accommodated with bicycle lanes, as are those heading eastbound after the crossing. Bicyclists traveling west, or east before the intersection, however, must share the road with vehicular traffic. As the area is relatively level, bicycling in all directions needs to neither ascend nor descend any hills immediately around this intersection.

COUNT LOCATION C – GREENLAKE

Count Location C is at the intersection of East Greenlake Drive North, Northeast Ravenna Boulevard, and Northeast 71st Street in the Greenlake Neighborhood. Bicycle traffic traveling on all three intersecting roadways is recorded, as travelers in all directions must stop at stop signs.

FIG. 9: Count Location Diagram – Greenlake

GREENLAKE COUNT LOCATION:
East Greenlake Drive North, Northeast Ravenna Boulevard, and Northeast 71st Street



This k-shaped intersection, located adjacent to the East side of Greenlake, is included in the quarterly counts conducted by the City of Seattle. Of the six intersections included in this pilot study, this represents the most complex, due to the shape and the inclusion of a boulevard with a wide, planted median separating one-way couplets. The location is controlled by five stop signs and a total of three flashing red beacons suspended above the intersection. With the lake to the west, single-store retail is on the east side of North Greenlake Drive East and residential land uses are within a block of the intersection. Traffic is moderately high on intersecting roads; however, very little on-street parking is available, making for a safer environment for bicyclists who do not have to watch for cars pulling away from or toward the curb.

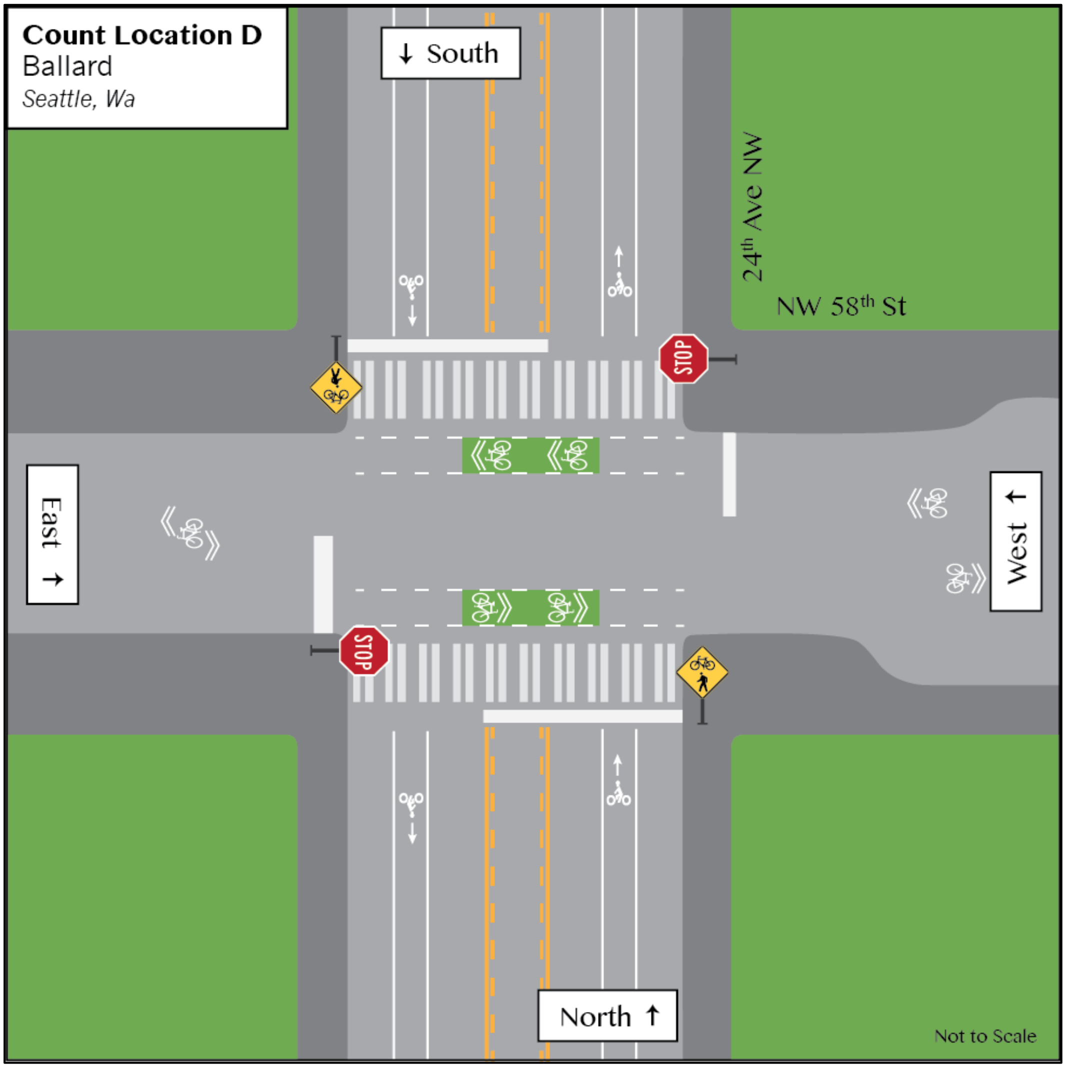
Bicyclists traveling north on East Greenlake Drive North, as well as those traveling east-west on NE 71st Street, must share the road. Southbound bicyclists on East Greenlake Drive North are provided a bicycle lane between the curb and the lane of traffic. Along Northeast Ravenna Boulevard, wide bicycle lanes are separated from vehicular traffic by two solid white lines with diagonal hatching. At the intersection, this boulevard also features a left-hand turn-lane for bicyclists.

COUNT LOCATION D – BALLARD

Count Location D is at the intersection of 24th Avenue Northwest and Northwest 58th Street in the Ballard Neighborhood. Only bicycle traffic entering the intersection from the east or west is recorded, as north-south bicyclists are not required to stop at a stop sign.

FIG. 10: Count Location Diagram – Ballard

BALLARD COUNT LOCATION:
24th Avenue Northwest and Northwest 58th Street



This intersection in Ballard is located along one of Seattle's neighborhood greenways, which are residential streets where non-motorized traffic has priority on the roadway (SDOT 2014, 32). In concert with the upgrade of this street to a greenway, as of February 2014, a bicycle counter one block east collects monthly total east-west bicycle traffic volumes (SDOT 2014b). Stop signs require those traveling on the Northwest 58th Street greenway to stop, and north-south traffic sees a yield sign at the intersection. Pedestrians and bicyclists on the greenway, however, are provided push-button actuation devices to activate a suspended flashing yellow beacon above the intersection. This beacon is meant to call attention to non-motorized greenway traffic, encouraging north-south traffic to yield more quickly to east-west traffic. The speed limit along the greenway is 25 mph, with a higher speed limit of 30 mph on 24th Avenue Northwest.

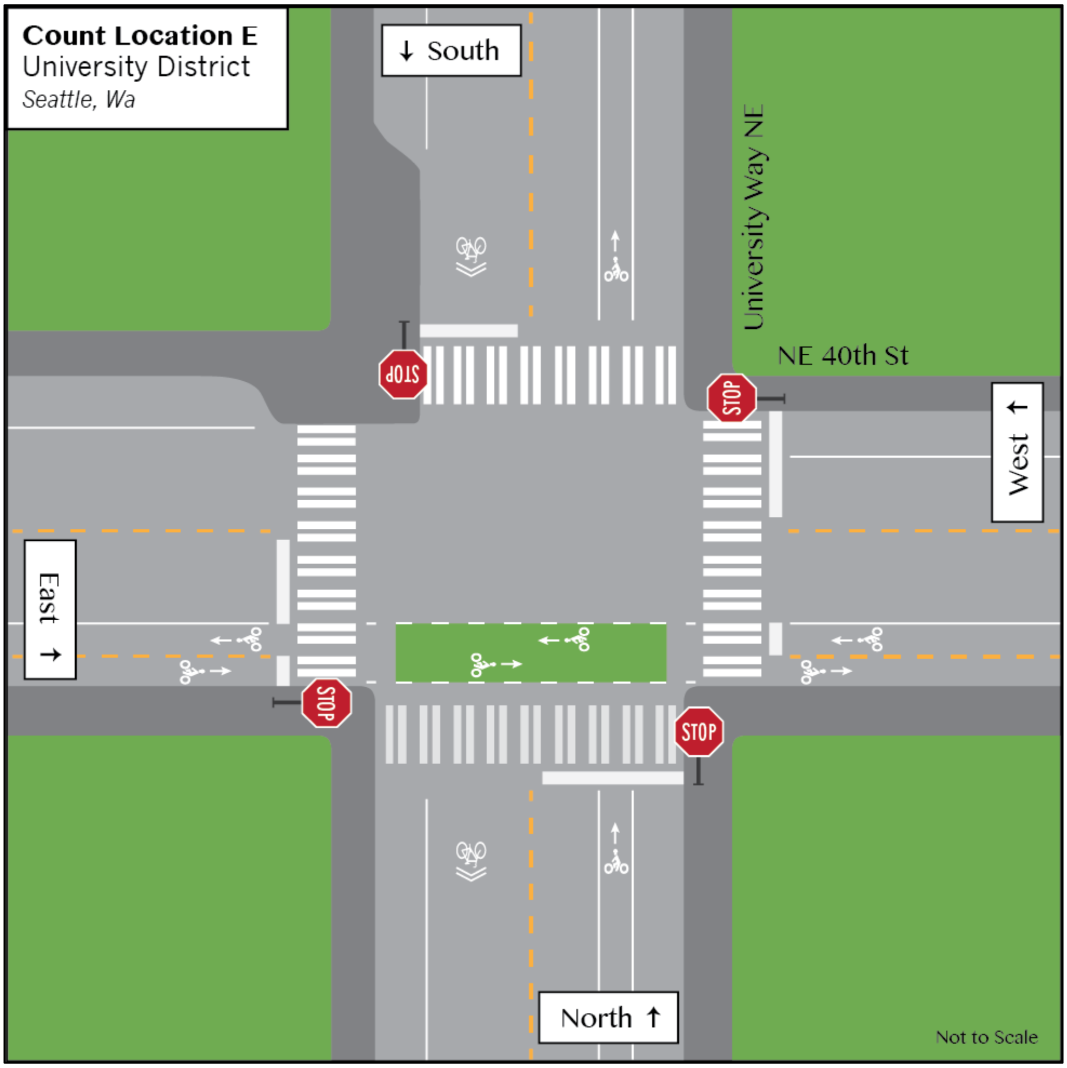
Bicyclists traveling east-west along Northwest 58th Street are accommodated with the greenway and green bicycle lanes through the intersections. The greenway itself is marked with signs and sharrow markings on the roadway. A bicycle lane is provided to northbound bicyclists traveling along 24th Avenue Northwest, making the climb up the avenue's slope. Southbound bicycle traffic rides with traffic, with sharrows marking the roadway.

COUNT LOCATION E – UNIVERSITY DISTRICT

Count Location E is at the intersection of University Way Northeast and Northeast 40th Street in the University District. All bicyclists crossing this intersection are recorded, as stop signs control all directions of traffic.

FIG. 11: Count Location Diagram – University District

UNIVERSITY DISTRICT COUNT LOCATION:
University Way Northeast and Northeast 40th Street



One block from a main entrance to the University of Washington, this location is along one of the City of Seattle's new bikeways. Stop signs are installed on each corner. As the bikeway functions as second two-way path on the roadway, stop bars are marked for vehicular traffic as well as on the bikeway. As this intersection was signalized before the installation of the bikeway, the traffic lights remain in place and the red signals flash as a suspended beacon might. A slight downhill occurs westbound after the intersection on Northeast 40th Street, and there is a relatively shallow hill to climb heading north up University Way Northeast. Along both intersecting streets, the speed limit is 30 mph. On-street parking is provided on each side of the intersection, with the exception of the curb the bikeway is located along.

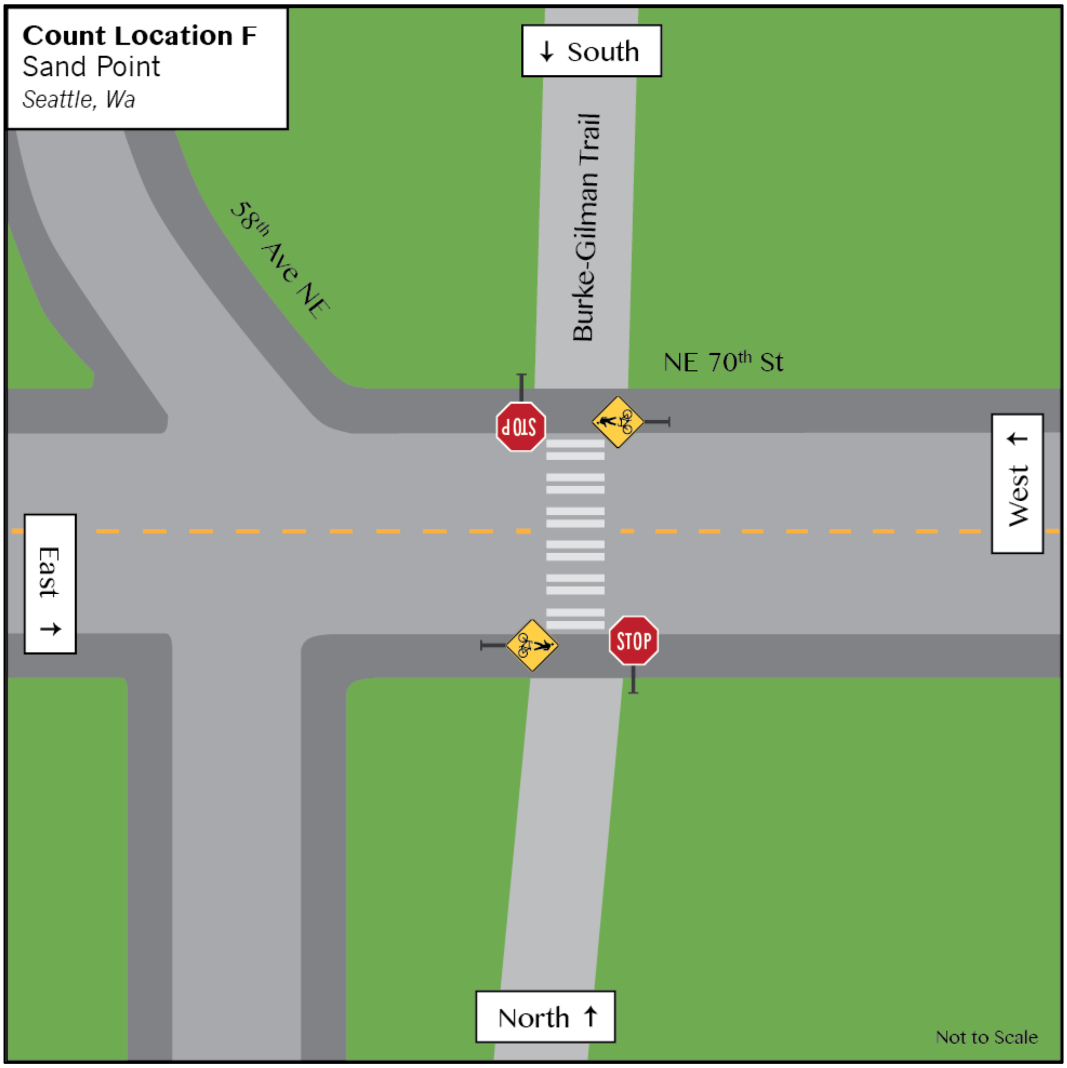
A bikeway is installed along the south side of Northeast 40th Street. This is a bi-directional bicycle lane located at-grade with and installed on the roadway. Bicyclists are separated from vehicular traffic by two solid white lines, diagonal hatching, and plastic bollards. At the crossing, bicyclists using the bikeway are provided a bi-directional green bicycle lane across the intersection. Heading north up University Way NE, a bicycle lane is installed to aid bicyclists climbing the hill, with sharrows provided for bicyclists traveling downhill in a southbound direction.

COUNT LOCATION F – SAND POINT

Count Location F is at the intersection of the Burke-Gilman Trail and Northeast 70th Street in the Sand Point neighborhood. The only bicyclists recorded are those traveling north or south on the Burke-Gilman Trail before the intersection with Northeast 70th Street, as only the trail riders must come to a stop at this crossing.

FIG. 12: Count Location Diagram – Sand Point

SAND POINT COUNT LOCATION:
Burke-Gilman Trail and Northeast 70th Street



At this intersection, the Burke-Gilman Trail intersects with a narrow arterial road that has no on street parking. While Sand Point is a largely residential part of Seattle, this trail is a regional artery of non-motorized transportation, and the location itself is very close to the large and well-used Magnuson Park. Long-range bicycle planning in the City of Seattle signals the importance of this location, as it is one of seven locations in the city where monthly bicycle traffic volumes are recorded using bicycle counters (SDOT 2014b).

On Northeast 70th Street, the intersection with this trail is marked with a standard piano key crosswalk and signs facing east and west bound traffic, warning road users that pedestrians and bicyclists might cross the intersection. Bicyclists on the trail are instructed to stop, by stop signs and wooden bollards aligned perpendicularly to the path. Bicyclists and pedestrians are required to come to a complete stop, wait for crossing traffic to yield, and then safely cross (Fucoloro 2011). The path itself is a paved trail with no markings. Any bicyclist turning off of the trail at the crossing must share the road with vehicular traffic; however, no sharrows are present.

OVERVIEW OF LOCATIONAL VARIABLES

This conclusion to the introduction to the six stop sign controlled intersections selected for observation in the pilot study is framed around the locational variables identified for analysis. Each variable describing the physical setting is intentionally focused on evaluating infrastructure related to visibility and protection. This thesis selected this collection of variables based on the rational that each may influence stopping behavior and are of interest for analysis. See Chapter 7 “Pilot Study Variables” and Chapter 9

"Pilot Study Results", for an extended discussion and presentation of results presented on each of the following variables.

SIGN CONFIGURATION, FLASHING BEACONS, AND GREEN BICYCLE LANES

Four of the six count locations feature four-way stops controlled by stop signs on each corner, including Capitol Hill, Queen Anne, Greenlake, and the University District (Fig. 13). In the past, the intersections in Queen Anne and the University District featured traffic signals. These now superfluous signals have been reprogrammed to flash red in all directions. In comparison with the flashing red beacons used at the other four-way stops, these flashing signals make the stop sign controls more highly visible to road users.

In Ballard, bicyclists using the east-west neighborhood greenway are required to stop at a stop sign. On each side of 24th Avenue Northwest, bicyclists and pedestrians are provided separate signal actuation buttons that illuminate flashing yellow beacons on yield signs to pedestrians and bicyclists located on both sides of the avenue. The situation is similar in Sand Point, where bicyclists riding on the Burke-Gilman trail, crossing Northeast 70th Street, are controlled by stop signs in both directions (Fig. 14). Traffic traveling on the intersecting roadway, however, is controlled with yield to pedestrian and bicycles signs, installed just before the trail crossing, but no signals are installed to illuminate the trail crossing to traffic on the street. At both of these intersections, with or without flashing signals, the law at these crossings is that non-motorized traffic must come to a stop at the intersection to ensure they are visible to crossing traffic. At the time a driver or other road user sees a pedestrian or bicyclist waiting to cross, they must yield the right-of-way (Fucoloro 2011).

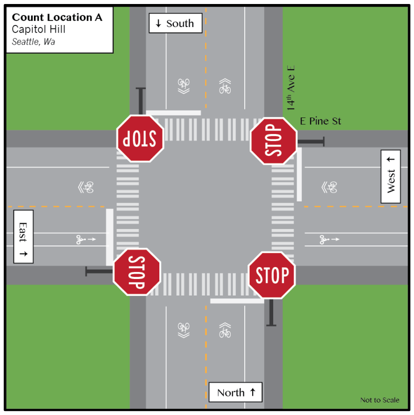
The highest quality crosswalk faculties are provided in Queen Anne, where the pavement is stamped with a brick pattern and two horizontal white bars are painted to distinctly identify the crosswalk's width. Piano key crosswalks are installed at the other count locations, with the exception of Ballard. No crosswalk is provided at the intersection of the greenway for North-South moving non-motorized traffic using the sidewalks. They are, however, installed for east-west moving pedestrians, adjacent to green bicycle lanes installed in the crossing. A different version of a green bicycle lane is installed along the bikeway in the University District (Fig. 15). These green bicycle lanes—which are not expressly allowed by the nation's Manual of Uniform Traffic Control Devices—are intended to inform traffic of bicycle crossings (Lindley 2011).

FIG. 13: Count Location Profile Maps – Stop Sign Configuration

INTERSECTION CONFIGURATIONS AT THE COUNT LOCATIONS:
Visual Description of Stop Sing Configurations

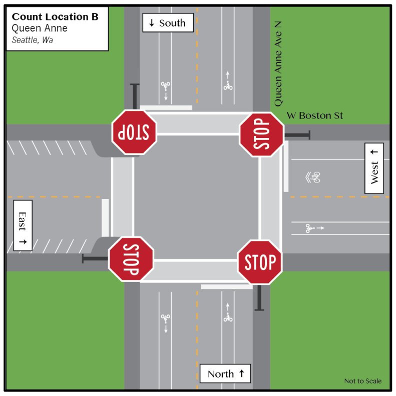
CAPITOL HILL

Four-Way Stop



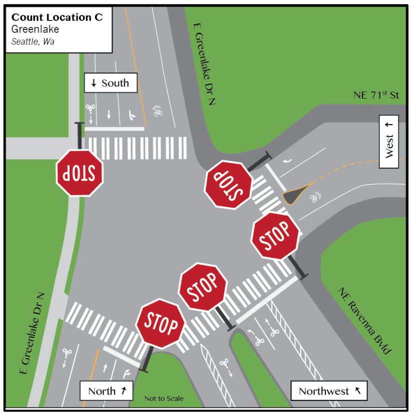
QUEEN ANNE

Four-Way Stop



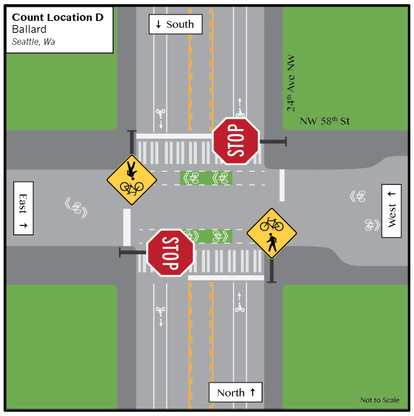
GREENLAKE

Unique Four-Way Stop



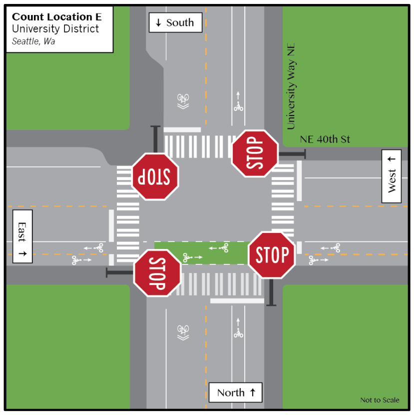
BALLARD

Two-Way Stop, Two-Way Yield



UNIVERSITY DISTRICT

Four-Way Stop



SAND POINT

Two-Way Stop, Two-Way Yield

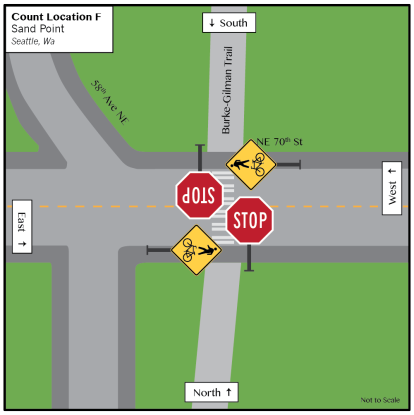


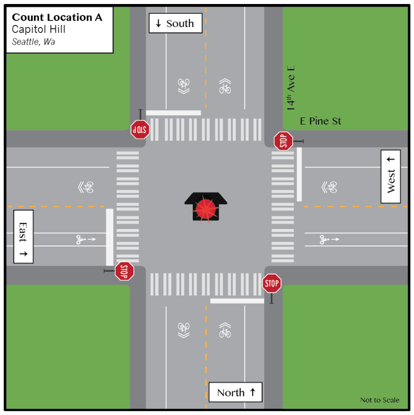
FIG. 14: Count Location Profile Maps – Flashing Beacon

FLASHING BEACONS PRESENT AT THE COUNT LOCATIONS:

Visual Description of Traffic Control Devices

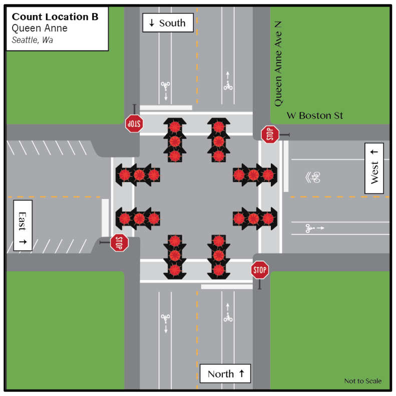
CAPITOL HILL

One Single Suspended Flashing Red Beacons



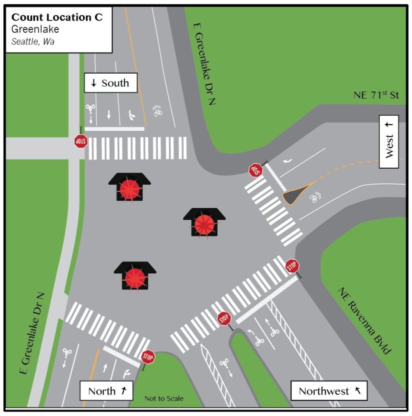
QUEEN ANNE

Repurposed Flashing Traffic Signals



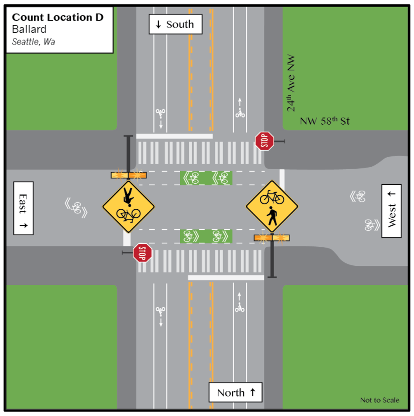
GREENLAKE

Three Suspended Flashing Red Beacons



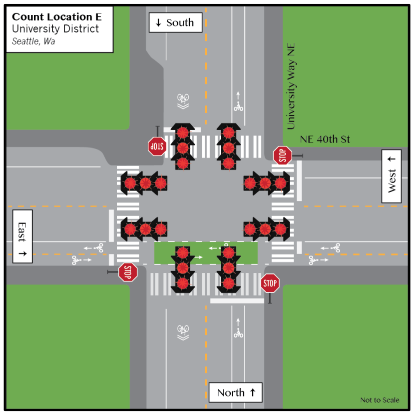
BALLARD

Flashing Yellow Beacons on Yield Signs



UNIVERSITY DISTRICT

Repurposed Flashing Traffic Signals



SAND POINT

No Flashing Beacons

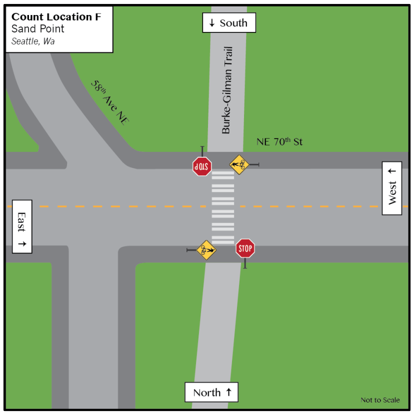


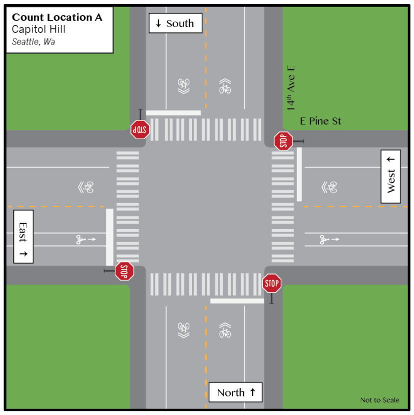
FIG. 15: Count Location Profile Maps – Green Bicycle Lanes

GREEN BICYCLE LANES PRESENT AT THE COUNT LOCATIONS:

Visual Description of Intersections with Green Bicycle Lanes

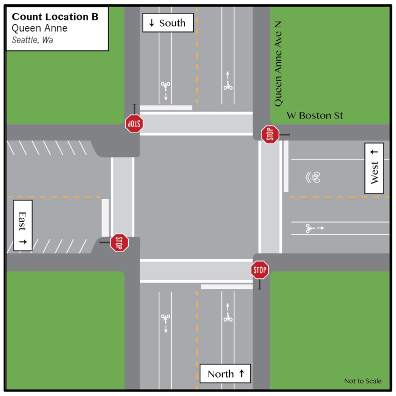
CAPITOL HILL

No Green Bicycle Lanes



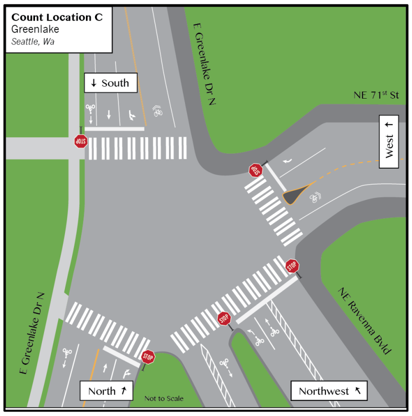
QUEEN ANNE

No Green Bicycle Lanes



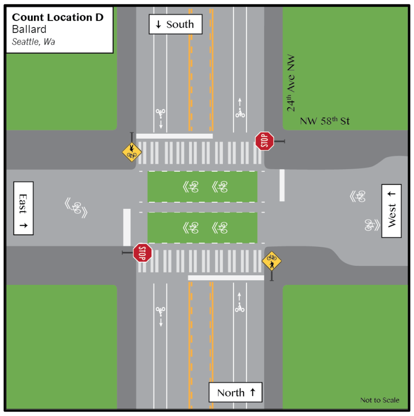
GREENLAKE

No Green Bicycle Lanes



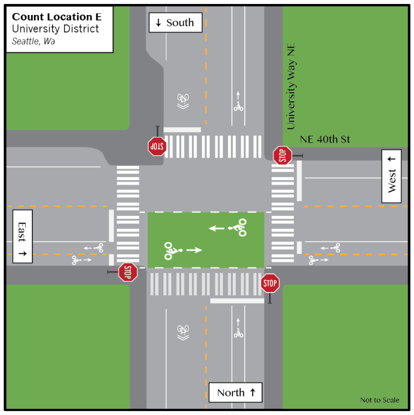
BALLARD

Green Bicycle Lanes Present



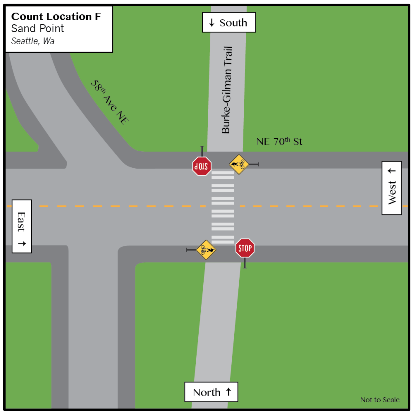
UNIVERSITY DISTRICT

Green Bicycle Lanes Present



SAND POINT

No Green Bicycle Lanes



BICYCLE FACILITIES AT COUNT LOCATIONS

A total of six types of bicycle facilities are examined in this pilot study. Shared roadways are present at all locations, with the exception of Ballard. The highest proportion of shared roadways is in place at the intersection observed in Capitol Hill, where all non-Eastbound bicyclists must share the road with other vehicles. This least protected type of facility is also present, in descending order, in Sand Point, Queen Anne, Greenlake, and the University District. Bicycle lanes are also present at five of six locations, with Sand Point being the only count location where bicycle lanes are not painted on the roadway. The count location in Queen Anne features the largest proportion of bicycle lanes, with Ballard and Greenlake not far behind, and Capitol Hill and the University District both have equal percentages of bicycle lanes.

Each of the remaining four types of bicycle facilities is only present at one of four count locations. Buffered bicycle lanes are installed on Northeast Ravenna Boulevard in Greenlake, and the neighborhood greenway under observation is located along Northwest 58th Street. The bi-directional bikeway, or non-grade-separated cycle track, examined through this study is located in the University District. Lastly, the only count location with an off-street path observed during this pilot study is located along the Burke-Gilman Trail in the Sand Point neighborhood. Diagrams of the bicycle facilities at each count location are shown on Figure 16.

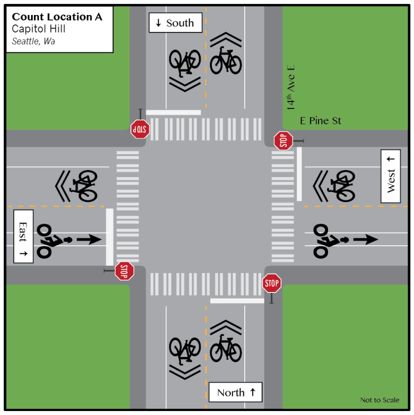
FIG. 16: Count Location Profile Maps – Bicycle Facilities

BICYCLE FACILITIES PRESENT AT THE COUNT LOCATIONS:

Visual Description of Bicycle Facilities

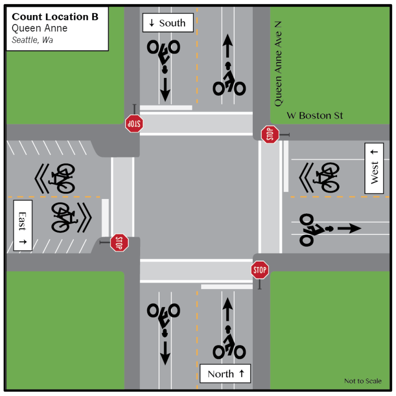
CAPITOL HILL

Shared Roadways and Bicycle Lanes



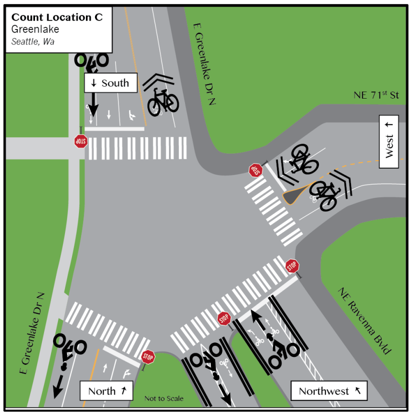
QUEEN ANNE

Shared Roadways and Bicycle Lanes



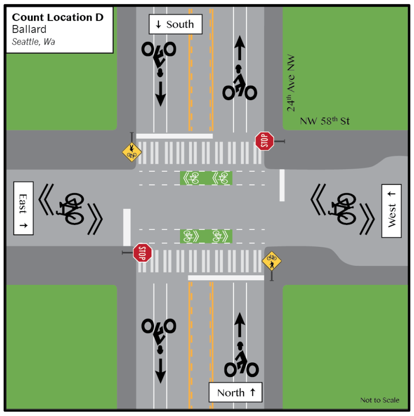
GREENLAKE

Shared Roads, Bicycle Lanes, and Buffered Lanes



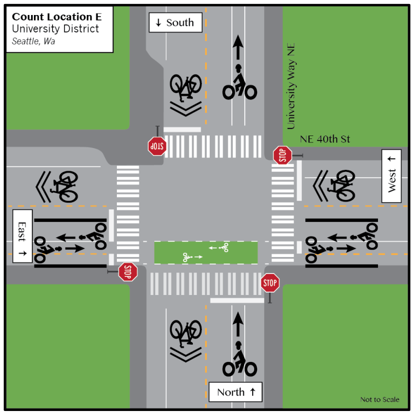
BALLARD

Bicycle Lanes and Neighborhood Greenway



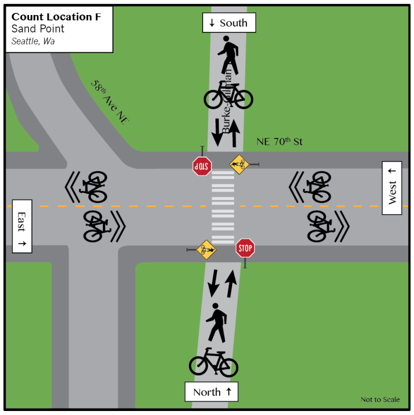
UNIVERSITY DISTRICT

Shared Roadways, Bicycle Lanes, and Bikeway



SAND POINT

Shared Roadways and Off-Street Path



ON-STREET PARKING ALLOWED AT COUNT LOCATIONS

Five of the six count locations permit on-street parking at or near to the intersection, defined as being allowed within 30 feet of the stop sign. In Capitol Hill and Queen Anne, on-street parking is allowed on all legs of the intersection. This is almost the case in Ballard, however a driveway located near to the intersection prohibits on-street parking on the north side of Northwest 58th Street, east of the intersection. With the exception of one roadway requiring back-in angle parking, all on-street parking is parallel parking. In the University District, on-street parking is allowed everywhere but next to the bikeway on the south side of Northeast 40th Street. Aside from Sand Point, where no parking is allowed adjacent to the crossing of the Burke-Gilman Trail, the count location at the east side of Greenlake permits the least among of on-street paring of all intersections under observation.

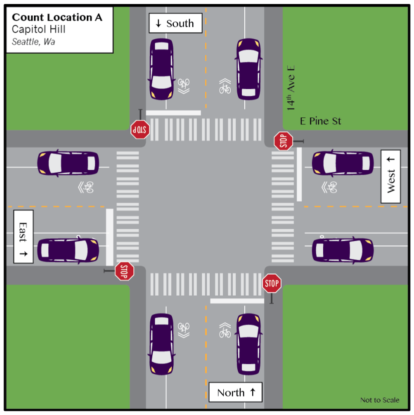
FIG. 17: Count Location Profile Maps – On-Street Parking

ON-STREET PARKING ALLOWED AT THE COUNT LOCATIONS:

Visual Description of On-Street Parking

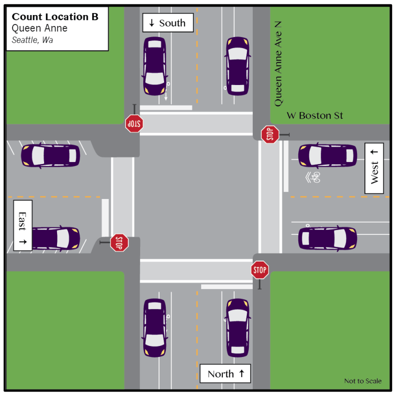
CAPITOL HILL

On-Street Parking on All Sides of the Crossing



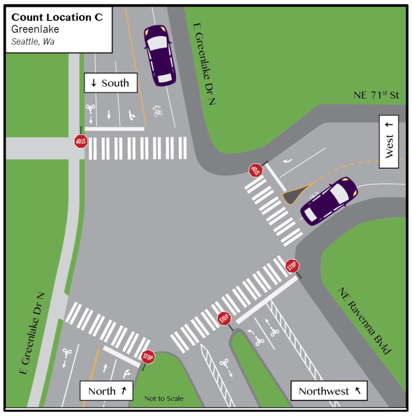
QUEEN ANNE

On-Street Parking on All Sides of the Crossing



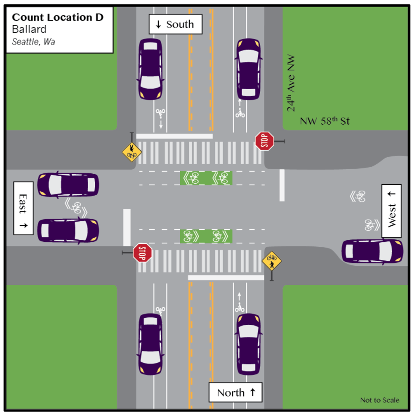
GREENLAKE

Minimal On-Street Parking at Crossing



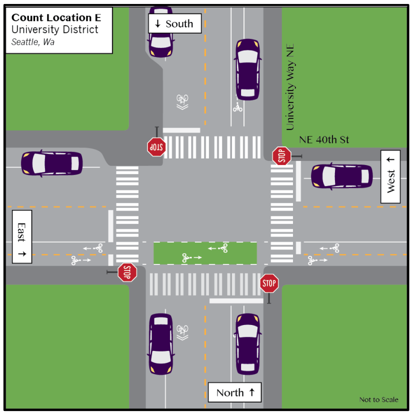
BALLARD

On-Street Parking on Most Sides of the Crossing



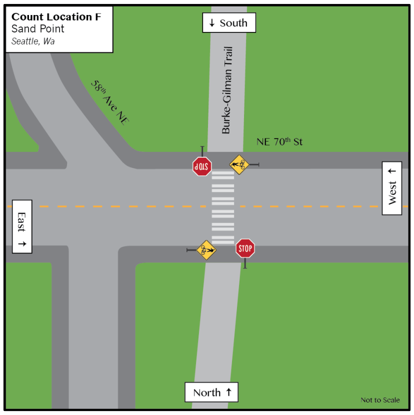
UNIVERSITY DISTRICT

On-Street Parking on Most Sides of the Crossing



SAND POINT

No On-Parking Allowed by Crossing



TOPOGRAPHY BEFORE AND AFTER THE CROSSINGS

As the topography in the City of Seattle varies from level to steep, the pilot study aimed to select six locations, each featuring a different set of topographical conditions. Due to the difficulty of locating intersections controlled by stop signs which meet all behavior-specific and location-specific criteria established for this study, topography is the same at two locations and is very similar at another two (Fig. 18). Looking to the more general variable for topography developed by the NBPDP, Greenlake and Queen Hill are level and all other intersections included in this pilot study feature moderate grades.

In both Queen Anne and Greenlake, all roads leading to the intersection are level, which means these two intersections feature an equal percentage of the roadways under investigation. Those traveling on the neighborhood greenway in Ballard are also riding on a level surface, although this intersection also features a moderate uphill for Northbound traffic and moderate downhill for Southbound traveling road users. The east side of the intersection observed in the University district is level; however, up- and down-hill slopes are present in the north-west roadway and on the west side of the intersection.

The highest proportion of steep up- and down-hill slopes is in Sand Point, where east-west riding bicyclists traveling on the shared roadway must climb or coast down a significant slope. While slopes are the most steep at this location, a steep hill is also present at the intersection with the most varied topographical conditions. Capitol Hill, north-south roadways are level, but an eastbound uphill slope creates moderate as well as steep up- and down-hill conditions for east-west traffic.

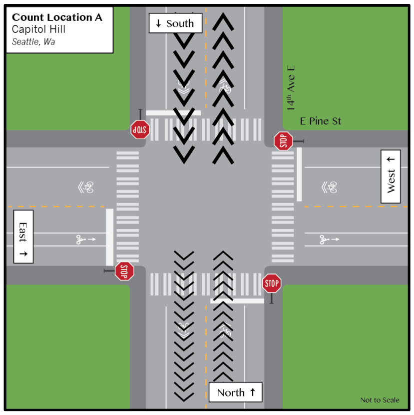
FIG. 18: Count Location Profile Maps – Topography

TOPOGRAPHY PRESENT AT THE COUNT LOCATIONS:

Visual Description of Topographical Conditions

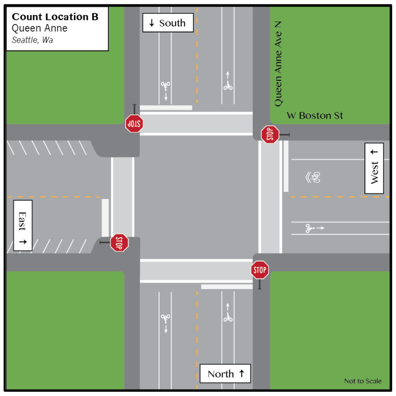
CAPITOL HILL

Moderate to Steep Slopes



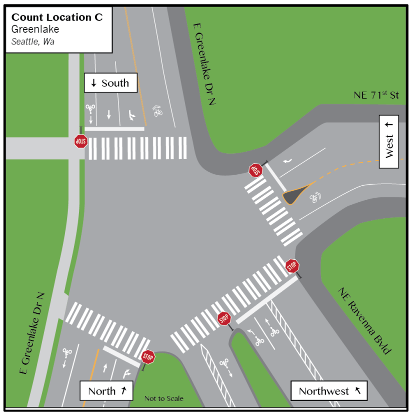
QUEEN ANNE

Level Roadways



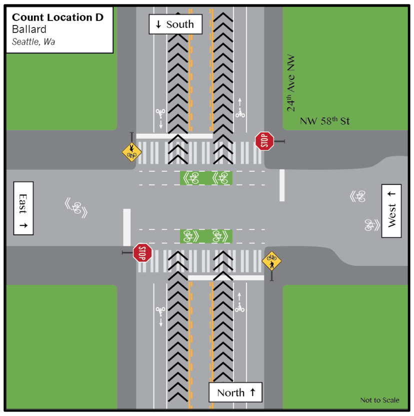
GREENLAKE

Level Roadways



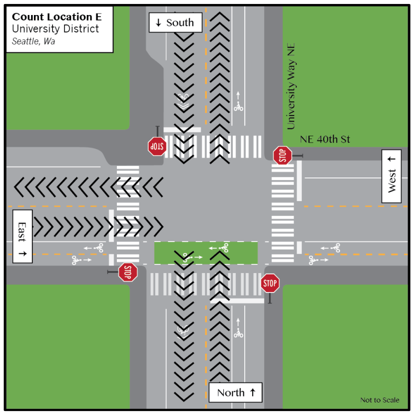
BALLARD

Level Roadway to Moderate Slopes



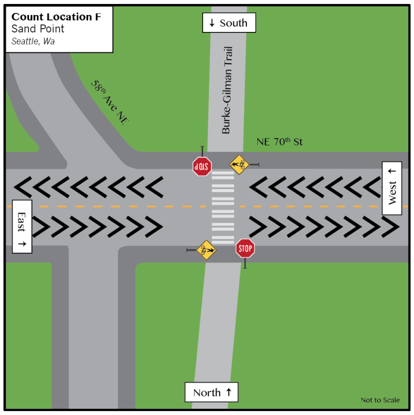
UNIVERSITY DISTRICT

Level Roadway to Moderate Slopes



SAND POINT

Level Roadway to Steep Slopes



CHAPTER 5:

PILOT STUDY COUNT SCHEDULE

CONNECTION TO STATEWIDE DOCUMENTATION PROJECT

As is briefly noted in Chapter 3, this pilot study is intentionally modeled after the annual statewide project in Washington State, which is coordinated by the Department of Transportation and the Cascade Bicycle Club. The ideal count schedule planned for the pilot study, therefore, is identical to the schedule used for the statewide counts in late September and/or early October. The purpose for doing so is to afford a more direct comparison with existing count data on bicyclists in Washington State. Furthermore, this methodology is designed to be compatible with this documentation project, enabling participating jurisdictions to augment the current counts with a collection of behavioral data.

COUNT SCHEDULE

In Washington State, the bicycle documentation project collects counts over a three-day period of time, spanning from a Tuesday to Thursday. Counts are conducted twice daily, with two-hour count periods from 7:00 to 9:00 and again from 16:00 to 18:00 (Cascade Bicycle Club 2014b, 3). The week of counts was scheduled for mid-November, spanning from Tuesday, November 18th to Thursday, November 20th. Materials produced for both the statewide project and the national documentation project indicate that travel patterns should not differ on these three days; hence, counting on these weekdays is recommended by well-established projects (Alta Planning + Design 2010a, 2).

Following this schedule to the tee, a total of 72-hours of observations would be recorded across the six count locations through this pilot study. However, due to the limited time period for volunteer recruitment, it was not possible to fill all time slots in this ideal count schedule. Despite this shortcoming, this pilot study successfully collected a total of 40-hours of observations of bicyclists' stopping behaviors during the three-day count period. In total, student and alumni volunteers from the University of Washington provided 10 hours of data collection, and the staff and volunteers from the Cascade Bicycle Club collected a total of 16 hours of observations.

COUNT SCHEDULE BY LOCATION

The following table presents the schedule for the three days of behavioral observations, with an "**X**" marked for each count period during which data was collected:

FIG. 19: Pilot Study Count Schedule

PILOT STUDY COUNT SCHEDULE: Morning and Evening Count Periods Covered by Data Collectors						
COUNT LOCATION	**Tuesday, Nov. 18, 2014**		**Wednesday, Nov. 19, 2014**		**Thursday, Nov. 20, 2014**	
	7-9am	**4-6pm**	**7-9am**	**4-6pm**	**7-9am**	**4-6pm**
Capitol Hill	X	X	X		X	
Queen Anne	X		X			
Greenlake	X		X	X	X	
Ballard	X		X			X
University District			X		X	X
Sand Point		X	X		X	X

As this table shows, this volunteer data collection effort generally documented activities during at least two morning count periods and one evening count period at each count location, with some variance in the schedule. Unfortunately, no observations were made from 16:00 to 18:00 at the Queen Anne location, due to the availability of volunteers.

This, however, is not considered a major data loss, as this location saw the lowest proportion of bicyclists of all observed intersections. As only 30 bicyclists were recorded during the four hours of morning observations at this intersection, it is not expected that evening counts in Queen Anne would have produced a substantial number of additional observations of bicyclists.

EXPECTATIONS AND CAVEATS

TIME-OF-YEAR WEATHER CONSIDERATIONS

Unlike the national and statewide counts that are conducted in early Autumn when outdoor non-motorized activities are at their peak, the pilot study was implemented during the considerably colder month of November. The purpose for this schedule was based on the timeframe of this thesis project, rather than with the express purpose of exploring behaviors in more frigid conditions. Based on the timing of this study, it is expected that the total number of bicyclists observed would be less than the totals recorded during annual counts in the Fall. This assumption is founded on the fact that weather conditions have a known influence on an individual's decision to ride a bicycle. It is expected that fewer bicyclists will choose to ride as winter sets in, which brings a reduction in temperature and daylight hours. This is discussed in more detail in the discussion on weather conditions in Chapter 7 “Pilot Study Variables”.

The best resource found in the course of this research for calculating the level of bicycle counts seen during the different months of the year is in the materials produced for the NBPDP. According to the adjustment factors calculation used by the NBPDP for extrapolating the total number of bicyclists expected in each month of the year, moderate climates see an average of 16% of non-motorized activities during the month of August, 8% in September, and only 6% in October, November, and December, respectively (Alta Planning + Design November 2009b). It should be noted that these percentages and adjustment factors are designed specifically for shared use paths and areas with a concentration of pedestrian and entertainment activities (Alta Planning + Design March 2009a, 1). This being the case, these calculations can be used to reliably predict bicycle volumes on these two types of infrastructure and can only provide qualitative evidence of volumes on the primarily on-street bicycle facilities investigated through this pilot study. As one off-street, shared-use path is included in this study, these factors and calculations are applicable to the count location in Sand Point along the Burke-Gilman Trail.

NATURE AND VALIDITY OF DATA COLLECTED

As is discussed in concert with the presentation of the count schedule for the 40 hours of observation, the profiles of data collected at each count location are somewhat different from each other. In Capitol Hill and Greenlake, a total of three morning counts and one evening count were completed. The University District and Ballard were each recorded twice in the morning and once during an evening count period. As noted, Queen Anne was only observed twice during the morning count period, this location with no observations made in the evening. Sand Point was the only location for which data was collected during two evening count periods, in addition to two morning count periods. Although the nature of this dataset is, therefore, somewhat inconsistent, a review of methods used in the NBPDP exhibits that this data meets the standards of this national methodology.

In order to use the adjustment factors calculation to extrapolate count data to annual estimates, the NBPDP recommends that count locations be observed during two to three (preferred) two-hour count periods during the week of observations (Alta Planning + Design 2010a, 2). At each location included in the pilot study, two to four two-hour count periods were observed during the three-day schedule. As this number of observation periods is considered adequate for the extrapolation purposes, this thesis asserts the number of ours of data collection at each location is also adequate and valid for the purposes of this research.

One caveat to this assertion, however, is the fact that the NBPDP recommends that weekday observations occur daily between 17:00 and 19:00, rather than the twice-daily counts performed in Washington. By recording observations during two separate two-hour periods, there is a variable for time of day in the pilot study and the Washington State counts that does not exist for document projects following the NBPDP methodology. Based on this distinction, this study recognizes a research caveat exists relying on the same number of observation periods as the national counts, when there is no control for the total hours of observation made during each time period. With this noted here and in the discussion on data analysis, this study does establish reliable data for predicting stopping behavior across these two time periods.

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CHAPTER 6:

PILOT STUDY DATA COLLECTION METHODS

PREPARATION FOR THE COUNTS

DATA COLLECTED PRIOR TO COUNT PERIODS

Before the dates during which bicyclists are observed, all locational data was collected to establish location-specific data collection guidelines. Preliminary research on each count location was done using Google Streetview, updated in 2014. Each location was then visited to confirm online research. All information presented within Chapter 4 "Pilot Study Count Locations" represents all of the locational variables collected prior to count periods.

DATA COLLECTION VOLUNTEER RECRUITMENT

The behavioral counts of bicyclists were taken by the author, students, and alumni of the University of Washington Master of Urban Planning and Master of Public Administration, as well as staff and volunteers from Cascade Bicycle Club. Student volunteers were contacted through student email lists, and announcements were made through social media. Cascade became involved two weeks prior to the count—through a connection at the College of Built Environments—and agreed to support the research by advertising the project through their volunteer recruitment website. Including the author of this study, a total of eight individuals assisted in collecting data for this pilot study, including the principal investigator.

DATA COLLECTION MATERIALS

All volunteers are provided with a detailed set of guidelines for conducting behavioral counts. This document includes details on each count location as well as specific instructions on coding observations on the data collection sheet. Upon request, volunteers were provided in-person training and review of data collection procedures. Data collection sheets were provided for volunteers, together with this set of guidelines.

These documents are partially modeled after those used by the national project as well as the statewide collection project in Washington. Many procedures for conducting counts are identical to those using these projects. For example, the total number of bicyclists, not bicycles, is recorded, and data is collected at 15-minute time intervals (Alta Planning + Design March 2010b, 3). The primary difference between the data collection sheet to use for this pilot study and these other documentation projects is in the collection chart itself. This is due to the fact that this pilot study examines more variables on each individual bicyclist, which requires a more complex collection sheet.

More details on the materials used are provided as the Appendix.

DATA COLLECTED DURING COUNT PERIODS

Data collectors were asked to briefly describe the weather conditions at the top of the data collection sheet prior to the start of the count time. Otherwise, the data collection sheets were provided to volunteers with all relevant information filled out—including their name, the count location, the date, and the count period.

With the weather circumstances noted, data is collected on all bicyclists observed passing stop signs at each count location during the two-hour count periods. A total of eight variables are observed during each count period, including:

(1) Time Interval;
(2) Gender;
(3) Helmet Use;
(4) Direction of Travel (before the intersection);
(5) Stopping Behavior;
(6) Turning Movement;
(7) Safety of Maneuvers; and
(8) Change in Circumstances.

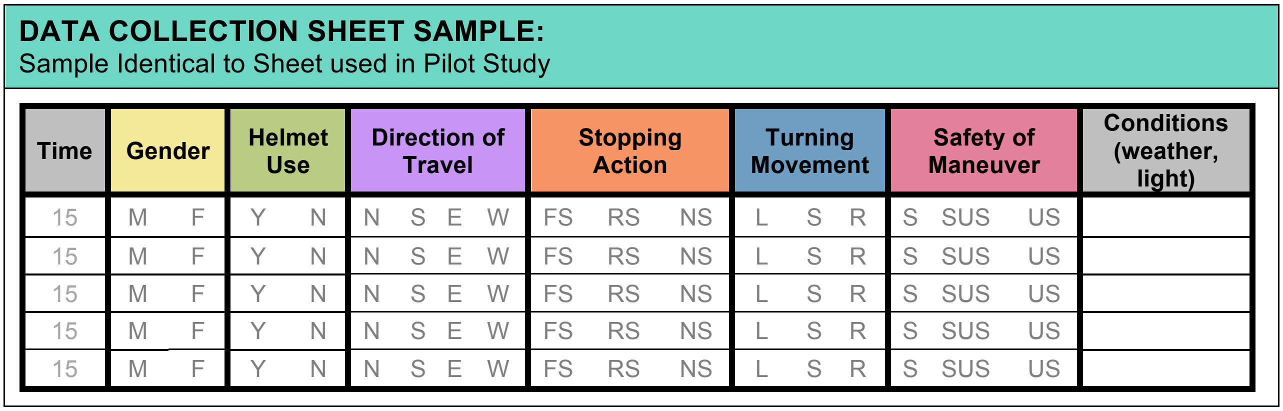
The first three variables are identical to those used by the NBPDP and Cascade Bicycle Club in Washington State, with the fourth also recorded in the state (Alta Planning + Design March 2010b, 3; Cascade Bicycle Club 2013, 7). All but the first are also used also used by the NHRC study, and the inclusion of the variable for safety is inspired by the same variable used in the study across three American states (Hunter et al. 1995, 83, 87). Variables for stopping behavior were developed specifically for this study in order to answer the primary research question. Although the NHRC study includes a variable for obeying or disobeying a traffic control device and the Hunter College studies observed whether bicyclists paused and then rode through red lights, the data collection of rolling stops at stop signs has not been undertaken by any studies found in the course of this research (Hunter et al. 1995, 87; Tuckel and Milczarski 2014, 8). Turning movement is looked at in in the NHRC study, and is included in this pilot study to facilitate an investigation of whether stopping behavior varies when different types of bicycle facilities are in place. Turning movements are looked at together with the direction of travel to determine the type of facility each observed bicyclist had access to at the intersection.

A more thorough discussion of each variable is provided in Chapter 7 “Pilot Study Variables”.

DATA RECORDING METHODOLOGY

The data collection chart includes eight columns, one for each variable. This chart is replicated in Figure 20, below:

FIG. 20: Example Data Collection Chart



DATA COLLECTION SHEET SAMPLE:
Sample Identical to Sheet used in Pilot Study

Time	Gender	Helmet Use	Direction of Travel	Stopping Action	Turning Movement	Safety of Maneuver	Conditions (weather, light)
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	

All instructions for using and understanding the data collection chart provided in the data collection guidelines are presented in the following eight sub-sections.

TIME INTERVAL

All data on bicyclist behavior should be collected in 15-minute intervals during the whole two-hour count time period. At the start of each new 15-minute period of time, the data collector should mark an "**X**" in the "Time" column. This mark will be in the row describing the first bicyclists observed during each new period. Therefore, only one "**X**" should be marked in this column every 15-minutes.

FIG. 21: Coding Examples – Time Intervals

TIME INTERVAL DATA COLLECTION METHODS:
Data Recording Methodology Specific to Variable

1st Observation in New 15-Minute Period

Time
~~15~~

An "**X**" is marked to show that new 15-minute period has passed.

This "**X**" should be marked on the same line as the first subject observed during the new time period.

During a Given 15-Minute Period

Time
15

No "**X**" is marked during any of the 15-minute count periods.

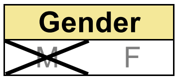
GENDER

Bicyclists observed in this study are identified as male (M) or female (F). Data collectors should mark an "**X**" over the letter representing the gender of each subject in the "Gender" column. Best judgment should be used to code bicycles for gender. This study regrets not including a category for transgender; however this variable was considered too difficult for all data collectors to reasonably record for all bicyclists observed.

FIG. 22: Coding Examples – Gender

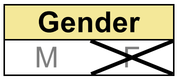
GENDER DATA COLLECTION METHODS:
Data Recording Methodology Specific to Variable

Subject is Male



An "**X**" is marked over the "M" to show that a subject is male.

Subject is Female



An "**X**" is marked over the "F" to show that a subject is female.

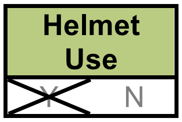
HELMET USE

The use of helmets is recorded in this study. Data collectors should record any instance of an individual not wearing a helmet by marking an "**X**" over the letter "N in the column labeled "Helmet Use". For those riders who are wearing a helmet, an "**X**" is instead marked above the letter "Y" for yes. As it is expected that most bicyclists observed will be wearing a helmet, it is allowable for data collectors to only record helmet use for subjects not wearing a helmet. Based on this, it will be assumed that a subject is wearing a helmet if the column "Helmet Use" is left blank.

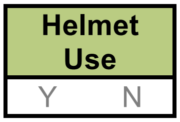
FIG. 23: Coding Examples – Helmet Use

HELMET USE DATA COLLECTION METHODS:
Data Recording Methodology Specific to Variable

Subject is Wearing a Helmet



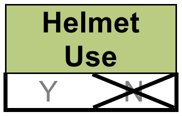
or



An "**X**" is marked over the "Y" to show that the subject is wearing a helmet.

It is also allowable to leave the column blank, with the assumption this means the subject is wearing a helmet.

Subject is Not Wearing a Helmet



An "**X**" is marked over the "N" to show that the subject is not wearing a helmet

DIRECTION OF TRAVEL

Site maps for each count location are provided to ensure that data collectors know how to code cardinal directions for each respective location. Under the "Direction of Travel" column, direction is reported as North (N), South (S), East (E), and West (W). Based on the explicit instruction for providing directions at each location, data collectors are asked to mark an "**X**" to describe the direction a given bicyclist is traveling in before reaching the intersection. To reiterate, the direction of travel is recorded based on bicyclists' direction as each individual approached the intersection.

FIG. 24: Coding Examples – Direction of Travel

DIRECTION OF TRAVEL DATA COLLECTION METHODS:
Data Recording Methodology Specific to Variable

In each example above, direction of travel is marked with an "**X**" over letter "N" for North, "S" for South, "E" for East, and "W" for West.

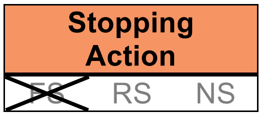
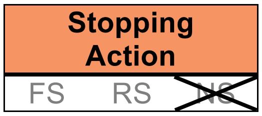
The direction of travel is that which the subject was traveling in **before** entering the intersection, not after.

STOPPING BEHAVIOR

The stopping behavior of bicyclists at intersections is the focus of this study. In the column titled "Stopping Action", an "**X**" should mark whether the bicyclist came to a full and complete stop (FS; short for full stop), used a rolling stop or track stand (RS; short for rolling stop), or if they did not stop or yield in any way (NS; short for no stop). See the sub-section titled “Types of Stopping Behaviors” for a more thorough definition of these three categories of safety.

FIG. 25: Coding Examples – Stopping Behavior

STOPPING BEHAVIOR DATA COLLECTION METHODS:
Data Recording Methodology Specific to Variable

Subject Comes to a Full, and Complete Stop	Subject Uses a Rolling Stop or Track Stand	Subject Does Not Stop or Yield
		
An “**X**” is marked over the “FS” to show that a subject came to a full and complete stop. A complete stop requires that the subject removes at least one foot from the pedal and places it on the ground or another surface.	An “**X**” is marked over the “RS” to show that a subject used a rolling stop or a track stand to partially stop and/or yield. A track stand, even one which might arguably be considered a stop, is always coded in the same category as a rolling stop.	An “**X**” is marked over the “NS” to show that a subject did not stop or make any attempt to yield before entering the intersection.

SAFETY OF MANEUVER

Having observed each bicyclist approach and move through the intersection, data collectors should assess the general safety of the maneuvers made by each subject. An “**X**” should be marked over the corresponding letter in the column titled “Safety of Maneuver” to record if a bicyclist’s are safe (S), somewhat unsafe (SUS), or unsafe (U). See the sub-section 7.3 titled “Definitions of the Categories of Safety” for a more thorough definition of these three categories of safety.

FIG. 26: Coding Examples – Safety of Maneuver

SAFETY OF MANEUVER DATA COLLECTION METHODS:
Data Recording Methodology Specific to Variable

Subject's Maneuver is Safe	Subject's Maneuver is Somewhat Safe	Subject's Maneuver is Unsafe
Safety of Maneuver ~~S~~ SUS US	**Safety of Maneuver** S ~~SUS~~ US	**Safety of Maneuver** S SUS ~~US~~
An "**X**" is marked over the "S" to show that a subject's stopping behavior and maneuvering was safe. It is possible for a bicyclist who used a rolling stop or did not stop at all to be safe in their actions.	An "**X**" is marked over the "SUS" to show that a subject's stopping behavior and maneuvering was somewhat unsafe.	An "**X**" is marked over the "US" to show that a subject's stopping behavior and maneuvering was decidedly unsafe.

CHANGE IN CONDITIONS

This column supplements the weather conditions reported on the top of the data collection sheet immediately before the start count time. As significant changes in weather and natural lighting are noticeable, data collectors should indicate this change in a brief note in the "Conditions" column. For example, a note should be made if it begins raining, snowing, the sun sets, etc. These notes should be made in the same row as the first observation made after the data collector noticed the change in conditions. This column may otherwise be used to record noteworthy qualities of a particular observation, such as an accident occurring at the intersection or the presence of a police vehicle near the intersection.

FIG. 27: Coding Examples – Change in Conditions

CHANGE IN CONDITIONS DATA COLLECTION METHODS:
Data Recording Methodology Specific to Variable

Change in Weather

Conditions (weather, light)
any text can be written here

Notes made in this column should be brief, ideally from one to three words.

As/if whether conditions change, write “rain” or “no rain” to indicate if it started or stopped raining. The same simple can be applied to snow, windy, foggy, etc.

Indicate when a change in natural light is observed using general categories of “sunrise”, “day”, “sunset”, or “night”

Additional notes may be made if noteworthy circumstances develop or events occur at the intersection.

DATA SUBMISSION POST-COUNT

All volunteer data collectors were asked to submit their completed data collection sheets by the weekend after the three-day count period. Most data collection sheets were returned as the original hard-copy, with one data collection sheet submitted as a photo of the completed sheet. All the forms were legible and the few questions that arose were resolved via email.

CHAPTER 7:

PILOT STUDY VARIABLES

INTRODUCTION TO VARIABLE CATEGORIES

Three categories of variables are included in the pilot study investigating bicyclists' stopping behavior in the City of Seattle. This includes variables related to the:

(1) Bicyclists observed at any given location, during any given count period;

(2) Circumstances at the time of the count; and

(3) Location of the count.

The second two categories represent collections of variables hypothesized to have an influence on the first category. Collectively, all three cover elements were highlighted as important to behavioral mobility from a theoretical perspective as is discussed in Chapter 3 "Methodological Case Examples".

Adhering to several elements of the methodology developed by the National Bicycle and Pedestrian Documentation Project, several locational variables are pulled directly from this project as well as the project conducted in Washington State (Alta Planning + Design March 2010b, 12–15) Each borrowed variable is identified with an asterisk (*). Augmenting the descriptive and analytical uses of the data collected, this pilot study further records several additional variables describing the physical setting existing at each location. These additional variables document the specific traffic control devices in place, bicycle facilities installed, whether or not on-street parking is available at the intersection, and the topography in each direction of travel.

Each variable, falling under each of these three categories, is introduced and described throughout the rest of this chapter.

Variables Type A:

BEHAVIORAL AND SUBJECT-SPECIFIC VARIABLES

Five variables collected during the pilot study relate to the behaviors and/or personal characteristics of each bicyclist observed.

A1 – BICYCLISTS' GENDER*

Gender is a primary variable used to describe the personal characteristics of bicyclists observed during the pilot study. As is discussed Chapter 6 "Pilot Study Data Collection Methods", all bicyclists observed are identified as:

(A) Male; or
(B) Female.

This variable is typical for bicycle documentation projects, including the national project and statewide counts in Washington. In 2013, only 19% of bicyclists observed in Washington State were female (Cascade Bicycle Club 2014, 2). This study intends to investigate whether the same proportional gender divide is observed during the pilot study as well as look at how stopping behavior may vary by the bicyclist's gender.

The 2014 study conducted at Hunter College in New York City found that 40.7% of male bicyclists ran red lights and only 26.3% of female bicyclist did the same. In regard to full and complete stops, this study found that 38.3% of female bicyclists used these types of stops and a slightly lower 28.4% of male bicyclists. Results further show that approximately a third of bicyclists of both genders will pause before crossing a red light

(Tuckel and Milczarski 2014, 8). Based on this finding, this thesis does not expect to see a significant difference in rolling stop behavior between male and female bicyclists.

A2 – BICYCLISTS’ HELMET USE*

The second characteristic recorded for all subjects observed is whether each bicyclist:

(A) Is Wearing a Bicycle Helmet; or

(B) Is Not Wearing a Bicycle Helmet.

In King County, it is required that bicyclists wear a helmet while riding on a “public roadway, bicycle path or on any public right-of-way or publicly owned facilities” in the county boundaries (King County Board of Health 2003, A). This study collects helmet use data in order to explore the question of whether bicyclists who break one bicycle law (helmet use) might be more or less likely to break another (stop sign law). As with gender, all documentation projects on bicyclists typically include this variable, including the NBPDP and the statewide counts in Washington. The 2013 documentation project in Washington State found that 83% of male and 89% of female bicyclists in the 38 cities counted were wearing a helmet (Cascade Bicycle Club 2014, 2).

A3 – BICYCLISTS’ TURNING MOVEMENTS

Findings from two different models produced through the NHRC study found higher rates of conflicts associated with the action of a bicyclist making a left turning movement (Hunter et al. 1999, 72). This study further found that bicyclists using wide curb lanes, rather than bicycle lanes, are more likely to turn left at an intersection using the crosswalk—acting more like a pedestrian than like a vehicle (Hunter et al. 1999, 74). This pilot study aims to learn whether any statistically significant relationships exist between a bicyclist's turning movements and their stopping behavior. Furthermore, including turning movement in this study allows additional variables to be studied related to the physical setting. During the pilot study, data collectors record direction of travel as well as turning movement. Based on the shape of each intersection, the following five turning directions are recorded in the pilot study: (A) Straight; (B) Left; (C) Slight Left; (D) Right; and (E) Slight Right. For analysis, slight left and left and slight right and right movements are grouped together, leaving the three following types of turning movements:

(A) Straight;
(B) Left; and
(C) Right.

As no evidence was found to suggest the actual cardinal direction of travel will influence a bicyclist's stopping behavior, direction is not included as a variable in the statistical analysis of this data. Together, these two pieces of information are used to establish variables related to bicycle facilities in place, on-street parking, and topography.

A4 – SAFETY OF BICYCLISTS' MANEUVERS

The final behavioral variable explored through this thesis is a qualitative assessment of the safety of the maneuvers each bicyclist observed made while approaching, proceeding through, and departing the intersection. This variable is used in the tri-state comparative study of bicycle lanes and wide curb lanes published by the produced by the National Highway Research Center, funded by the USDOT. Three levels of safety are included in this study's methodology, which are as follows: (A) Maneuver Safe; (B)

Maneuver Somewhat Unsafe; and (C) Maneuver Unsafe (Hunter et al. 1995, 30). As this study did not publish the exact definitions for each level of safety, this pilot study has established a set of definitions to be used by data collectors during observation periods.

In this pilot study, the safety of a bicyclist's overall behavior and actions is subjective, but follows a general set of descriptive criteria. The core concept for coding this variable is that any type of stopping behavior can be any level of safety. Therefore, this variable examination of the safety of bicyclists' maneuvers is somewhat detached from whether or not bicyclists come to a complete stop at intersections, are wearing a helmet, or are breaking any other traffic law. Rather, this variable focuses on whether the bicyclist acts predictably, and keeps a safe distance from other road users, or puts themselves or others into danger. This thesis asserts that individual data collectors likely recorded this more abstract variable with some personal bias. Although descriptive results are presented and compared to the National Highway Research Center case example, this variable is left out of the full statistical analysis, based on this concern for a lack of reliability.

The table on the following page exhibits the guidelines presented to data collectors to inform how to code for safety during observations. This guidance notwithstanding, this study recognizes that this variable for safety may not be highly reliable. The experience and knowledge of bicycling each data collector brings with them may present bias in what each volunteer considers safe or unsafe. With this shortcoming recognized, this variable for safety is considered of interest and relevance to this general, introductory discussion of the express of the express allowance, or not, of rolling stops at intersections controlled by stop signs.

FIG. 28: Safety of Bicyclists' Maneuvers

Safety of Bicyclists' Maneuvers:
General Definition for Degrees of Safety of Each Bicyclist Observed

SAFE MANEUVER:

- Yields the right-of-way to all other road users who approached the intersection before the bicyclist.
- Does not endanger himself or herself, or any other road user.
- Uses turning signals and/or signals to pass with their voice or a bell.
- Does not weave around other road users, with the exception of avoiding parking cars or potential incidences with other road users.

SOMEWHAT SAFE MANEUVER:

- Does not yield the right-of-way at the intersection, taking the turn of another road user who arrived at the intersection first.
- Weaves around or cuts off another road user while approaching or after passing through the intersection.
- Confuses other road users with their behavior or maneuvers.
- Breaks a traffic law in a somewhat unsafe manner, such as riding on the wrong side of the street against traffic.

UNSAFE MANEUVER:

- Engages in several "somewhat unsafe" behaviors, or is decidedly unsafe while engaging in any behavior listed under "somewhat unsafe"
- Follows or rides too close to another road user.
- Causes a dangerous situation and/or near-accident.
- Causes an accident they are directly involved with, or which occurred with other road users due to the bicyclist's actions.

A5 – BICYCLISTS' STOPPING BEHAVIOR

This is the primary dependent variable of focus in this pilot study. In the second chapter of this thesis, three types of stopping behaviors are identified for the investigation. These stopping behaviors include:

(A) Full and Complete Stop–bicyclist takes at least one foot off the pedal and touches their foot to the ground or other surface;

(B) Rolling Stop, or Track Stand—bicyclist slows and yields the right-of-way, or comes to a near-stop but keeps feet on the pedals; and

(C) No Stop, Slow, or Yield—bicyclist does not yield the right-of-way and does not significantly reduce their speed.

In Washington State, is required that bicyclists riding on the roadway come to s stop at any intersection where any motor vehicle is required to stop (Washington State Legislature 1975). What it means for a bicyclist to stop, however, is not expressly identified in the RCW, which opens up a discussion on what type of stop is a legitimate stop. This thesis and pilot study breaks stopping behavior into two categories of stops, with the third for not stopping, to investigate which type of stop is more or less common in the City of Seattle.

Although this thesis includes that track stand are unique from a rolling stop, the two are grouped together for the observational study. The primary difference between the two movements is that using a rolling stop is to approach an intersection at a reduced speed and slowly yield the right-of-way before traveling through the crossing. Those who use track stands, alternatively, come to a near-stop or complete stop by balancing on their pedals and shifting their bicycle from side-to-side to maintain a stationary position. Despite this distinction, this study grouped them together based on the assumption that from the point of view of a driver not well versed in bicycling, a rolling stop and track stand may appear to be the same thing. Furthermore, with the limited training provided to data collectors, it was uncertain whether different volunteers would similarly distinguish between these two types of stops and reliably code them in the same way.

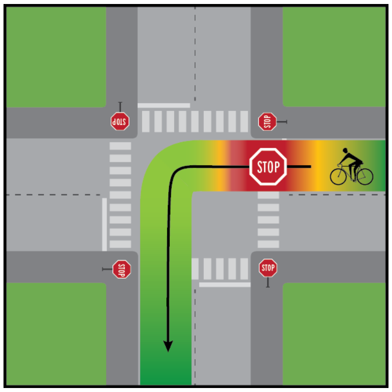
The following table provides notes and diagrams describing the characteristics of each type of stopping behavior.

FIG. 29: Stopping Behaviors of Bicyclists

Types of Bicyclists' Stopping Behaviors:
Defined Categories of Stopping Behavior

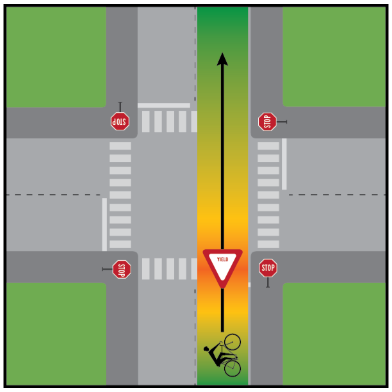
FULL and COMPLETE STOP:

- Slows and comes to a complete stop before entering the intersection.
- At least one foot is off one pedal and is on the ground or another surface in the roadway. (It is not a full and complete stop if no foot is on the ground.)
- Waits at or near the stop bar while yielding the right-of-way until it is the bicyclist's turn to proceed.



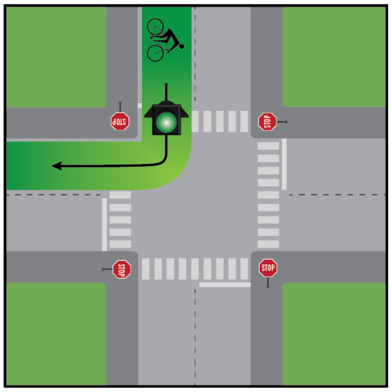
ROLLING STOP or TRACK STAND:

- Reduces speed at the intersection and rolls through without coming to a complete stop.
- Yields near the stop sign, giving the right-of-way to any other vehicles arriving at the intersection before the bicyclist.
- A brief stop only occurs if the bicyclist rolls too far into the intersection while yielding the right-of-way and must stop for safety reasons.
- Track stands are included under this category. This is a move in which the bicyclist balances on their pedals in order to sustain a near-stationary position with little movement.



NO STOP:

- Does not come to a full and complete stop or uses a rolling stop at the intersection.
- Does not slow or attempt to stop at the intersection.
- Does not yield the right-of-way to any other road users.



Variables Type B:

CIRCUMSTANTIAL VARIABLES

In this second group of variables, a total of five factors are documented to investigate how uncontrollable, environmental conditions influence bicyclists' stopping behaviors. This group of variables is, therefore, primarily comprised of time and weather related variables. The more general weather conditions variable produced by the NBPDP was not used, as weather conditions did not vary during the six count periods, preventing this pre-established variable from being useful for data analysis. Instead, this thesis included several variables related to specific weather conditions. The inclusion of these more specific variables allows for a more fine-grain study of the impacts of environmental circumstances on bicyclists' stopping behaviors.

One variable this thesis is surprised to omit from this analysis is rain, or wet roadways. This pilot study was designed so that the variable for rain measured the total number of tenths of inches of precipitation. Rather than using an ordinal variable for degree of rainy or snowy conditions, this measurement was expected to be more precise and had the potential for producing a data set more accurately representing conditions on the ground. Unfortunate to the analysis of this pilot study's results, only a negligible amount of rain fell during the pilot study's count periods and the level of precipitation never exceeded 0.0 inches. Moreover, no data collectors recorded weather events relevant to rain or surface wetness. With no information gathered on precipitation, this thesis and pilot study are unable to comment on the influence of damp or wet weather conditions on the behaviors of bicyclists at stop sign controlled intersections in Seattle.

A second circumstantial variable excluded from the statistical analysis is the potential variable describing the day of the week the count took place—Tuesday, Wednesday, or Thursday. The NBPDP indicates that no difference should be expected between commute patterns on these mid-week days (Alta Planning + Design 2010a, 2). While this data was collected, this thesis, therefore, elected to omit this variable from the already long list of variables included in the regression analysis.

With these notable omissions explained, each of the six circumstantial variables are introduced on the following pages.

B1 – TIME PERIOD*

The count schedule for the pilot study included two-hour count periods two times per day. This schedule is organized exactly as the documentation project in Washington state is planned, with counts between:

(A) 7:00 and 9:00; and

(B) 16:00 and 18:00.

In order to look at trends occurring within the two-hour count periods, observations are recorded marking every 15-minute interval. This method count recording method is used for the statewide counts in Washington as well as the National Bicycle and Pedestrian Documentation Project (Alta Planning + Design March 2010b, 3). With regards to the final analysis of the data collected through this study, it is expected that more bicyclists will fail to stop or use rolling stops during the morning. No evidence, however, was found in the course of this research to support this assumption.

B2 – NATURAL LIGHTING CONDITIONS

This variable is recorded in the pilot study, as it allows for a detailed examination of the impact that natural lighting conditions may have on bicyclists' behaviors at intersections. The expectation is that less obedient bicyclist stopping behavior will occur when more natural light is available. Similar to the variable for time period, however, no research was found supporting this assumption. The rationale suggested in this thesis is that bicyclists will feel more comfortable not stopping or using rolling stops when circumstances allow for the high levels of visibility.

The categories used for this variable are based on the following astronomical definitions (Weather Underground 2014a):

(A) Daylight—the period of times between sunrise and sunset, during which time there is visible natural light;

(B) Sunrise or Sunset—these are the times of day when the sun rises or falls beyond the horizon and direct sunlight is either emerging or withdrawing;

(C) Civil Twilight—the sun is 0-6 degrees below the horizon, bright stars are visible, and normal activities can continue outdoors without additional light;

(D) Nocturnal Twilight—the sun is 6-12 degrees below the horizon, some natural visibility still exists, but extra light is generally necessary to engage in outdoor activities; and

(E) Astronomical Twilight—the sun is 12-18 degrees below the horizon and brings absolutely no light to the night sky.

During observation, data collectors are asked to record their own observations on change in daylight conditions. Their notes are used to confirm the accuracy of these categories of twilight reported through the Weather Underground, verifying that data collectors observed dimmer lighting conditions during the same period of time that sun has fallen further beyond the horizon—which they did. No counts occurred during astronomical twilight; however, all other conditions of twilight were observed during the pilot study. This variable is looked at together with the variable for the presence of streetlights, which are expected to compensate for lighting conditions on the public right-of-way in the evening and at night.

B3 – TEMPERATURE (in degrees Fahrenheit)

This is the first of three variables describing the relatively specific weather conditions at the beginning of each observation period—see also visibility and wind speed. Each of these variables is populated using historic weather data reported by the Weather Underground (Weather Underground 2014a). This website provides hourly weather data collected at the Seattle-Tacoma International Airport. This means that this data is specific to each location, but is able to describe general conditions experienced in the City of Seattle. In regard to temperature, it should be noted that the temperature reported at the airport was several degrees Fahrenheit higher than what data collectors reported at the time of observations at each given location. This notwithstanding, temperature was not recorded at all locations and observations, so the temperature reported by the Weather Underground presents the most reliable, consistent data for this variable. This variable is reported as a range in degrees Fahrenheit.

The inclusion of this and other variables related to weather conditions is based on the assumption that weather conditions have an influence on bicyclist activities and bicyclists' actions. Temperature was found to have strong, significant influence on the decision to ride a bicycle, according to a report produced by the University of Vermont in 2012 (Flynn et al. 2012, 11). That same year, another study on bicycle commuters found statistically significant associations between high temperatures and lower bicycling rates, but no significant results were found for low temperatures (Buehler and Pucher 2012, 419).

B4 – VISIBILITY

Just as the variable for precipitation acts as a quantitative measure for surface wetness caused by rain or other weather conditions, a measurement of visibility obviates the need to otherwise describe the degree to which fog, rain, or snow might influence an individual's ability to see ahead of him or herself and safely navigate the roadway. This variable is measured in the number of miles of visibility weather conditions allow if no structures, objects, or steep topography blocks the view corridor. (See the variable for Temperature for details on the data used for this variable.) Similar to the logic introduced under the variable for natural lighting conditions, higher levels of visibility are expected to be associated with less obedience to stopping laws and a higher incidence of not stopping and using rolling stops. Visibility is often described as a measure of fog in other studies. In a study of bikeshare in Washington D.C., fog was not found to share a statistical relationship with the number of bicycle trips (Gebhart and Noland 2013, 13). As with the other circumstantial variables, these results provide an interesting point of discussion, but do not contribute to better understanding of bicyclists' behaviors.

B5 – WIND SPEED

The final variable describing weather conditions is a measure for the speed of wind in the number of miles per hour. (See the variable for Temperature for details on the data used for this variable.) Wind speed is frequently included in statistical investigations studying bicyclists. For example, the study in Washington D.C included a variable for wind and found a decline in bikeshare trips as wind speeds increased (Gebhart and Noland 2013, 13). In Vermont, only a modest negative relationship was found between wind speeds and rates of bicycling (Flynn et al. 2012, 11). This thesis aims to build on this national data on the influence of wind on American bicyclists.

Note: While the direction of wind is not reported in this pilot study due to time constraints, this data is available and is recommended for examination in future studies. The direction and speed of wind may be particularly interesting to a study of sites involving steep topography for a consideration of the impact head- or tail-wind might have on decisions to stop at, or roll through, intersections.

Variables Type C:

LOCATIONAL VARIABLES

A total of seven locational variables is included in this pilot study. Another six variables were also included in the study from the beginning, which are as follows:

(1) Streetlight*;

(2) Crossing and Protection*;

(3) Road Condition*;

(4) Surrounding Land Uses*;

(5) Traffic Speeds*; and

(6) Traffic Volumes*.

Due to the characteristics of the six count locations, there was little variation within the categories for these omitted variables. This thesis recommends that future studies that have a more diverse set of observation locations consider using the full thirteen locational variables—possibly in addition to others of particular interest to the given study.

C1 – LOCATION OF OBSERVATION

A total of six locations were observed during this pilot study for documenting bicycle behaviors at stop signs. Each location was located in one of the following neighborhoods in the City of Seattle, including:

(A) Capitol Hill;

(B) Queen Anne;

(C) Greenlake;

(D) Ballard;

(E) the University District; or

(F) Sand Point.

Specific information detailing each location is on provided in Chapter 4 "Pilot Study Count Locations".

C2 – INTERSECTION SIGN TYPE

All intersections observed during the pilot study are controlled by stop signs. The configuration at each count location is either:

(A) Four-Way Stop; or

(B) Two-Way Stop, Two-Way Yield to Bikes and Pedestrians.

Four of the six count locations feature a Four-Way Stop. At the other two locations, bicyclists under observation are controlled by a stop sign, where they must wait until crossing traffic allows safe movement into the intersection.

This thesis expects that bicyclists will be more likely to use full stops at two-way stop, two-way yield crossings because perpendicular moving traffic is not required to stop. It is, furthermore, expected that a higher incidence of not stopping and using rolling stops will occur at Four-Way Stops. The geosemiotics theory argues that most road users can reasonably expect predictable behaviors at four-Way Stops, as road users traveling in all directions must behave in the same way at the crossing (Scollon and Scollon 2003, 205). Compared with a location with intersecting traffic following two separate traffic control devices, more bicyclists are expected to feel safe using rolling stops or entirely disregarding signals. Furthermore, data collected through the NHRC study found a distinct behavioral difference between Four-Way Stops and intersections controlled by traffic signals. This study found that only 8.4% of bicyclists disobeyed signals, yet a total of 25.3% disobeyed stop signs (Hunter et al. 1999). These findings support the theory that bicyclists will alter their actions, in part, in response to the traffic control devices in place.

C3 – FLASHING BEACON

A study conducted by Hunter et al., at the Highway Safety Research Center at the, on rectangular rapidly flashing beacons at a trail crossing in St. Petersburg, Florida, supports these assumptions. A before and after study showed that succeeding the installation of these yellow flashing beacons, the percentage of motorists yielding to non-motorized trail users increased from 2% to 54% when the new signals were activated and flashing. When these signals were not flashing, an increase in yielding was still observed, with 53% of drivers yielding to pedestrians and bicyclists (Hunter, Srinivasan, and Martell 2009, vi). Based on these findings, this thesis assumes that this kind of flashing beacon, and others, may affect bicyclists' stopping behaviors.

At intersections controlled by stop signs, flashing beacons can also be used to enhance the visibility and legibility of the intersection. Of the six count locations, each feature either:

(A) No Beacon or Signal;
(B) Yellow Rectangular Rapidly Flashing Beacons on Yield Signs;
(C) Suspended Flashing Red Beacon(s); or
(D) Traffic Signals Flashing Red.

This list is presented in terms of the degree of control each type of beacon or signal provides, based on how visible each type of traffic control device is. The yellow flashing lights on yield signs installed at the curb are less visible to drivers than are suspended beacons, which are less visible than are the flashing red bulbs on traffic signals at formally signalized intersections. The incidence of bicyclists passing stop signs without stopping as well as using rolling stops is expected to decrease at intersections where increasingly visible flashing beacons are installed.

C4 – GREEN BICYCLE LANES

Two of the six count locations observed in this pilot study feature a different type of green bicycle lane(s) painted across the intersections, which means that each location include either:

(A) No Green Bicycle Lane Painted Across the Intersection;

(B) Two Paired One-Way Green Bicycle Lanes Painted Across the Intersection; or

(C) One Bi-Directional Green Bicycle Lane in the Intersection.

The two types of green bicycle lanes are grouped together in the analysis of pilot study results. Each is identified here for descriptive purposes; however, this thesis does not attempt to differentiate between the two in analysis of intersection treatment types.

In 2010, Hunter published research evaluating the effects of a green bicycle lane installed in St. Petersburg, Florida along an intersection approach, showing vehicles where to cross over the bicycle lane. After the installation of a green bicycle lane paired with “Yield to Bikes” signage, a more drivers use turn signals when making right turns and a larger proportion of bicyclists actively to look for cars as they used the colored bicycle lane. (Hunter, Srinivasan, and Martell 2008, 12). Statistically significant findings also showed an increase in the proportion of drivers yielding to bicyclists where the colored bicycle lane was installed (Hunter, Srinivasan, and Martell 2008, 8).

As this research suggests that green on the approach influences bicyclists' and drivers' behaviors, this pilot study assumes that green bicycle lanes painted across intersections will also have an influence on mobile behaviors. The presence of a green bicycle lane painted across an intersection is expected to have a negative association with full stops and a more positive relationship with rolling stops and track stands. This is based on the finding in Florida that fewer bicyclists slowed for or otherwise yielded to cars after the green lanes were painted (Hunter, Srinivasan, and Martell 2008, 9). Logic argues that a similar trend will be observed where green bicycle lanes are installed across intersections, with a greater incidence of noncompliance and not yielding the right-of-way expected.

C5 – TYPE OF BICYCLE FACILITY

This study catalogs the type of bicycle facilities present at each count location in order to investigate whether or not stopping behavior is correlated with the type of facility in place. To that end, the type of bicycle facility installed on each side of each count location is recorded and presented in Chapter 4 "Pilot Study Count Locations". The types of bicycle facilities included in this study represent the six primary typologies installed within the City of Seattle, which include:

(A) Shared Roadways;
(B) Bicycle Lanes;
(C) Buffered Bicycle Lanes;
(D) Neighborhood Greenways;
(E) Bikeways; and
(F) Off-Street Paths.

The set of intersections selected for this study intentionally collectively features each of these facility types, with the first two types present at multiple locations.

These facility types are listed from least to most comfortable for bicyclists to use. Assumptions made for comfort level are based on the physical protection bicyclists are afforded from motor vehicles and other road users. Shared roadways and arterial roads with no pavement markings logically provide the least secure environment for bicyclists, putting them directly in the lane of traffic. Bicycle lanes are a degree safer, as lines of paint delineate a physical space for bicyclists to use the right-of-way. Buffered bicycle lanes are an elevated version of a bicycle lane, with a wider gap painted, separating bicycles from normal roadway traffic.

Although no real separation exists, the neighborhood greenways relatively new to the City of Seattle are provide a roadway with predictably low speeds where the policy imposed social contract is that motor vehicles should yield to non-motorized users along the entire stretch of each block, as well as at the intersection. The even more recently implemented bikeways are considered second most comfortable, just below off-street paths or trails. Bikeways are bi-directional buffered bicycle lanes that are separated from moving traffic with plastic bollards, objects, or a narrow curb, providing superior protection to all bicyclists riding on-street. Affording the maximum separation and highest protection from motor traffic, off-street paths are the most comfortable facilities provided in the City of Seattle. Unlike all other types of bicycle facilities, bicyclists only come into contact with motorized vehicles at intersections, and only under very rare conditions along the path.

A consideration was made for the use of the list of bicycle facility types used by the NBPDP; however, using this Seattle-specific variable allows for a more relevant and useful investigation for the geography region under study. This pilot study recommends that future studies likewise code this locational variable using the types of facilities installed where behavioral observations are made. Establishing this, or any other, place-specific variable, however, does necessarily obviate the practicality of also recording locational variables using this or any other variable used by the NBPDP.

C6 – ON-STREET PARKING

The presence of on-street parking is recorded at each count location and included as an independent variable in the final regression analysis. This variable was included under the assumption that on-street parking reduces bicycle safety. In the late 2000's, a group of researchers at the University of Texas at Austin found that the presence of on-street parking has a statistically significant influence on where bicyclists ride on a roadway. When on-street parking is present, bicyclists are more likely to rider further out into the roadway. However, if a motor vehicle passes on the left, bicyclists reposition themselves and ride closer to the parked cars. Finally, increasingly protective bicycle facilities are associated with an increase in the distance bicyclists ride away from parallel-parked cars (Torrance et al. 2008, 41–42). The NHRC study, likewise, found a relationship between on-street parking and higher conflict rates between motor vehicles and bicyclists, with high turnover spaces leading to the most conflicts (Hunter et al. 1999, 65, 75). These results notwithstanding, the Austin study did not find a statistically significant relationship between on-street parking turnover rates and the lateral position bicyclists take on the roadway. Their survey data suggests that bicyclists' comfort levels decrease when on-street parking experiences high turnover, but observational data was unable to confirm an effect on behaviors and practice.

Equipped with these findings supporting the assumption that on-street parking has an influence on bicyclists' behaviors, this thesis aims to discover whether this behavioral relationship extends the types of stops bicyclists use at stop sign controlled intersections. The assumption is that on-street parking will increase the use of full stops and decrease the use of other stopping types. Similarly to how bicyclists shift their position in the roadway depending on the presence of parked cars, this thesis argues that stopping behavior will likewise be altered based on the presence of parked cars.

The presence of on-street parking is recorded for each intersecting road, in both directions of travel if it is allowed within 30 feet of the stop or yield sign before the intersection as well as at the corner on the side after the intersection. This is similar to the variables describing directional topography and bicycle facilities, and allows an investigation into the influence on-street parking before and after a turning movement has on stopping behaviors and bicyclists' safety.

C7 – TOPOGRAPHY

Level topography is idea for bicycling, as minimizes resistance and helps maintain the enjoyment of the ride. Steeper grades, on the other hand, can either act as a speed assist (downhill) or a barrier (uphill). Severe enough topography can even act as edge, steering potential riders away from using a bicycle for their trip. The bicyclist perception survey findings produced by Sanders at the University of California Berkeley suggest that the presence of hilly topography acts as a stronger barrier for individuals who bicycle infrequently. Among the “daily cyclists” respondents, topography was the les important potential barrier to bicycling, with hills less important to these regular riders than the presence of bicycle facilities and fears of motor vehicle behaviors (Sanders 2013, 02). A study conducted by graduate students at the University of Washington in 2009 included an indicator for topography in an investigation of bike-share use. This study found that topography had no influence on actual bike-share usage, but results did not imply that route choice is affected (Gregerson et al. 2010, 29). Neither study, however, provides insight into how topography may influence stopping behavior, nor do any other domestic studies reviewed during the course of this research.

Logic suggests that topography can be particularly important at intersections, as the act of stopping prior to a hill can make a climb considerably more difficult, given the lack of momentum. The NBPDP and the counts in Washington State both record the following three general categories of topography, but they do not distinguish between uphill and downhill slopes. This pilot study addresses this data gap. In the design phase of the pilot study, a total of five categories of topography were included. However, based on the physical characteristics of each count location and bicycle volumes recorded during the pilot study, only the following three categories are included in data analysis:

(A) Level, No Topography;
(B) Uphill Slope; and
(C) Downhill Slope.

Originally, the category for uphill slopes was separated between moderate and steep uphill. The category for downhill slopes was likewise originally represented by the categories of moderate downhill and steep downhill. No differences were observed for the two categories for each direction of topography; thus, categories were combined to reflect only the most distinct categories. As the pilot study collected the direction of travel of the bicyclists prior to the intersection and the bicyclists' turning movement, the results of the pilot study provide data on the direction of topography before and after the intersection. By recording this more fine-grained variable for topography, the pilot study yields data affording a more complete understanding of how the terrain influences bicyclists' stopping behaviors.

CHAPTER 8:

PILOT STUDY DESCRIPTIVE STATISTICS

OVERVIEW OF DESCRIPTIVE RESULTS

The stopping behaviors of a total of 2,616 bicyclists were recorded during the 40 hours of observation conducted over the 3-day count period. A total of 1,446 of these bicyclists used rolling stops or track stands, accounting for 55.3% of all observations. Another 24.8% of bicyclists did not stop before proceeding through the intersection and a full and complete stop, as defined by this research, was only used by 19.9% of all bicyclists observed. These illustrative results provide the first answer to the primary research question explored through this thesis.

This chapter presents the descriptive statistics and breakdown of stopping behavior for each variable introduced in Chapter 7 “Pilot Study Variables”. Further discussion and statistical analysis of this raw data is presented in Chapter 9 “Pilot Study Statistical Analysis Methods” and Chapter 10 “Pilot Study Analysis Results”.

Variables Type A:

BEHAVIORAL AND SUBJECT-SPECIFIC VARIABLES

Three-quarters of all bicyclists observed during the observation period were male, which is a nearly equal to proportion reported for the City of Seattle in the 2012 annual statewide bicycle and pedestrian documentation project. Only 4% of bicyclists observed during the pilot study were not wearing a helmet, which is slightly lower than the 6.5%

percent helmet law non-compliance reported during the counts two years ago (Cascade Bicycle Club 2013, 37).

The most distinct directional trend observed is the prevalence of southbound riders during the morning hours. A total of 25% of subjects were recorded as approaching the intersection in a southbound direction, which is more than twice the total observed traveling in any direction during either time period. At the intersection, 71.9% of bicyclists traveled straight, with another 21.1% turning left and only 7% turning right.

FIG. 30: Overview of Results for Behavioral Variables Included in the Pilot Study

OVERVIEW OF BEHAVIORAL AND SUBJECT-SPECIFIC VARIABLES:
Description of the Total Number of Observations and Percentage within Each Variable Sub-Category

		TOTAL OBSERVATIONS RECORDED BY TIME OF DAY				TOTALS FOR ALL OBSERVATIONS RECORDED	
		Morning		Evening		Frequency	Percent
		Σ	%	Σ	%	Σ	%
A1	**GENDER**						
1	Male	1,136	43.4%	784	30.0%	**1,920**	**73.4%**
2	Female	453	17.3%	243	9.3%	**696**	**26.6%**
A2	**HELMET USE**						
1	Helmet	1,542	58.9%	970	37.1%	**2,512**	**96.0%**
2	No Helmet	47	1.8%	57	2,2%	**104**	**4.0%**
A3	**TURNING MOVEMENT**						
1	Straight	1,000	38.2%	880	33.6%	**1,880**	**71.9%**
2	Left	486	18.6%	66	2.5%	**552**	**21.1%**
3	Right	103	3.9%	81	3.1%	**184**	**7.0%**
A4	**STOPPING BEHAVIOR**						
1	Maneuver Safe	1,240	47.4%	629	31.7%	**2,069**	**79.1%**
2	Maneuver Somewhat Unsafe	255	9.7%	162	6.2%	**417**	**16.0%**
3	Maneuver Unsafe	94	3.6%	36	1.4%	**130**	**5.0%**
A5	**STOPPING BEHAVIOR**						
1	Full and Complete Stop	316	12.1%	204	7.8%	**520**	**19.9%**
2	Rolling Stop or Track Stand	850	32.5%	596	22.8%	**1,446**	**55.3%**
3	No Stop, Slow, or Yield	423	16.2%	227	8.7%	**650**	**24.8%**

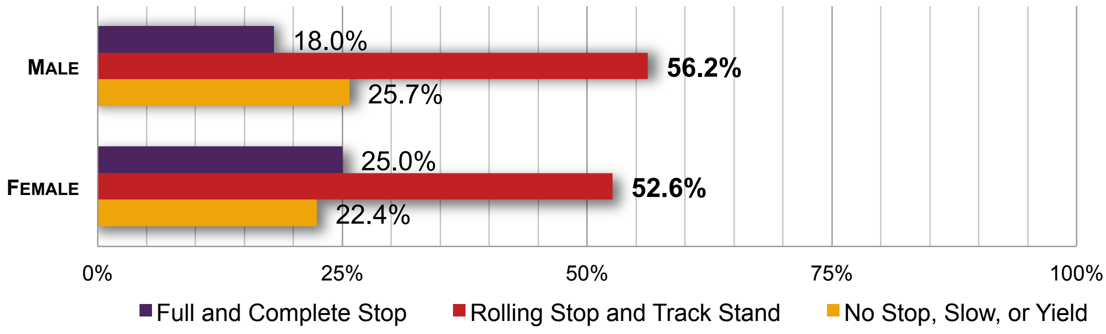
In regard to the most interesting variable in this study, a majority, 55.3%, of bicyclists observed during this pilot study used rolling stops or track stands. Of all bicyclist observed in this pilot study, the largest proportion used maneuvers considered safe by data collectors. In total, 79.1% of bicyclists were considered to be using safe maneuvers, 16% were using somewhat unsafe maneuvers, and only 5% of bicyclists observed were clearly using unsafe maneuvers at the intersections.

A1 – BICYCLISTS' GENDER

Of all bicyclists observed during the pilot study, a substantial 73.4% were male and only 26.6% female. Both male and female bicyclists used rolling stops, similar proportions of both genders not stopping or yielding before traveling through one of the locations under observation. The biggest difference is seen in the finding that 7% fewer male riders than female riders were observed coming to full and complete stops.

FIG. 31: Descriptive Statistics – Gender of Bicyclists Observed

GENDER OF OBSERVED BICYCLISTS:
By Percentage within the Variable for Gender



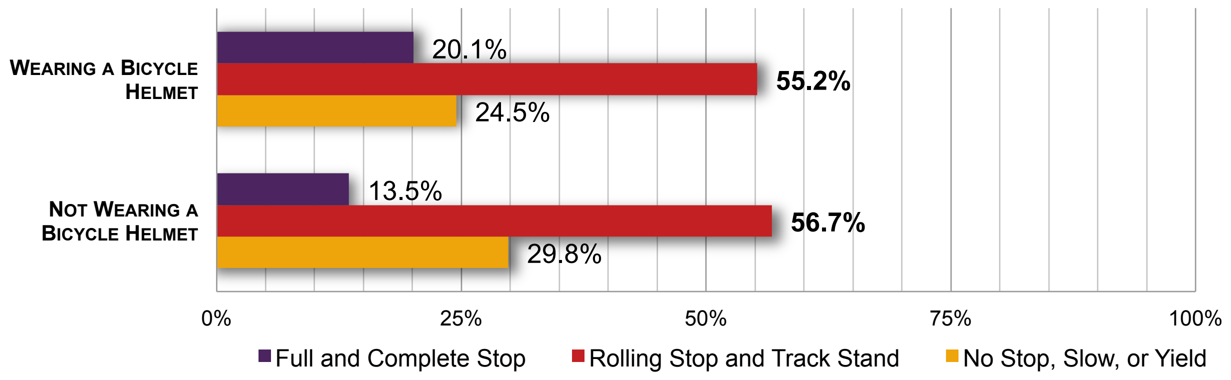
Gender	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Male Bicyclists				
Total Count	346	1,080	494	1,920
% within Male Gender	**18.0%**	**56.2%**	**25.7%**	**100%**
Female Bicyclists				
Total Count	174	366	156	696
% within Female Gender	**25.0%**	**52.6%**	**22.4%**	**100%**

A2 – BICYCLISTS' HELMET USE

A very positive finding of the pilot study is that 97.3% of all bicyclists observed were wearing a helmet. Most helmet-wearing bicyclists used rolling stops, with 20.1% coming to a full and complete stop and 24.5% traveling through the intersection without stopping. Bicyclists without a helmet came to no stop 5.3% more often than did bicyclists with a helmet, and only 13.5% of bicyclists without a helmet to a full stop.

FIG. 32: Descriptive Statistics – Helmet Use of Bicyclists Observed

HELMET USE OF OBSERVED BICYCLISTS:
By Percentage within the Variable for Helmet Use



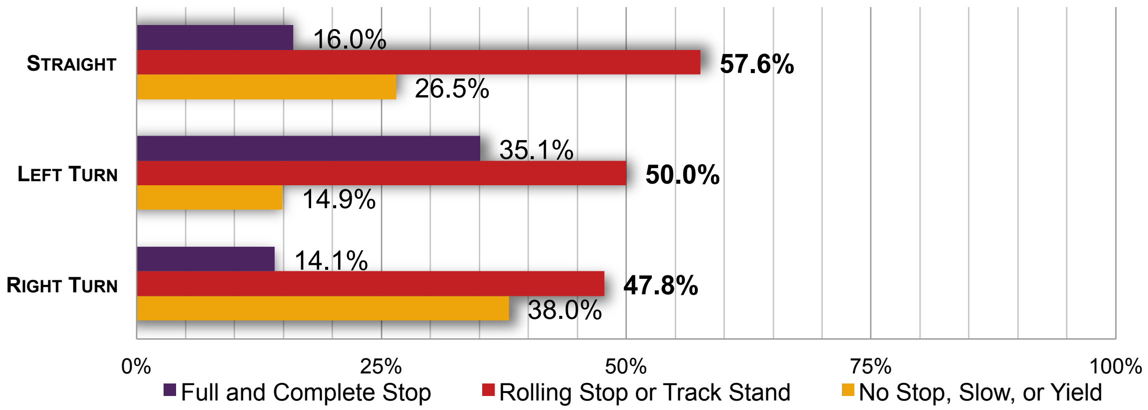
Helmet Use	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Bicyclists Wearing a Helmet				
Total Count	506	1,387	619	2,512
% within Helmet Users	**20.1%**	**55.2%**	**24.6%**	**100%**
Bicyclist Not Wearing a Helmet				
Total Count	14	59	31	104
% within Female Gender	**13.5%**	**56.7%**	**29.8%**	**100%**

A3 – BICYCLISTS' TURNING MOVEMENTS

Most bicyclists recorded during the pilot study traveled straight through the intersections under observation. A total of 57.6% of bicyclists traveling straight used a rolling stop, 16% stopped completely before riding through the intersection, and 26.5% chose to not stop before crossing. Of those bicyclists observed turning right, 38% did not use a stop

FIG. 33: Descriptive Statistics – Turning Movements Made by Bicyclists Observed

TURNING MOVEMENTS MADE BY BICYCLISTS AT STOP SIGNS:
By Percentage with Each Type of Turning Movement



Turning Movement	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Straight				
Total Count	300	1,082	498	1,880
% within Turning Movement	**16.0%**	**57.6%**	**26.5%**	**100.0%**
Left Turn				
Total Count	194	276	82	552
% within Turning Movement	**35.1%**	**50.0%**	**14.9%**	**100.0%**
Right Turn				
Total Count	26	88	70	184
% within Turning Movement	**14.1%**	**47.8%**	**38.0%**	**100.0%**

and only 14.1% came to a complete stop with at least one foot on the ground. In perfect contrast, among left turning bicyclists, only 14.9% failed to stop and a total of 35.1% used full and complete stops.

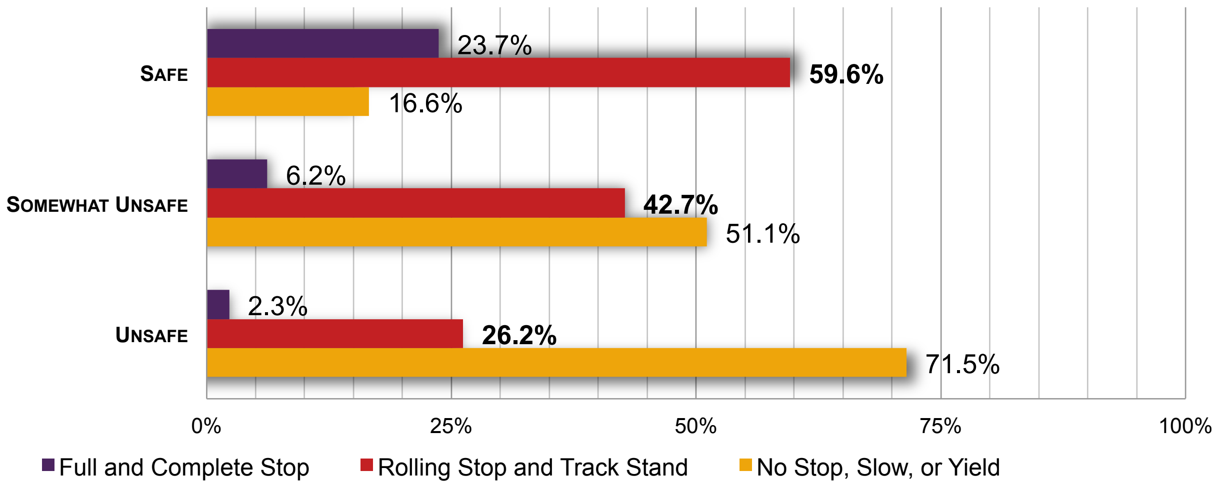
A4 – SAFETY OF BICYCLISTS' MANEUVERS

Data collectors documented 79.1% of all bicyclists as employing safe, predictable maneuvers when approaching, crossing, and departing the intersection at all count locations. Another 15.9% of bicyclists were categorized as using somewhat unsafe behaviors, and only 5% of the 2,616 bicyclists observed were considered to be unsafe in their actions and behaviors.

A total of 59.6% of the safe bicyclists used rolling stops, with 23.7% coming to a complete stop and 16.6% failing to stop at the crossing (Fig. 34). This pattern is nearly identical to stopping behaviors for the entire population under investigation and is distinct from the results for the other two types of stopping behaviors. Over 70% of unsafe bicyclists disregarded the stop sign, and only 2.3% came to a full and complete stop. The action of not stopping or yielding is also most common among somewhat unsafe bicyclists, with 51.1% not stopping, 42.7% using rolling stops, and 6.2% coming to a full and complete stop.

FIG. 34: Descriptive Statistics – Safety of Bicyclists' Maneuvers

SAFETY OF MANEUVERS MADE BY BICYCLISTS AT STOP SIGNS:
By Percentage with Each Type of Turning Movement



Bicyclists' Safety	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Safe				
Total Count	491	1,234	344	2,069
% within Safety of Maneuver	**23.7%**	**59.6%**	**16.6%**	**100.0%**
Somewhat Unsafe				
Total Count	26	178	213	417
% within Safety of Maneuver	**6.2%**	**42.7%**	**51.1%**	**100.0%**
Unsafe				
Total Count	3	34	93	130
% within Safety of Maneuver	**2.3%**	**26.2%**	**71.5%**	**100.0%**

Variables Type B:

CIRCUMSTANTIAL VARIABLES

All data recorded in this pilot study were collected over a three-day period of time, in the month of November, in 2014. As is discussed in Chapter 5 "Pilot Study Count Schedule", the schedule used is modeled after the methodology used for the statewide bicycle and pedestrian documentation project conducted in Washington State. This means that counts occurred twice daily on a Tuesday, Wednesday, and Thursday from 7:00-9:00 and 16:00-18:00. The largest proportion of observations, 44.6%, was made on Thursday and an average of 60.7% bicyclists were recorded during the morning period.

Weather conditions during the morning counts were clear and dry each day, with freezing temperatures experienced at several count locations the first two mornings of the pilot study. Overall, due to the low temperatures experienced during this pilot study, 79.6% of observations were made under weather conditions defined as "poor" by the National Bicycle and Pedestrian Documentation Project.

No rain was experienced during the pilot study, with the exception of light rain experienced at the end of the evening count period on the third day of observations. This rain did not result in perception above 0.0 inches and was not included as a variable in this regression analysis.

FIG. 35: Overview of Results for Circumstantial Variables Included in the Pilot Study

OVERVIEW OF CIRCUMSTANTIAL VARIABLES:
Description of the Total Number of Observations and Percentage within Each Variable Sub-Category

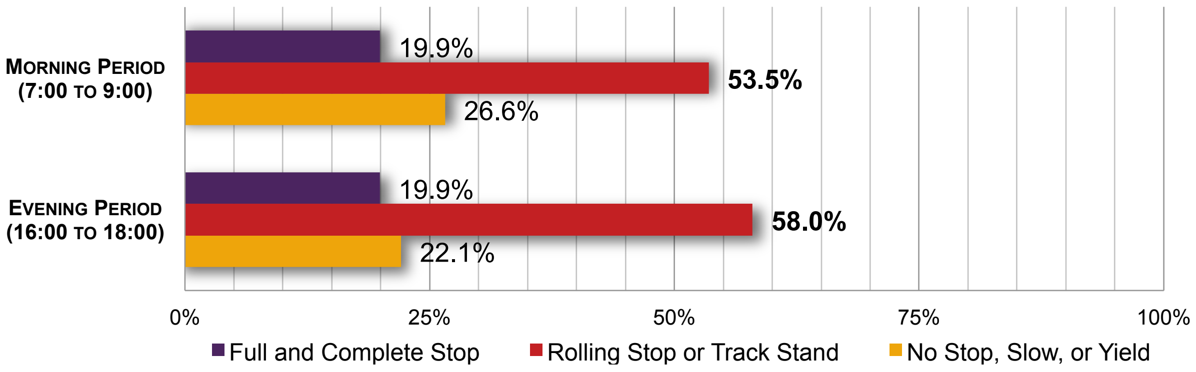
		TOTAL OBSERVATIONS RECORDED BY TIME OF DAY				**TOTALS FOR ALL OBSERVATIONS RECORDED**	
		Morning		**Evening**		**Frequency**	**Percent**
		Σ	**%**	**Σ**	**%**	**Σ**	**%**
B1	**TIME OF OBESERVATION**						
A	7:00 to 9:00 AM	1,589	60.7%	-	-	**1,589**	**60.7%**
B	16:00 to 18:00 PM	-	-	1027	39.3%	**1,027**	**39.3%**
B2	**DAYLIGHT AND TWILIGHT**						
A	Daylight	1,474	56.3%	190	7.3%	**1664**	**63.6%**
B	Sunrise or Sunset	115	4.4%	315	12.0%	**430**	**16.4%**
C	Civil Twilight	0	0%	362	13.8%	**362**	**13.8%**
D	Nocturnal Twilight	0	0%	160	6.1%	**160**	**6.1%**
E	Astronomical Twilight	0	0%	0	0%	**0**	**0%**
B3	**TEMPERATURE**						
	Range of Temperature in Degrees Fahrenheit	Three-Day AM Average of 3.9 Degrees		Three-Day PM Average of 47 Degrees		Three-Day Average of **43 Degrees**	
B4	**VISIBILITY**						
	Range in the Number of Miles of Visibility	Three-Day AM Average of 10 Miles		Three-Day PM Average of 7.3 Miles		Three-Day Average of **8.7 Miles**	
B5	**WIND SPEED**						
	Range in the Wind Speed by Miles per Hour	Three-Day AM Average of 2.7 mph		Three-Day AM Average of 2.3 mph		Three-Day Average of **2.5 mph**	

B1 – TIME PERIOD*

Due to the unbalanced count schedule, 61% of the counts were observed in morning count period between 7:00 to 9:00 AM, and 39% were observed in the evening from 16:00 to 18:00 PM. A somewhat greater proportion of bicyclists used rolling stops and/or track stands during the evening, accounting for 58% of all observations made in the evening, compared to 53.5% of morning riders. During both time periods, a total of

FIG. 36: Descriptive Statistics – Time of Day

INFLUENCE OF TIME OF DAY ON BICYCLISTS’ STOPPING BEHAVIOR:
By Percentage with Each Count Period



Time of Day (Morning or Evening)	**Full and Complete Stop**	**Rolling Stop or Track Stand**	**No Stop, Yield, or Slow**	**TOTAL**
Morning Count Periods – from 7:00 to 9:00				
Total Count	316	850	423	1,589
% within Morning Period	**19.9%**	**53.5%**	**26.6%**	**100.0%**
Evening Count Periods – from 16:00 to 18:00				
Total Count	204	596	227	1,027
% within Evening Period	**19.9%**	**58.0%**	**22.1%**	**100.0%**

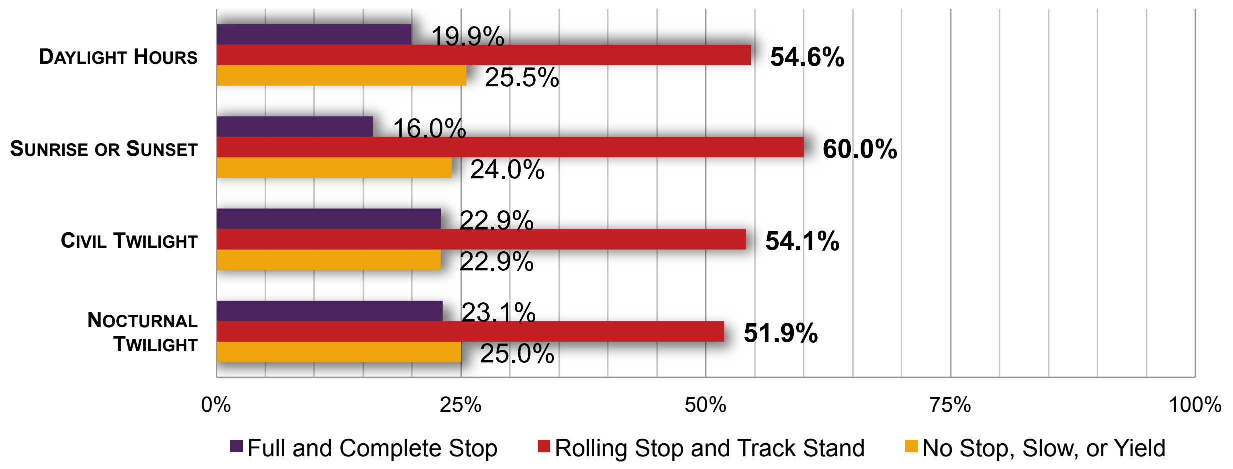
19.9% of bicyclists observed came to a full and complete stop. A failure to stop was more often observed in the morning than in the evening, at 26.6% and 22.1%, respectively.

B2 – NATURAL LIGHTING CONDITIONS

Observational data exhibits somewhat similar stopping behavior during the various levels of natural light, as defined by the four astronomical conditions identified in Chapter 7 “Pilot Study Variables”. Rolling stops were observed the most often during sunrise and sunset, during which time the lowest percentages of full stops were observed. Approximately a quarter of bicyclists observed under each lighting condition did not stop before entering the intersection.

FIG. 37: Descriptive Statistics – Natural Lighting Conditions

NATURAL LIGHT CONDITIONS OBSERVED DURING PILOT STUDY:
By Percentage within the Variable for Daylight and Twilight



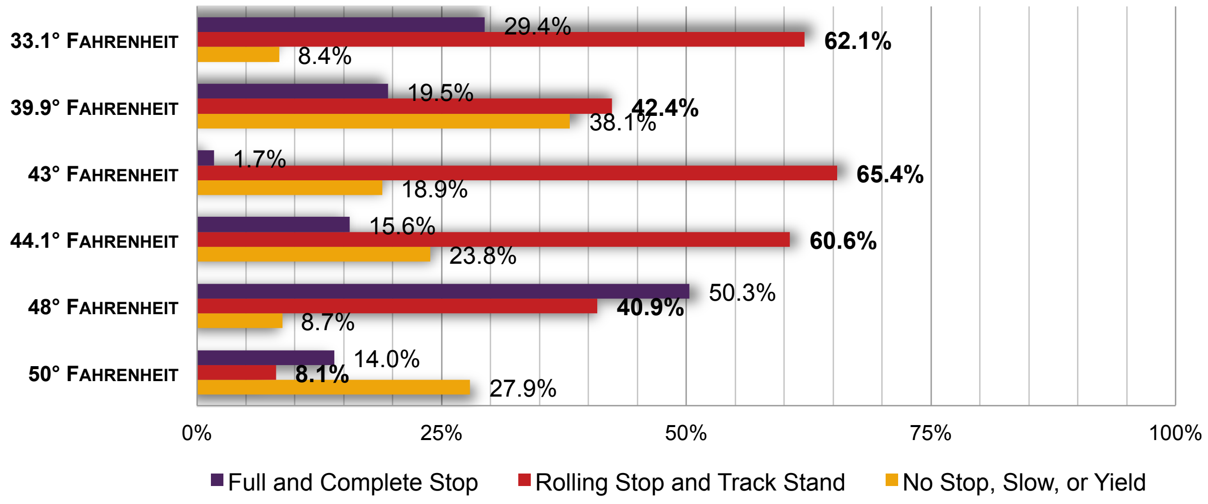
Daylight and Twilight Hours	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Daylight Hours				
Total Count	331	909	424	1,664
% within Daylight & Twilight	**19.9%**	**54.6%**	**25.5%**	**100.0%**
Sunrise or Sunset				
Total Count	69	258	103	430
% within Daylight & Twilight	**16.0%**	**60.0%**	**24.0%**	**100.0%**
Civil Twilight				
Total Count	83	196	83	362
% within Daylight & Twilight	**22.9%**	**54.1%**	**22.9%**	**100.0%**
Nocturnal Twilight				
Total Count	37	83	40	160
% within Daylight & Twilight	**23.1%**	**51.9%**	**25.0%**	**100.0%**

B3 – TEMPERATURE (in degrees Fahrenheit)

Descriptive results for the variable describing temperature are varied, as the pilot study relied on weather statistics collected at Seattle-Tacoma International Airport, rather than on exact temperatures at each location. When looking at the recorded temperature at the beginning of a count period, bicyclists' stopping behavior differs with only one notable, though imperfect, trend. Rolling stops and track stands were observed in far greater proportion during count periods beginning in the low thirties and low forties, accounting for over 60% of stopping behaviors. When reaching fifty degrees Fahrenheit, however, only 8.1% of bicyclists were seen using this type of stopping behavior (Fig. 38).

FIG. 38: Descriptive Statistics – Temperature

TEMPERATURES OBSERVED DURING PILOT STUDY:
By Percentage within the Variable for the Temperature at the Beginning of Each Count Period



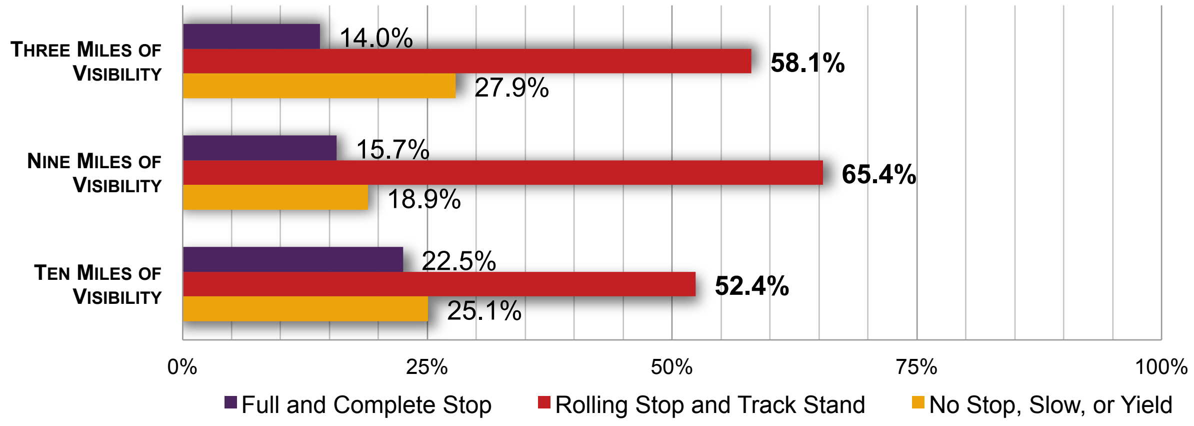
Recorded Temperatures	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
33.1° Fahrenheit				
Total Count	91	192	26	309
% within Temperature	**29.4%**	**62.1%**	**8.4%**	**100.0%**
39.9° Fahrenheit				
Total Count	126	274	246	646
% within Temperature	**19.5%**	**42.4%**	**38.1%**	**100.0%**
43.0° Fahrenheit				
Total Count	54	225	65	344
% within Temperature	**15.7%**	**65.4%**	**18.9%**	**100.0%**
44.1° Fahrenheit				
Total Count	99	384	151	634
% within Temperature	**15.6%**	**60.6%**	**23.8%**	**100.0%**
48.0° Fahrenheit				
Total Count	75	61	13	149
% within Temperature	**50.3%**	**40.9%**	**8.7%**	**100.0%**
50.0° Fahrenheit				
Total Count	75	310	149	534
% within Temperature	**14.0%**	**58.1%**	**27.9%**	**100.0%**

B4 – VISIBILITY

Three different levels of visibility were recorded at SeaTac Airport during the six observation periods of the pilot study. With three miles of visibility, only 14% of bicyclists were observed using full and complete stops, and with nine miles of visibility, only 15.7% were observed doing the same. Notably, however, under conditions with ten miles of visibility, 22.5% of bicyclists were observed using full and complete stops (Fig. 39). This finding is counter to the expectation that bicyclists would employ more cautious behaviors under conditions with lower levels of visibility.

FIG. 39: Descriptive Statistics – Visibility

VISIBILITY OBSERVED DURING PILOT STUDY:
By Percentage within the Variable for Visibility



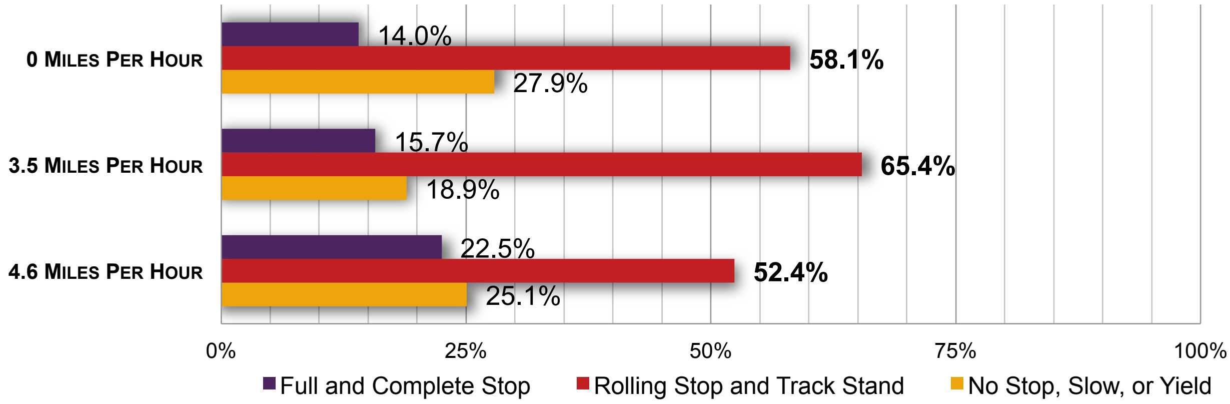
Recorded Miles of Visibility	**Full and Complete Stop**	**Rolling Stop or Track Stand**	**No Stop, Yield, or Slow**	**TOTAL**
Three Miles of Visibility				
Total Count	75	310	149	534
% within Visibility	**14.0%**	**58.1%**	**27.9%**	**100.0%**
Nine Miles of Visibility				
Total Count	54	225	65	344
% within Visibility	**15.7%**	**65.4%**	**18.9%**	**100.0%**
Ten Miles of Visibility				
Total Count	391	911	436	1,738
% within Visibility	**22.5%**	**52.4%**	**25.1%**	**100.0%**

B5 – WIND SPEED

Wind speeds recorded at Seattle-Tacoma International Airport were relatively low during the count periods observed. Similar to results for temperature and visibility, both descriptive and analytical results for wind speed in this analysis are limited. The highest wind speed recorded during the pilot study was only 4.6 miles per hour, with zero miles an hour being the lowest. On this scale, full and complete stops were used by a higher percentage of bicyclists when wind speeds are higher than when they were lower (Fig. 40). Findings for the other two stopping behaviors, however, do not exhibit similar patterns.

FIG. 40: Descriptive Statistics – Wind Speed

WIND SPEED OBSERVED DURING PILOT STUDY:
By Percentage within the Variable for Wind Speed



Recorded Wind Speeds	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
0 Miles per Hours				
Total Count	180	311	499	990
% within Wind Speed	**18.2%**	**50.4%**	**31.4%**	**100.0%**
3.5 Miles per Hours				
Total Count	249	755	313	1,317
% within Wind Speed	**18.9%**	**57.3%**	**23.8%**	**100.0%**
4.6 Miles per Hours				
Total Count	91	192	26	309
% within Wind Speed	**29.4%**	**62.1%**	**8.4%**	**100.0%**

Variables Type C:

LOCATIONAL VARIABLES

The largest proportions of bicyclists observed during the pilot study were seen in the University District and Greenlake neighborhoods, representing 37.15% and 24.4% of all bicyclists observed. This means that over half of the observations were only made at a third of count locations With this being the case, the data collected for each of the locational variables is skewed toward the representation of these particular count locations rather than a general population of locations.

As locational variables are the most easily impacted by policy, planning, and traffic engineering fields, it is important that the data set be recognized as imperfect; results are not well developed enough for credible application to decision-making. This is especially important, as three of the four most significant findings, discussed earlier in this chapter, are locational variables that would be easily adjusted through facilities design changes.

FIG. 41: Overview of Results for Locational Variables Included in the Pilot Study

OVERVIEW OF LOCATIONAL VARIABLES:
Description of the Total Number of Observations and Percentage within Each Variable Sub-Category

VARIABLES		TOTALS AND PERCENTS BY TIME OF DAY				TOTALS FOR ALL OBSERVATIONS	
		Morning		Evening		Frequency	Percent
		Σ	%	Σ	%	Σ	%
C1	**LOCATION OF OBSERVATION**						
A	Capitol Hill	193	7.4%	204	7.8%	**397**	**15.2%**
B	Queen Anne	30	1.1%	0	0%	**30**	**1.1%**
C	Greenlake	489	18.7%	149	5.7%	**638**	**24.4%**
D	Ballard	42	1.6%	14	0.5%	**56**	**2.1%**
E	University District	591	22.6%	379	14.5%	**970**	**37.1%**
F	Sand Point	244	9.3%	281	10.75	**525**	**20.1%**

FIG. 41: Overview of Results for Locational Variables Included in the Pilot Study (cont.)

OVERVIEW OF LOCATIONAL VARIABLES: (cont.)
Description of the Total Number of Observations and Percentage within Each Variable Sub-Category

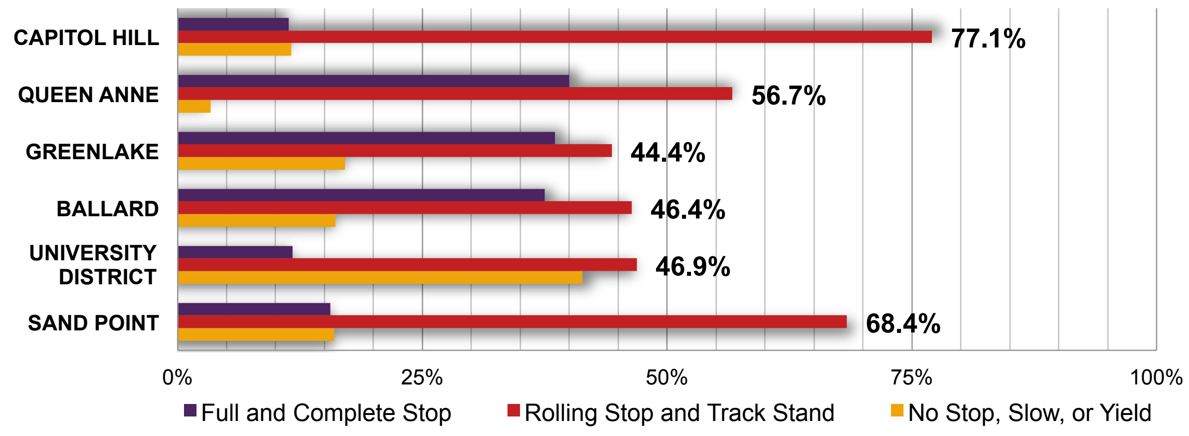
VARIABLES		**TOTALS AND PERCENTS BY TIME OF DAY**				**TOTALS FOR ALL OBSERVATIONS**	
		Morning		**Evening**		**Frequency**	**Percent**
		Σ	**%**	**Σ**	**%**	**Σ**	**%**
C2	**INTERSECTION SIGN CONTROL TYPE**						
A	Four-Way Stop	1,303	49.8%	732	28.0%	**2,035**	**77.8%**
B	Two-Way Stop, Two-Way Yield to Bikes and Pedestrians	286	10.9%	295	11.3%	**581**	**22.2%**
C3	**SIGNAL OR BEACON**						
A	No Beacon or Signal	244	9.3%	281	10.7%	**525**	**20.1%**
B	Flashing Yellow Beacon on Yield Sign	42	1.6%	14	0.5%	**56**	**2.1%**
C	Suspended Flashing Red Beacon	682	26.1%	353	13.5%	**1,035**	**39.6%**
D	Traffic Signals Flashing Red	621	23.7%	379	14.5%	**1,000**	**38.2%**
C4	**GREEN BICYCLE LANE**						
A	Green Bicycle Lanes in the Intersection (bi-directional and one-way couplets)	633	24.2%	393	15.0%	**1,026**	**39.2%**
B	No Green Bicycle Lane in the Intersection	956	36.5%	634	24.2%	**1,590**	**60.8%**
C5	**BICYCLE FACILITIES** (facilities used by bicyclists before and after the intersection)						
A	Shared Roadway	346	13.2%	177	6.7%	**523**	**20.0%**
B	Bicycle Lane	396	11.3%	197	7.5%	**493**	**18.8%**
C	Buffered Bicycle Lane	190	7.3%	55	2.1%	**245**	**9.3%**
D	Neighborhood Greenway	36	1.4%	10	0.4%	**46**	**1.8%**
E	Bi-Directional Bikeway	492	18.8%	313	11.9%	**805**	**30.8%**
F	Bi-Directional Off-Street Path	230	8.8%	277	10.6%	**508**	**19.3%**
C6	**ON-STREET PARKING**						
A	No On-Street Parking at Intersection	1,224	46.6%	701	26.8%	**1,924**	**73.5%**
B	On-Street Parking at Intersection	366	14.0%	327	12.5%	**692**	**26.5%**
C7	**TOPOGRAPHY***						
A	Level	1,181	45.1%	700	26.8%	**1,881**	**71.9%**
B	Uphill	228	8.7%	138	5.3%	**228**	**8.7%**
C	Downhill	181	6.9%	190	7.2%	**371**	**14.2%**

C1 – LOCATION OF OBSERVATION

Observations made at the count locations in Capitol Hill and Sand Point saw the highest proportions of rolling stops and track stands, respectively totaling 77.1% and 68.4% of all bicyclists at each location. 40% of bicyclists in Queen Anne, 38.6% in Greenlake, and 37.5% in Ballard used full and complete stops (Fig. 42). These are the very highest percentages for complete stops among the six count locations, with only 15% of riders

FIG. 42: Descriptive Statistics – Pilot Study Count Locations

LOCATIONS OBSERVED DURING PILOT STUDY:
By Percentage within the Variables for Count Location



Intersection Types Observed	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Capitol Hill				
Total Count	45	306	46	397
% within Location	**11.3%**	**77.1%**	**11.6%**	**100.0%**
Queen Anne				
Total Count	12	17	1	30
% within Location	**40.0%**	**56.7%**	**3.3%**	**100.0%**
Greenlake				
Total Count	246	283	109	638
% within Location	**38.6%**	**44.4%**	**17.1%**	**100.0%**
Ballard				
Total Count	21	26	9	56
% within Location	**37.5%**	**46.4%**	**16.1%**	**100.0%**
University District				
Total Count	114	455	401	970
% within Location	**11.8%**	**46.9%**	**41.3%**	**100.0%**
Sand Point				
Total Count	82	359	84	525
% within Location	**15.6%**	**68.4%**	**16.0%**	**100.0%**

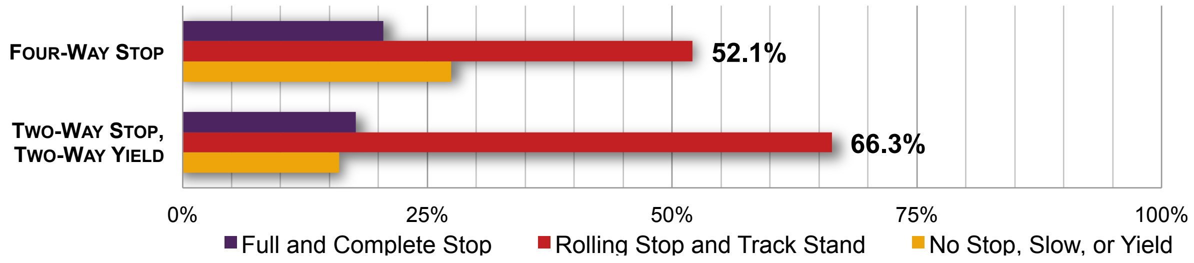
in Sand Point coming to a complete stop and around 11% of observed riders at the remaining two locations. In the University District, the incidence of not stopping accounts the behaviors of 41.3% of all bicyclists observed, which is over double the proportion of bicyclists engaging in this same practice at all other locations.

C2 – INTERSECTION STOP SIGN CONFIGURATION

Two types of intersections were observed during the pilot study, including intersections controlled by four-way stop signs and those controlled by stop signs in two directions and yield signs in the intersecting directions. A greater proportion of bicyclists at the two-way stop, two-way yield intersections used rolling stops and track stands than at the four-way stops, accounting for 66.3% and 52.1% of stopping behaviors at each type of location, respectively. Conversely, the percentage of bicyclists not stopping or yielding is higher at four-way stops than it is at two-way stops, two-way yields. A total of 27.4% the bicyclist's observed at four-way stop sign controlled intersections failed to stop, with

FIG. 43: Descriptive Statistics – Intersection Stop Sign Configuration

STOP SIGN CONFIGURATIONS OBSERVED DURING PILOT STUDY:
By Percentage within the Variable for Wind Speed



Stop Sign Configuration	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Four-Way Stop Sign Controlled Intersection				
Total Count	417	1,061	557	2,035
% within Intersection Type	**20.5%**	**52.1%**	**27.4%**	**100.0%**
Two-Way Stop Sign, Two-Way Yield Sign Controlled Intersection				
Total Count	103	385	93	581
% within Intersection Type	**17.7%**	**66.3%**	**16.0%**	**100.0%**

only 16% doing the same at the other type of crossing. The incidence of full and complete stops was relatively similar at both types, with 20.5% of bicyclists practicing this behavior at four-way stops and 17.7% using complete stops at two-way stop, two-way yields (Fig. 43).

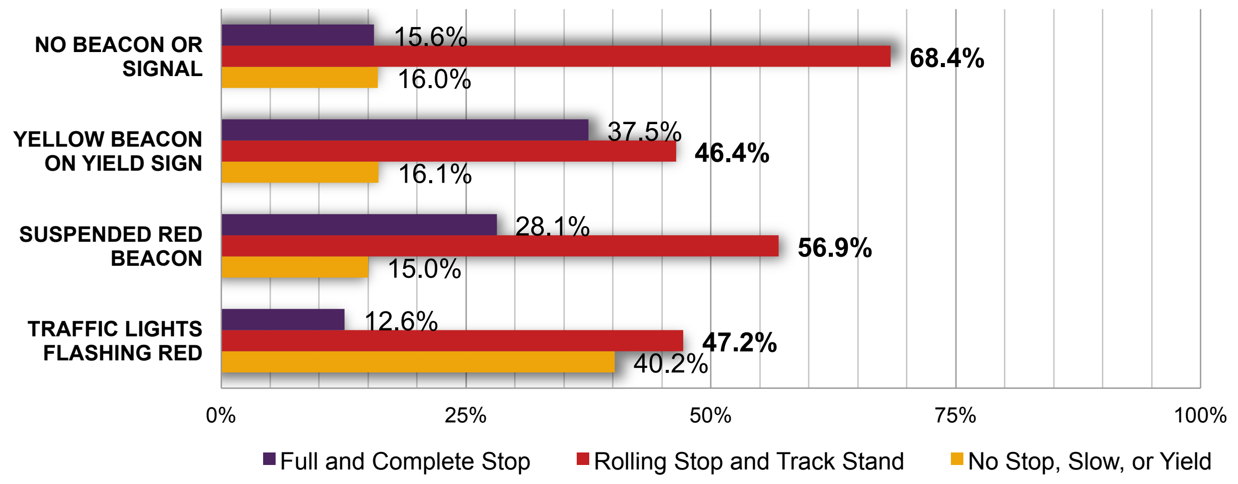
C3 – FLASHING BEACON

More than with the other locational variables, the descriptive statistics highlight issues of multicollinearity between the variable for beacon type and the count locations (Fig. 14 and 44). For example, the stopping behaviors observed at intersections with no beacon and at crossings with a flashing yellow light on the yield sign directly reflect observations made in Sand Point and Ballard, respectively. At the location along the Burke-Gilman Trail in Sand Point where no beacon is installed, 68.4% of bicyclists observed used rolling stops, with near equal proportions using the other two stopping behaviors. The 56 observations made in Ballard found only a ten percent difference between the incidences of using full and complete stops and rolling stops or track stands, respectively accounting for 27.5% and 46.4% of bicyclists observed at this location.

At the other end of the spectrum, the two locations where converted traffic signals act as flashing beacons are Queen Anne and the University District. A total of 1.1% and 24.4% of all bicyclists counted during the pilot study were observed, respectively. As is addressed, bicyclists observed in the University District were less obedient to the law than at the other locations. Therefore, the findings that 40.2% of bicyclists did not stop or yield before crossing an intersection are more indicative of stopping behaviors practiced in the University District than of behaviors used at highly visible flashing beacons.

FIG. 44: Descriptive Statistics – Flashing Beacon

FLASHING BEACON TYPES OBSERVED DURING PILOT STUDY:
By Percentage within the Variable for Wind Speed



Increasingly Visible Beacon Types	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
No Beacon or Signal				
Total Count	82	359	84	525
% within Wind Speed	**15.6%**	**68.4%**	**16.0%**	**100.0%**
Yellow Flashing Beacon on Yield Sign				
Total Count	21	26	9	56
% within Wind Speed	**37.5%**	**46.4%**	**16.1%**	**100.0%**
Suspended Flashing Red Beacon				
Total Count	291	589	155	1,035
% within Wind Speed	**28.1%**	**56.9%**	**15.0%**	**100.0%**
Traffic Light with Flashing Red in All Bulbs				
Total Count	126	472	402	1,000
% within Wind Speed	**12.6%**	**47.2%**	**40.2%**	**100.0%**

Multicollinearity is also an issue for bicycle facility type, but to a lesser extent, because the types of facilities are more varied at the six different count locations.

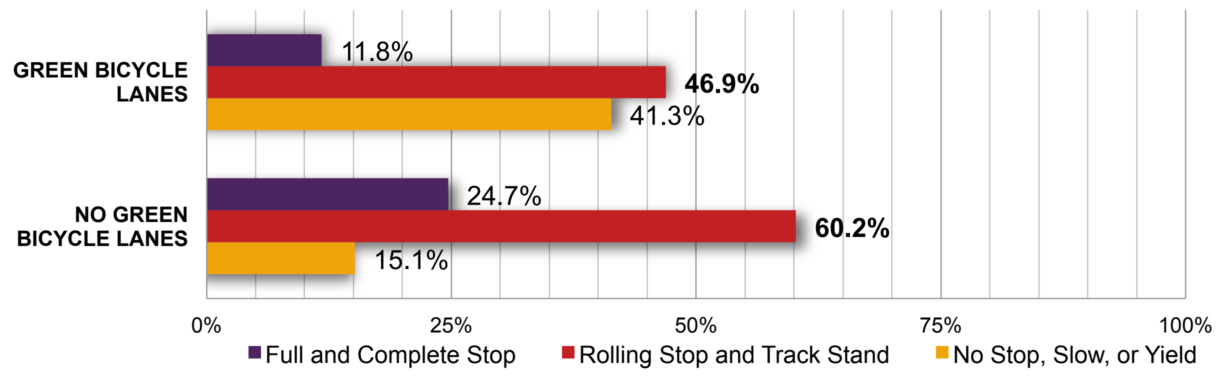
C4 – GREEN BICYCLE LANES

Observations made in the University District have a strong impact on this variable. The two count locations featuring green bicycle lanes are located in the University District and Ballard. As with Queen Anne, an unexpectedly low number of observations were made in Ballard, leaving the data collected in the University District to represent bicyclists’ stopping behavior. This caveat explains why the ratio between rolling stops and not stopping are nearly identical to observations organized by the variable for traffic signals flashing red beacon type (Fig. 44).

The issues with this data aside, descriptively, a near equal number of bicyclists used a rolling stop or failed to stop at locations with green bicycle lanes in place. A total of 41% of bicyclists failed to stop or yield at intersections with green lanes were present, and

FIG. 45: Descriptive Statistics – Green Bicycle Lanes

GREEN BICYCLE LANES USED BY BICYCLISTS OBSERVED DURING PILOT STUDY:
By Percentage within the Variable for Wind Speed



Presence of Green Bicycle Lanes	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Green Bicycle Lanes in the Intersection				
Total Count	114	455	401	970
% within Green Bike Lanes	**11.8%**	**46.9%**	**41.3%**	**100.0%**
No Green Bicycle Lanes in the Intersection				
Total Count	406	991	249	1646
% within Green Bike Lanes	**24.7%**	**60.2%**	**15.1%**	**100.0%**

46.9% used rolling stops or track stands. Where green bicycle lanes are not in place, however, a substantially greater proportion of bicyclists were observed using rolling stops and track stands, accounting for a total of 60.2%. Full and complete stops were used by 24.7% of bicyclists at intersections without green bicycle lanes, and only 15.1% disregarded the stop sign (Fig. 45).

C5 – TYPE OF BICYCLE FACILITY

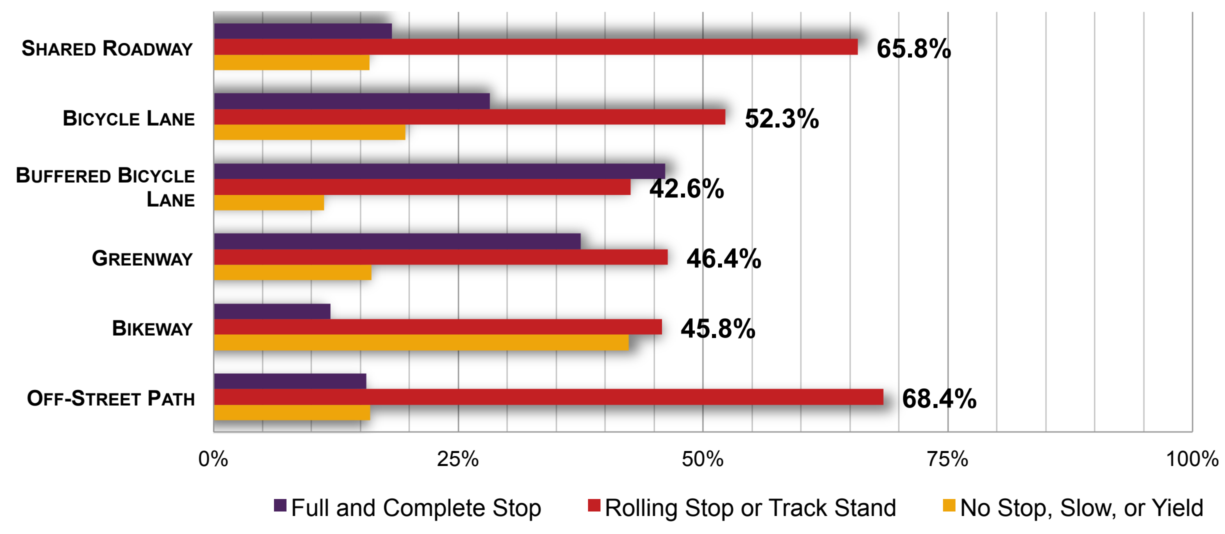
Figures 46 and 47 describe the stopping behaviors used by bicyclists before and after crossing through the intersection. Bicyclists were observed coming to a complete stop and bringing at least one foot to the ground most often when approaching an intersection on buffered bicycle lanes and the neighborhood greenway, representing 46.1% and 37.5% of stopping behaviors at each type of facility (Fig. 46). Bicyclists traveling onto these moderately protective facilities after crossing an intersection also used complete stops in the greatest proportions, with 42.5% and 52.8% choosing to use this stopping behavior respectively (Fig. 47). These high percentages represent the only two incidences in the pilot study data revealing a greater proportion of full and complete stops than rolling stops or track stands—with this being the case for bicyclists approaching the crossing on the neighborhood greenway in Ballard and those traveling onto the buffered bicycle lane after crossing the intersection in Greenlake.

Rolling stops and track stands were seen over 60% of the time when a bicyclist was recorded using shared roadways and the off-street path before and after crossing the intersection. Otherwise, rolling stops were used by 42.6% to 54.1% of bicyclists using the majority of bicycle facilities. This type of stop was practiced the least by bicyclists traveled onto the neighborhood greenway in Ballard after their turn, which makes up 36.1% of subjects observed using this facility type (Fig. 46).

The largest proportions of bicyclists failing to stop at a stop sign were observed using bicycle lanes or the bikeway before and/or after crossing the intersection. A total of

FIG. 46: Descriptive Statistics – Bicycle Facilities, Before the Intersection

BICYCLE FACILITY USED BY BICYCLISTS BEFORE THE INTERSECTION:
By Percentage within the Variable for Type of Bicycle Facility

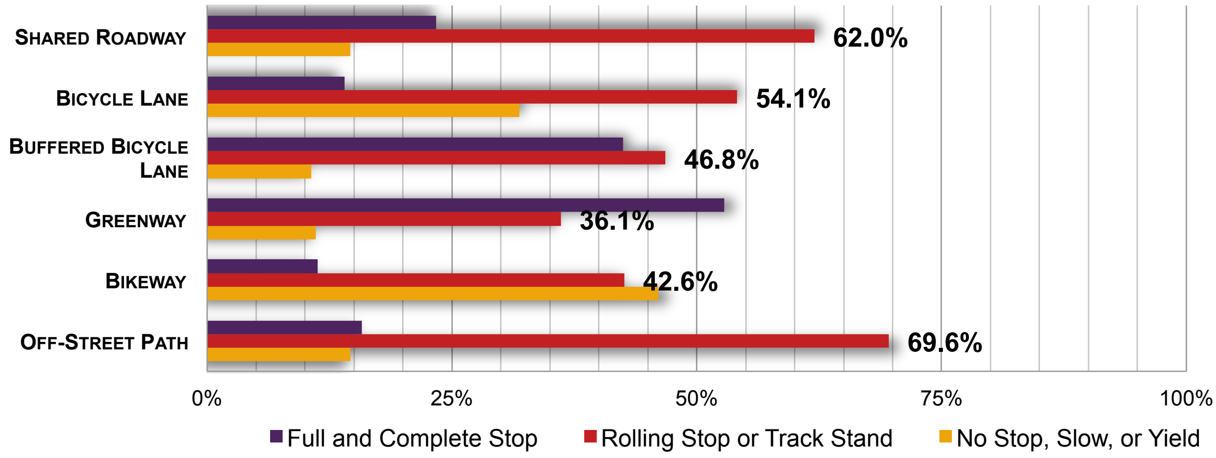


Facility Used Before the Intersection	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Shared Roadway (with or without ‘sharrow’ markings)				
Total Count	87	314	76	477
% within Shared Roadways	**18.2%**	**65.8%**	**15.9%**	**100.0%**
Bicycle Lane				
Total Count	167	310	116	593
% within Bicycle Lanes	**28.2%**	**52.3%**	**19.6%**	**100.0%**
Buffered Bicycle Lane				
Total Count	65	60	16	141
% within Buffered Lanes	**46.1%**	**42.6%**	**11.3%**	**100.0%**
Neighborhood Greenway				
Total Count	21	26	9	56
% within Greenways	**37.5%**	**46.4%**	**16.1%**	**100.0%**
Bikeway				
Total Count	98	377	349	824
% within Bikeways	**11.9%**	**45.8%**	**42.4%**	**100.0%**
Off-Street Path				
Total Count	82	359	84	525
% within Off-Street Paths	**15.6%**	**68.4%**	**16.0%**	**100.0%**

19.6% and 42.4% of bicyclists did not stop at the stop sign when approaching on a bicycle lane or bikeway, respectively. This percentage is nearly identical, at 42%, for bicyclists traveling onto the bikeway after the intersection, and raised to 31.9% for those using bicycle lanes after the crossing (Fig. 47).

FIG. 47: Descriptive Statistics – Bicycle Facilities, After the Intersection

BICYCLE FACILITY USED BY BICYCLISTS AFTER THE INTERSECTION:
By Percentage within the Variable for Type of Bicycle Facility



Facility Used After the Intersection	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Shared Roadway (with or without 'sharrow' markings)				
Total Count	133	352	83	588
% within Shared Roadways	**23.4%**	**62.0%**	**14.6%**	**100.0%**
Bicycle Lane				
Total Count	55	212	125	392
% within Bicycle Lanes	**14.0%**	**54.1%**	**31.9%**	**100.0%**
Buffered Bicycle Lane				
Total Count	148	163	37	348
% within Buffered Lanes	**42.5%**	**46.8%**	**10.6%**	**100.0%**
Neighborhood Greenway				
Total Count	19	13	4	36
% within Greenways	**52.8%**	**36.1%**	**11.1%**	**100.0%**
Bikeway				
Total Count	88	367	330	785
% within Bikeways	**11.2%**	**46.8%**	**42.0%**	**100.0%**
Off-Street Path				
Total Count	77	339	71	487
% within Off-Street Paths	**15.8%**	**69.6%**	**14.6%**	**100.0%**

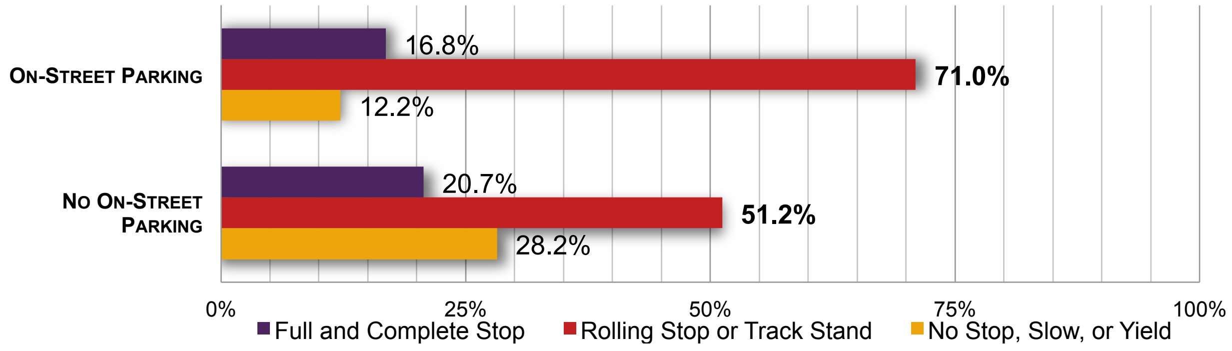
C6 – ON-STREET PARKING

On-street parking is not available on the same side of the street as the bikeway in the University District and is also only available where the two segments of shared roadways are in place after the intersection observed in Greenlake. As the largest number of observations were recorded in these two neighborhoods, it is not surprising that 79.3% bicyclists, in total, were not observed riding adjacent to on-street parking.

As is shown in Figure 48, where on-street parking was present, a total of 71% and 60.9% of bicyclists elected to use a rolling stop before and after crossing an intersection. This total shifts, however, in the absence of on-street parking before or after the intersection, where only 51.2% and 52.6% of bicyclists, respectively, were

FIG. 48: Descriptive Statistics – On-Street Parking, Before the Intersection

ON-STREET ON ROADWAYS BICYCLISTS' RIDE ON BEFORE THE INTERSECTION:
By Percentage within the Variable for On-Street Parking

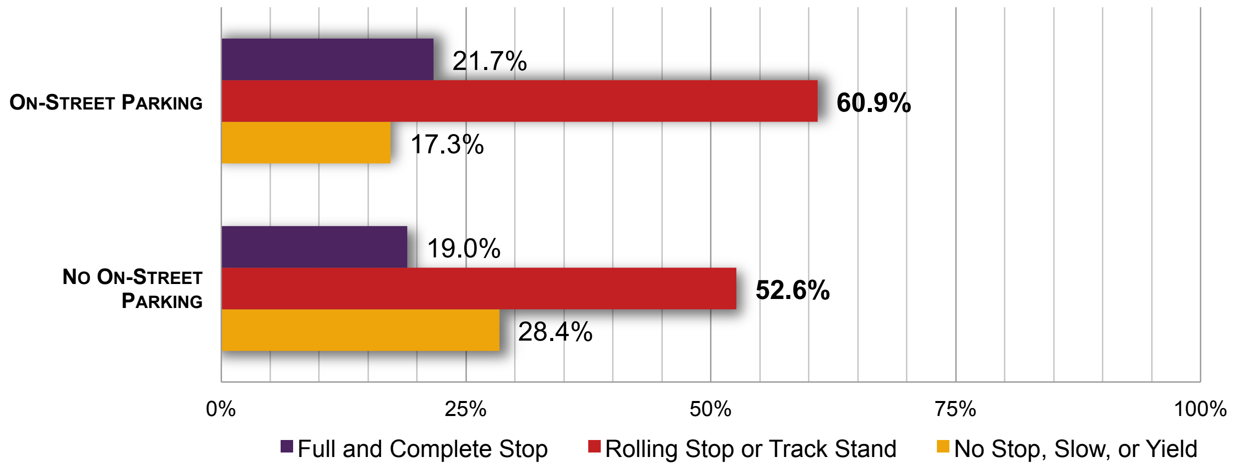


On-Street Parking Before the Intersection	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
On-Street Parking				
Total Count	91	385	66	542
% within On-Street Parking	**16.8%**	**71.0%**	**12.2%**	**100.0%**
No On-Street Parking				
Total Count	429	1,061	584	2,074
% within On-Street Parking	**20.7%**	**51.2%**	**28.2%**	**100.0%**

documented using rolling stops or track stands. 52.6% of bicyclists, respectively, were observed using rolling stops or track stands. The presence of on-street parking appears to have the opposite effect on the decision not to stop at the intersection. For example, only 12.2% of bicyclists do not stop when on-street parking is present before the intersection, and a total of 28.2% of bicyclists did not stop when they were not riding next to on-street parking before the crossing. A near-equal proportion of bicyclists used full and complete stops where on-street parking was and was not present. The greatest variance is in the slight 4% increase in use of full stops before the intersection when no on-street parking is allowed on the roadway.

FIG. 49: Descriptive Statistics – On-Street Parking, After the Intersection

ON-STREET ON ROADWAYS BICYCLST' RIDE ON AFTER THE INTERSECTION:
By Percentage within the Variable for On-Street Parking



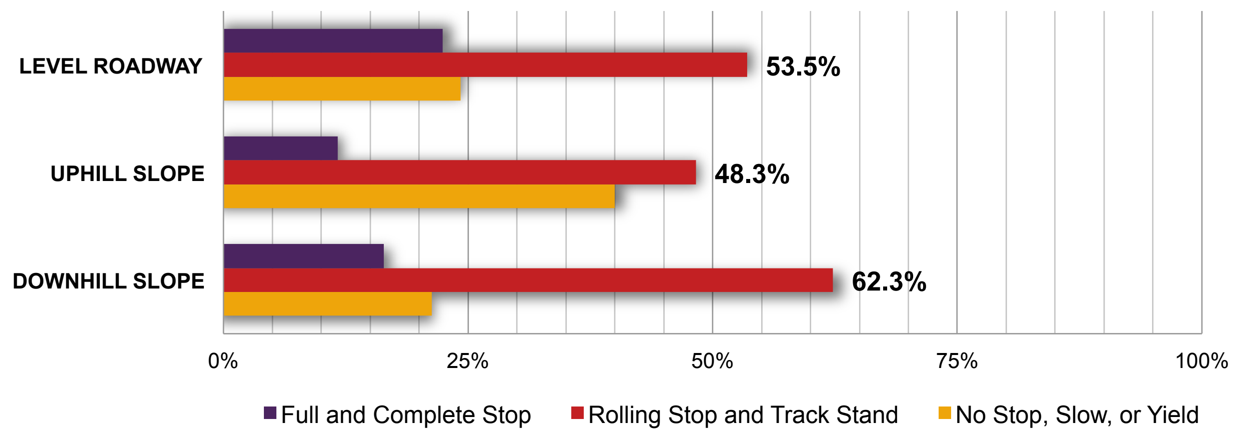
On-Street Parking After the Intersection	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
On-Street Parking				
Total Count	183	513	146	842
% within On-Street Parking	**21.7%**	**60.9%**	**17.3%**	**100.0%**
No On-Street Parking				
Total Count	337	933	504	1,774
% within On-Street Parking	**19.0%**	**52.6%**	**28.4%**	**100.0%**

C7 – TOPOGRAPHY

The vast majority of bicyclists were observed riding on level roadways before and after crossing the intersection. Full and complete stops were observed in greatest proportion on level surfaces, accounting for the highest totals, of 24.2% and 22.6%, of behaviors observed in a given category of topography. When bicyclists were recorded using downhill slopes, the observed incidence of full and complete stops was relatively low, at 16.4% before and 10.2% of stopping behaviors used after the crossing. Full and complete stops were, likewise, observed being used by only 11.7% of bicyclists traveling uphill before an intersection, and 13.6% of bicyclists traveling uphill after (Fig. 50 and 51).

FIG. 50: Descriptive Statistics – Topography, Before the Intersection

TOPOPGRAPHY TRAVERSED BY BICYCLISTS BEFORE THE INTERSECTION:
By Percentage within the Variable for Topography

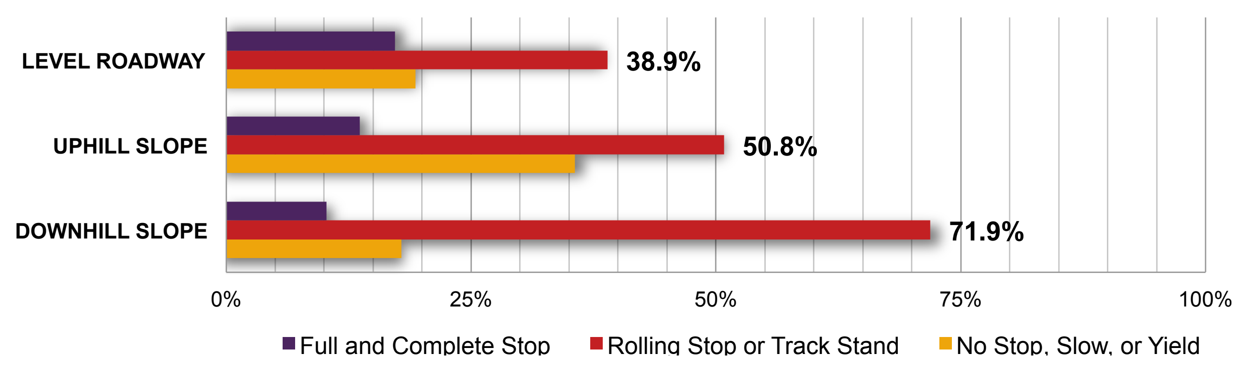


Topography Before the Intersection	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Level Roadway				
Total Count	427	944	395	1766
% within Topography	**24.2%**	**53.5%**	**22.4%**	**100.0%**
Uphill Topography				
Total Count	63	261	216	540
% within Topography	**11.7%**	**48.3%**	**40.0%**	**100.0%**
Downhill Topography				
Total Count	30	114	39	183
% within Topography	**16.4%**	**62.3%**	**21.3%**	**100.0%**

A total of 62.3% of bicyclists use rolling stops when approaching an intersection on a downhill slope, and a larger total of 71.7% of these behaviors were observed being used by bicyclists departing on downhill slopes. Substantially fewer bicyclists used rolling stops when traveling onto level surfaces after the intersection, with only 38.9% of riders observed using rolling stops in this situation (Fig. 51). Approximately half of all bicyclists traveling on an uphill roadway on the approach to or departure from the intersection used rolling stops at the stop sign. The remaining 40% of bicyclists traveling toward the intersection on an uphill slopes and 35.6% departing on an uphill slope fail to stop or yield before crossing. This disregard of stop signs was observed by only 24.2% and 19.3% of stops or level conditions as well as only 21.3% and 17.9% of stopping behaviors when downhill topography is used (Fig. 50 and 51).

FIG. 51: Descriptive Statistics – Topography, After the Intersection

TOPOPGRAPHY TRAVERSED BY BICYCLISTS AFTER THE INTERSECTION:
By Percentage within the Variable for Topography



Topography After the Intersection	Full and Complete Stop	Rolling Stop or Track Stand	No Stop, Yield, or Slow	TOTAL
Level Roadway				
Total Count	450	1,040	505	1,995
% within Topography	**22.6%**	**52.1%**	**25.3%**	**100.0%**
Uphill Topography				
Total Count	26	97	68	191
% within Topography	**13.6%**	**50.8%**	**35.6%**	**100.0%**
Downhill Topography				
Total Count	44	309	77	430
% within Topography	**10.2%**	**71.9%**	**17.9%**	**100.0%**

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CHAPTER 9:

PILOT STUDY STATISTICAL ANALYSIS METHODS

PREDICTING STOPPING BEHAVIOR

In order to develop a more nuanced understanding of stopping behavior than the descriptive statistics were able to provide, the two following linear regression models for predicting stopping behaviors were developed:

REGRESSION MODEL SET A *(All Variables Included)*

This first set of regression models includes binary and ordinal independent variables for each of the 16 variables introduced in Chapter 7 “Pilot Study Variables”. Based on descriptive results and the sheer difference in bicycle volumes recorded at different count locations, Regression Model Set A includes separate binary variables for each location observed during the study.

REGRESSION MODEL SET B *(Similar Location Variables Combined)*

All of the variables used in Regression Model Set A are also included in Regression Model Set B. The primary difference between these two sets of regression models is the transformation of the many binary locational variables into one single binary variable.

Based on the results from Regression Model Set A, count locations found to be statistically similar were grouped into two separate Groups. Capitol Hill and Sand Point comprise one group, and the neighborhoods of Queen Anne, Greenlake, Ballard, and the University District make up the second group.

REGRESSION MODEL FORMULAS

The 10 dependent variables for stopping behavior are collectively described as "StopType" in Figure 52, below.

FIG. 52: Linear Regression Formulas

LINEAR REGRESSION FORMULAS	
Regression Model A	**Regression Model B**
StopType = $\mathit{Constant} + \mathrm{Gend}_i + \mathrm{Helm}_i + \mathrm{TurnL}_i + \mathrm{TurnR}_i + \mathrm{Time}_i + \mathrm{Temp}_i + \mathrm{Visblty}_i + \mathrm{Wind}_i + \mathrm{Sign}_i + \mathrm{Beacon}_i + \mathrm{Green}_i + \mathrm{BikeBfr}_i + \mathrm{BikeAftr}_i + \mathrm{ParkBfr}_i + \mathrm{ParkAft}_i + \mathrm{TopoBfr}_i + \mathrm{TopoAftr}_i + \mathrm{Loc\_Cap}_i + \mathrm{Loc\_Green}_i + \mathrm{Loc\_Bal}_i + \mathrm{Loc\_UD}_i + \mathrm{Loc\_Sand}_i$	**StopType** = $\mathit{Constant} + \mathrm{Gend}_i + \mathrm{Helm}_i + \mathrm{TurnL}_i + \mathrm{TurnR}_i + \mathrm{Time}_i + \mathrm{Temp}_i + \mathrm{Visblty}_i + \mathrm{Wind}_i + \mathrm{Sign}_i + \mathrm{Beacon}_i + \mathrm{Green}_i + \mathrm{BikeBfr}_i + \mathrm{BikeAftr}_i + \mathrm{ParkBfr}_i + \mathrm{ParkAft}_i + \mathrm{TopoBfr}_i + \mathrm{TopoAftr}_i + \mathrm{Loc\_Grp}_i$

The following two sub-sections describe each dependent and independent variable contained in the two linear regression models, including a description of the variable coding used in analysis.

DEPENDENT VARIABLES

As the stopping behavior of bicyclists is the focus of this research, all dependent variables investigated in this analysis are related to the type of stop observed. A total of nine binary dependent variables were constructed, in addition to one continuous variable for the degree of stop, from a full and complete stop to no stop at all. Each of these 10 dependent variables is described in the table below, presenting the variable titles and coding used in the analysis. This same set of 10 dependent variables is analyzed using both Regression Model Sets A and B.

FIG. 53: Regression Model Sets A and B – Dependent Variables

DEPENDENT VARIABLE			
VARIABLE	**DESCRIPTION**	**TYPE**	**CODING and LABLES**
StopFS	Bicyclist Used a Full Stop at the Intersection, Compared to All Other Bicyclists Observed	Binary	1 = Full and Complete Stop 0 = Rolling Stop and/or Track Stand and No Stop
StopFS_RS	Bicyclist Used a Full Stop at the Intersection, Compared to Bicyclists using Rolling Stops and/or Track Stands	Binary	1 = Full and Complete Stop 0 = Rolling Stop and/or Track Stand
StopFS_NS	Bicyclist Used a Full Stop at the Intersection, Compared to Bicyclists who Did Not Stop	Binary	1 = Full and Complete Stop 0 = No Stop
StopRS	Bicyclist Used a Rolling Stop at the Intersection	Binary	1 = Rolling Stop and/or Track Stand 0 = Full and Complete Stop or No Stop
StopRS_NS	Bicyclist Used a Rolling Stop at the Intersection, Compared to Bicyclists who Did Not Stop	Binary	1 = Rolling Stop and/or Track Stand 0 = No Stop
StopRS_FS	Bicyclist Used a Rolling Stop at the Intersection, Compared to Bicyclists Using Full and Complete Stops	Binary	1 = Rolling Stop and/or Track Stand 0 = Full and Complete Stop
StopNS	Bicyclists Did Not Stop at the Intersection, Compared to All Other Bicyclists Observed	Binary	1 = No Stop 0 = Rolling Stop and/or Track Stand and Full and Complete Stop
StopNS_FS	Bicyclists Did Not Stop at the Intersection, Compared to Bicyclists Using Full and Complete Stops	Binary	1 = No Stop 0 = Full and Complete Stop
StopNS_RS	Bicyclists Did Not Stop at the Intersection, Compared to Bicyclists using Rolling Stops and/or Track Stands	Binary	1 = No Stop 0 = Rolling Stop and/or Track Stand
StopCont	Range of Stopping Types	Continuous	1 = Full and Complete Stop 2 = Rolling Stop and/or Track Stand 3 = No Stop

INDEPENDENT VARIABLES

All circumstantial and locational variables introduced in Chapter 7 “Pilot Study Variables” are included as independent variables in the two regression model sets. Only three of the five primary behavioral and subject-specific variables, however, are included as independent variables here. Stopping behavior is omitted from this list because all types of stopping behavior are included, in many forms, as the dependent variables in this analysis. Although descriptive results are provided for the level of safety of bicyclists observed, this variable is not included as an independent variable here, as it is considered highly subjective and not reliable enough for statistical analysis.

Independent variables are presented in two groups. The first includes the variables that are identical in the two different regression model sets. The second table provides a description of the different locational variables used in the original and refined regression models.

FIG. 54: Regression Model Sets A and B – Independent Variables, Behavioral

INDEPENDENT VARIABLES TYPE A – Behavioral and Subject-Specific Variables			
VARIABLE	**DESCRIPTION**	**TYPE**	**CODING and LABLES**
Gend	Bicyclist’s Gender	Binary	1 = Male 0 = Female
Helm	Bicyclist’s Use of a Helmet while Riding	Binary	1 = Wearing a Helmet 0 = Not Wearing a Helmet
TurnL	Bicycle Turns Left or Slightly Left at the Intersection	Binary	1 = Left Turn 0 = Straight or Right Turn
TurnR	Bicycle Turns Right or Slightly Right at the Intersection	Binary	1 = Right Turn 0 = Straight or Left Turn

FIG. 55: Regression Model Sets A and B – Independent Variables, Circumstantial

INDEPENDENT VARIABLES TYPE B – Circumstantial Variables			
VARIABLE	**DESCRIPTION**	**TYPE**	**CODING and LABLES**
Time	Two-Hour Period of Observation	Binary	1 = 7:00 to 9:00 AM 0 = 16:00 to 18:00 PM
Twlgt	Daylight Conditions and Astronomical Conditions	Ordinal	0 = Daylight 1 = Sunrise or Sunset 2 = Civil Twilight 3 = Nocturnal Twilight
Temp	Average Daily Temperature at Sea-Tac airport	Continuous	Range of Temperature in Degrees Fahrenheit
Vsblty	Visibility at Sea-Tac airport	Continuous	Range in the Number of Miles of Visibility
Wind	Wind Speed at Sea-Tac airport	Continuous	Range in the Wind Speed by Miles per Hour

FIG. 56: Regression Model Sets A and B – Independent Variables, Locational

INDEPENDENT VARIABLES TYPE C – Locational Variables			
VARIABLE	**DESCRIPTION**	**TYPE**	**CODING and LABLES**
Sign	Traffic Control Signs at Intersections	Nominal	1 = Four-Way Stop 0 = Two-Way Stop, Two-Way Yield to Bicyclists and Pedestrians
Beacon	Type of Solid Flashing Beacons or Traffic Lights at the Intersections	Ordinal	0 = No Beacon or Signal 1 = Flashing Yellow Beacon on Yield Sign 2 = Suspended Flashing Red Beacon 3 = Traffic Signals Flashing Red
Green	Green Paint Installed Across the Intersection in the one Direction at the Intersection	Binary	1 = Green Paint Across the Intersection 0 = No Green Painted Across the Intersection

FIG. 56: Regression Model Sets A and B – Independent Variables, Locational (cont.)

INDEPENDENT VARIABLES TYPE C – Locational Variables (cont.)			
VARIABLE	**DESCRIPTION**	**TYPE**	**CODING and LABLES**
BikeBfr	Type of Bicycle Facility Installed on the Roadway from which the Bicyclist Approached the Intersection	Ordinal	0 = Shared Roadway 1 = Bicycle Lane 2 = Protected Bicycle Lane 3 = Neighborhood Greenway 4 = Bi-Directional Bikeway 5 = Bi-Directional Off-Street Path
BikeAftr	Type of Bicycle Facility Installed on the Roadway the Bicyclist Traveled onto After Passing Through the Intersection	Ordinal	0 = Shared Roadway 1 = Bicycle Lane 2 = Protected Bicycle Lane 3 = Neighborhood Greenway 4 = Bi-Directional Bikeway 5 = Bi-Directional Off-Street Path
ParkBfr	On-Street Parking Allowed within 30-feet of the Stop Sign Before the Intersection	Binary	1 = On-Street Parking 0 = No On-Street Parking
ParkAftr	On-Street Parking Allowed within 30-feet of the Corner After the Intersection	Binary	1 = On-Street Parking 0 = No On-Street Parking
TopoUBfr	Uphill Topography Before the Intersection	Binary	1 = Moderate or Steep Uphill 0 = Level or Moderate to Steep Downhill
TopoDBfr	Downhill Topography Before the Intersection	Binary	1 = Moderate or Steep Downhill 0 = Level or Moderate to Steep Uphill
TopoUAftr	Uphill Topography After the Intersection	Binary	1 = Moderate or Steep Uphill 0 = Level or Moderate to Steep Downhill
TopoDAftr	Downhill Topography After the Intersection	Binary	1 = Moderate or Steep Downhill 0 = Level or Moderate to Steep Uphill
Loc_Cap	Count Location: Capitol Hill	Binary	1 = Capitol Hill 0 = Any other Count Location
Loc_Green	Count Location: Greenlake	Binary	1 = Greenlake 0 = Any other Count Location
Loc_Bal	Count Location: Ballard	Binary	1 = Ballard 0 = Any other Count Location

FIG. 56: Regression Model Sets A and B – Independent Variables, Locational (cont.)

INDEPENDENT VARIABLES TYPE C – Locational Variables (cont.)			
VARIABLE	**DESCRIPTION**	**TYPE**	**CODING and LABLES**
Loc_UD	Count Location: University District	Binary	1 = University District 0 = Any other Count Location
Soc_Sand	Count Location: Sand Point	Binary	1 = Sand Point 0 = Any other Count Location
Loc_Grp	Comparison Groups of Statistically Similar Count Locations	Binary	1 = Capitol Hill or Sand Point 0 = Queen Anne, Greenlake, Ballard, or the University District

VARIABLE EXPECTATIONS

The following several pages provide a summary explanation of the expectations for each of the 26 variables included collectively in Regression Model Sets A and B (Fig. 59 through 61). Theories and assumptions validating the expectations presented here are introduced in Chapter 7 “Pilot Study Variables”. The accuracy of these variable-specific expectations is briefly discussed in Chapter 9 “Pilot Study Regression Results”.

FIG. 57: Regression Model Sets A and B Expectations – Independent Variables, Behavioral

INDEPENDENT VARIABLES TYPE A – Behavioral and Subject-Specific Variables
Expectations (and Expected Coefficients) by General Stopping Type Categories

VARIABLE	**Full and Complete Stop**	**Rolling Stop and/or Track Stand**	**No Stop or Yield**
Gender	**(-)** Men are expected to use full and complete stops ***less often*** than women.	**(+)** Men are expected to use rolling stops and track stands ***more often*** than women.	**(+)** Men are expected to fail to stop ***more often*** than women.
Helmet Use	**(+)** Helmet users are expected to use full and complete stops ***more often*** than bicyclists not wearing helmets.	**(+)** Helmet users are expected to use rolling stops and track stands ***more often*** than bicyclists not wearing helmets.	**(-)** Helmet users are expected to fail to stop ***less often*** than bicyclists not wearing helmets.
Left Turn Movements	**(+)** Bicyclists turning left are expected to use full and complete stops ***more often*** than those traveling straight or turning right.	**(-)** Bicyclists turning left are expected to use rolling stops and track stands ***less often*** than those traveling straight or turning right.	**(-)** Bicyclists turning left are expected to fail to stop ***less often*** than those traveling straight or turning right.
Right Turn Movements	**(-)** Bicyclists turning right are expected to use full and complete stops ***less often*** than those traveling straight or turning left.	**(+)** Bicyclists turning right are expected to use rolling stops and track stands ***more often*** than those traveling straight or turning left.	**(+)** Bicyclists turning right are expected to fail to stop ***more often*** than those traveling straight or turning left.

FIG. 58: Regression Model Sets A and B Expectations – Independent Variables, Circumstantial

INDEPENDENT VARIABLES TYPE B – Circumstantial Variables
Expectations (and Expected Coefficients) by General Stopping Type Categories

VARIABLE	Full and Complete Stop	Rolling Stop and/or Track Stand	No Stop or Yield
Time of Count Period	(-) Morning riders are expected to use full and complete stops ***less often*** than evening riders.	(+) Morning riders are expected to use rolling stops and track stands ***more often*** than evening riders.	(+) Morning riders are expected to fail to stop ***more often*** than evening riders.
Natural Light Conditions	(+) As daylight turns to nocturnal twilight, bicyclists are expected to use a full and complete stop ***more often***.	(+) As daylight turns to nocturnal twilight, bicyclists are expected to rolling stops and track stands ***more often***.	(-) As daylight turns to nocturnal twilight, bicyclists are expected to fail to stop ***less often***.
Temperature in Degrees Fahrenheit	(-) Bicyclists are expected to use full and complete stops ***less often*** when temperatures are higher.	(+) Bicyclists are expected to use rolling stops and track stands **more often** when temperatures are higher.	(+) Bicyclists are expected to fail to stop ***more often*** when temperatures are higher.
Visibility	(-) Bicyclists are expected to use full and complete stops ***less often*** when visibility is higher.	(+) Bicyclists are expected to use rolling stops and track stands ***more often*** when visibility is higher.	(+) Bicyclists are expected to fail to stop ***more often*** when visibility is higher
Wind Speed	(+) Bicyclists are expected to use full and complete stops ***more often*** when wind speeds are higher.	(+) Bicyclists are expected to use rolling stops and track stands ***more often*** when wind speeds are higher.	(+) Bicyclists are expected to fail to stop ***more often*** when wind speeds are higher.

FIG. 59: Regression Model Sets A and B Expectations – Independent Variables, Locational

INDEPENDENT VARIABLES TYPE C – Locational Variables
Expectations (and Expected Coefficients) by General Stopping Type Categories

VARIABLE	Full and Complete Stop	Rolling Stop and/or Track Stand	No Stop or Yield
Stop Sign Type	**(-)** Bicyclists observed at 4-way stop sign controlled intersections are expected to use full and complete stops ***more often*** than at 2-way stop, 2-way yield intersections.	**(-)** Bicyclists observed at 4-way stop sign controlled intersections are expected to rolling stops and track stands ***less often*** than at 2-way stop, 2-way yield intersections.	**(-)** Bicyclists observed at 4-way stop sign controlled intersections are expected to fail to stop ***less often*** than at 2-way stop, 2-way yield intersections.
Flashing Beacon Type	**(+)** Bicyclists are expected to use full and complete stops ***more often*** when more highly visible flashing beacons are present at the count location.	**(+)** Bicyclists are expected to use rolling stops and track stands ***more often*** when more highly visible flashing beacons are present at the count location.	**(-)** Bicyclists are expected to fail to stop ***less often*** when more highly visible flashing beacons are present at the count location.
Green Bicycle Lane	**(-)** Bicyclists are expected to use full and complete stops ***more often*** when green bicycle lanes are painted across the intersections.	**(+)** Bicyclists are expected to use rolling stops and track stands ***more often*** when green bicycle lanes are painted across the intersections.	**(+)** Bicyclists are expected to fail to stop ***less often*** when green bicycle lanes are painted across the intersections.
Type of Bicycle Before the Intersection	**(+)** Bicyclists observed approaching the count location on a right-of-way with more highly protected bicycle facilities are expected to use full and complete stops ***more often*** than when using less protected facilities.	**(+)** Bicyclists observed approaching the count location on a right-of-way with more highly protected bicycle facilities are expected to use rolling stops and track stands ***more often*** than when using less protected facilities.	**(+)** Bicyclists observed approaching the count location on a right-of-way with more highly protected bicycle facilities are expected to use a full and complete stop ***more often*** than when using less protected facilities.

FIG. 59: Regression Model Sets A and B Expectations – Independent Variables, Locational (cont.)

INDEPENDENT VARIABLES TYPE C – Locational Variables
Expectations (and Expected Coefficients) by General Stopping Type Categories

VARIABLE	**Full and Complete Stop**	**Rolling Stop and/or Track Stand**	**No Stop or Yield**
Type of Bicycle After the Intersection	**(-)** Bicyclists observed departing the count location on a right-of-way with more highly protected bicycle facilities are expected to use full and complete stops ***less often*** than when using less protected facilities.	**(+)** Bicyclists observed departing the count location on a right-of-way with more highly protected bicycle facilities are expected to use rolling stops and track stands ***more often*** than when using less protected facilities.	**(+)** Bicyclists observed departing the count location on a right-of-way with more highly protected bicycle facilities are expected to use a full and complete stop ***more often*** than when using less protected facilities.
On-Street Parking Before the Intersection	**(+)** Bicyclists observed approaching the count location on a right-of-way with on-street parking are expected to use full and complete stops ***more often*** than when on-street parking is not present.	**(-)** Bicyclists observed approaching the count location on a right-of-way with on-street parking are expected to use rolling stops and track stands ***less often*** than when on-street parking is not present.	**(-)** Bicyclists observed approaching the count location on a right-of-way with on-street parking are expected to fail to stop ***less often*** than when on-street parking is not present.
On-Street Parking After the Intersection	**(+)** Bicyclists observed departing the count location on a right-of-way with on-street parking are expected to use full and complete stops ***more often*** than when on-street paring is not present.	**(-)** Bicyclists observed departing the count location on a right-of-way with on-street parking are expected to use rolling stops and track stands ***less often*** than when on-street parking is not present.	**(-)** Bicyclists observed departing the count location on a right-of-way with on-street parking are expected to fail to stop ***less often*** than when on-street parking is not present.
Uphill Topography Before the Intersection	**(+)** Bicyclists observed approaching the count location on an uphill grade are expected to use full and complete stops ***more often*** than when the terrain is level or downhill.	**(+)** Bicyclists observed approaching the count location on an uphill grade are expected to use rolling stops and track stands ***more often*** than when the terrain is level or downhill.	**(-)** Bicyclists observed approaching the count location on an uphill grade are expected to fail to stop ***less often*** than when the terrain is level or downhill.

FIG. 59: Regression Model Sets A and B Expectations – Independent Variables, Locational (cont.)

INDEPENDENT VARIABLES TYPE C – Locational Variables Expectations (and Expected Coefficients) by General Stopping Type Categories			
VARIABLE	**Full and Complete Stop**	**Rolling Stop and/or Track Stand**	**No Stop or Yield**
Uphill Topography After the Intersection	(-) Bicyclists observed departing the count location on an uphill grade are expected to use full and complete stops ***less often*** than when the terrain is level or downhill.	(+) Bicyclists observed departing the count location on an uphill grade are expected to use rolling stops and track stands ***more often*** than when the terrain is level or downhill.	(+) Bicyclists observed departing the count location on an uphill grade are expected to fail to stop ***more often*** than when the terrain is level or downhill.
Downhill Topography Before the Intersection	(-) Bicyclists observed approaching the count location on an downhill grade are expected to use full and complete stops ***less often*** than when the terrain is level or uphill.	(+) Bicyclists observed approaching the count location on an downhill grade are expected to use rolling stops and track stands ***more often*** than when the terrain is level or uphill.	(+) Bicyclists observed approaching the count location on an downhill grade are expected to fail to stop ***more often*** than when the terrain is level or uphill.
Downhill Topography After the Intersection	(+) Bicyclists observed departing the count location on an downhill grade are expected to use full and complete stops ***more often*** than when the terrain is level or uphill.	(+) Bicyclists observed departing the count location on an downhill grade are expected to use rolling stops and track stands ***more often*** than when the terrain is level or uphill.	(-) Bicyclists observed departing the count location on an downhill grade are expected to fail to stop ***less often*** than when the terrain is level or uphill.

FIG. 59: Regression Model Sets A and B Expectations – Independent Variables, Locational (cont.)

INDEPENDENT VARIABLES TYPE C – Locational Variables (cont.) Expectations (and Expected Coefficients) by General Stopping Type Categories			
VARIABLE	**Full and Complete Stop**	**Rolling Stop and/or Track Stand**	**No Stop or Yield**
Location: Capitol Hill	(-) Bicyclists observed at the location in Capitol Hill are expected to use full and complete stop ***less often*** than at other locations.	(+) Bicyclists observed at the location in Capitol Hill are expected to use rolling stops and track stands ***more often*** than at other locations.	(-) Bicyclists observed at the location in Capitol Hill are expected to fail to stop ***less often*** than at other locations.
Location: Greenlake	(+) Bicyclists observed at the location in Greenlake are expected to use full and complete ***more often*** than at other locations.	(-) Bicyclists observed at the location in Greenlake are expected to use rolling stops and track stands ***less often*** than at other locations.	(-) Bicyclists observed at the location in Greenlake are expected to fail to stop ***less often*** than at other locations.
Location: Ballard	(+) Bicyclists observed at the location in Ballard are expected to use full and complete stops ***more often*** than at other locations.	(+) Bicyclists observed at the location in Ballard are expected to use rolling stops and track stands ***more often*** than at other locations.	(-) Bicyclists observed at the location in Ballard are expected to fail to stop ***less often*** than at other locations.
Location: University District	(-) Bicyclists at the location in the University District are expected to use full and complete stops ***less often*** than at other locations.	(+) Bicyclists observed at the location in the University District are expected to use rolling stops and track stands ***more often*** than at other locations.	(+) Bicyclists at the location in the University District are expected to fail to stop ***more often*** than at other locations.
Location: Sand Point	(-) Bicyclists observed at the location in Sand Point are expected to use full and complete stops ***less often*** than at other locations.	(+) Bicyclists observed at the location in Sand Point are expected to use rolling stops and track stands ***more often*** than at other locations.	(-) Bicyclists observed at the location in Sand Point are expected to fail to stop ***less often*** than at other locations.
Location: Groups	(-) Bicyclists observed in Capitol Hill and Sand Point are expected to use full and complete stops ***less often*** than at the other four locations.	(+) Bicyclists observed in Capitol Hill and Sand Point are expected to use rolling stops and track stands ***more often*** than at the other four locations.	(-) Bicyclists observed in Capitol Hill and Sand Point are expected to fail to stop ***less often*** than at the other four locations.

LIMITATIONS OF RESEARCH

This pilot study provides preliminary evidence describing bicyclists’ stopping behavior in the City of Seattle, but results may not accurately reflect behaviors citywide. The findings of this pilot study are largely skewed to represent the count locations where the highest bicycle traffic volumes were observed—University District and Sand Point. For more accurate data, future observational studies should be implemented at a larger scale and may consider including additional variables not included in this pilot study.

CHAPTER 10:

PILOT STUDY REGRESSION RESULTS

ANALYTICAL FINDINGS

This chapter presents the findings of the two binary linear regression models developed to predict and describe bicyclists' stopping behaviors at stop sign controlled intersections. Before presenting results, the predictive capabilities of Regression Model A and B are reviewed with a consideration for the impact different groups of variables have on the model outcomes. Hypothesis tests regarding what predicts the dependent variable as well as the assumptions made for each independent variable follow the introduction to results.

All of the compiled results of the two linear regression models, run on the ten dependent variables, are then presented in a series of tables. Following this overview of results, as was done with the descriptive statistics, an in-depth review of regression results is presented for each variable included in the models. This final section provides the most detailed discussion of how these different variables influence bicyclists' stopping behavior in this thesis.

MODELS' PREDICTIVE CAPABILITIES

To afford an investigation of the importance of the three groups of variables, each was added to the regression model separately and prediction accuracy of the model as a whole was recalculated with the inclusion of each new group. As this thesis recognizes that results are skewed to reflect conditions at particular count locations, the variables describing the exact count location were separated from the other locational variables and added to the model as the final block in the regression model. Therefore, variables were added to the regression analysis of each dependent variable, grouped in the following order:

(1) Behavioral Variables
(2) Circumstantial Variables
(3) Locational Variables (sans Count Location Variable(s))
(4) Count Location Variable(s)

Overall, the dependent variable predicted with the greatest accuracy—with approximately 80% prediction accuracy—-is the variable that compares bicyclists' decision to use a full and complete stop rather than performing either of the other two types of stopping behaviors. Most other dependent variables are predicted with 70-75% accuracy. Prediction accuracy for the use of rolling stops and/or track stands over other stopping behaviors is the lowest among all dependent variables investigated. For this stopping behavior, which is of primary interest in this research, both Regression Models A and B are only able to correctly predict the behaviors of approximately 63% of bicyclists, with Regression Model A yielding predictions only 0.1% more exact than Regression Model B. See Figures 60 and 61 for graphic depictions of these results.

The variables included in Regression Models A and B were ineffective in improving the capacity for predicting several dependent variables. For each of the following five variables, little change is seen in accuracy with the introduction of all four groups of variables studied here:

(1) Full and Complete Stop, not Rolling Stop or No Stop

(2) Full and Complete Stop, not Rolling Stop

(3) Rolling Stop and/or Track Stand, not Full and Complete Stop

(4) No Stop, not Full Stop or Rolling Stop

(5) No Stop, not Rolling Stop

As predictive powers did not increase the introduction of each category of variables, the accuracy of predictions for each of the above mentioned dependent variables could not reasonably be attributed to the variables included in this pilot study.

With the different treatment of the variable(s) for count location in the two binary linear regression models, slight differences are observed in the accuracy of predictions for all dependent variables. No difference was seen in the predictive correctness for the dependent variable describing a preference for rolling stops over a failure to stop. Regression Model A is more effective in predicting full stops—-full stops over not stopping, as well as not stopping over full stops. Regression Model B predicts the stopping behavior for five remaining dependent variables with slightly greater accuracy than can the regression model treating each location as a separate binary variable.

Due to the time constraints for the data analysis, the variable for degree of stop is unfortunately not included in this discussion.

FIG. 60: Regression Model Sets A – Prediction Accuracy

PREDICTIVE POWERS REGRESSION MODEL A:
Comparison Percentage Predicted Correct by Variable Group for Regression Model Set A

VISUAL DESCRIPTION DEPENDENT VARIABLE

GRAPH OF PERCENTAGE OF ACCURATE PREDICTIONS

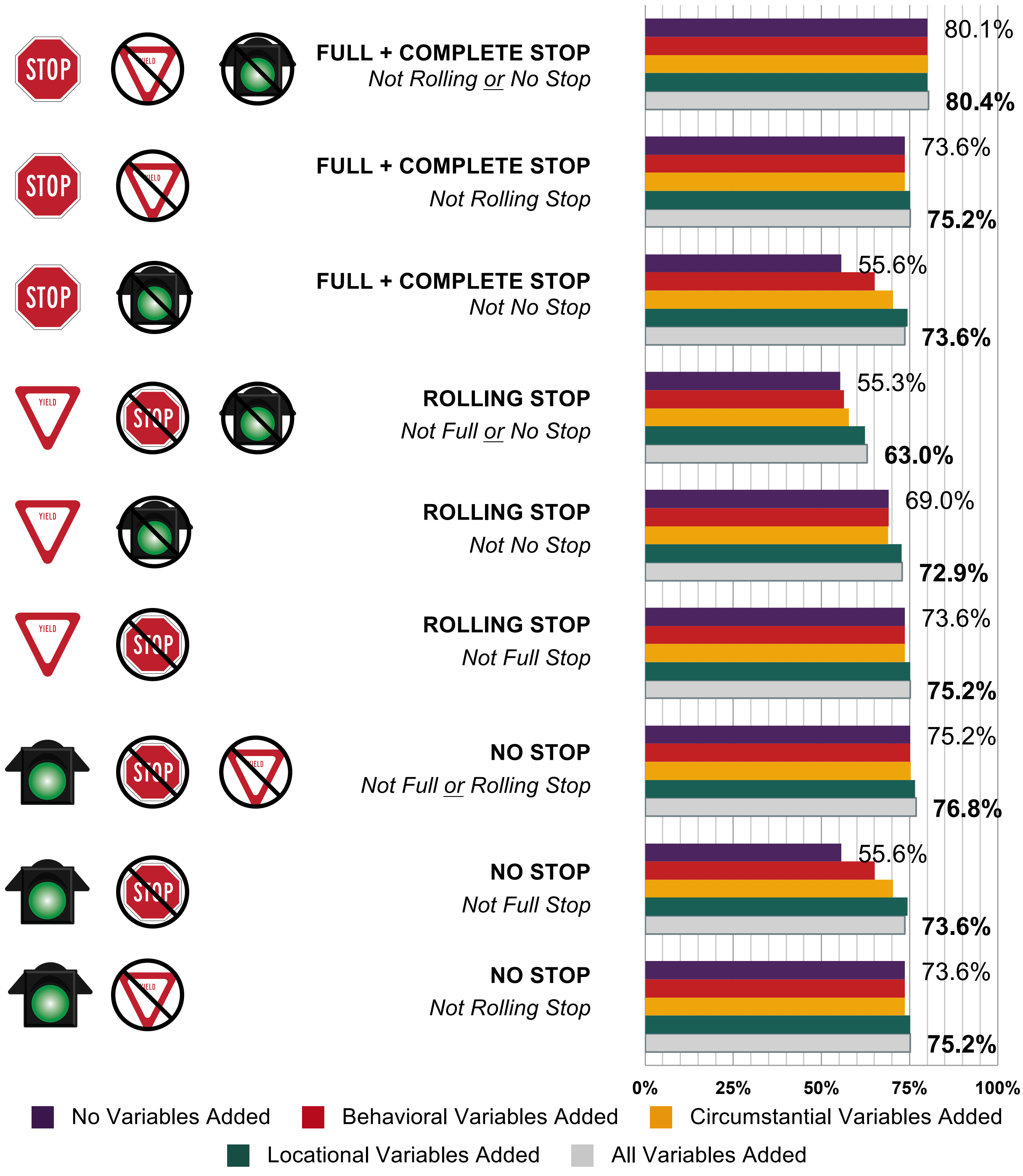
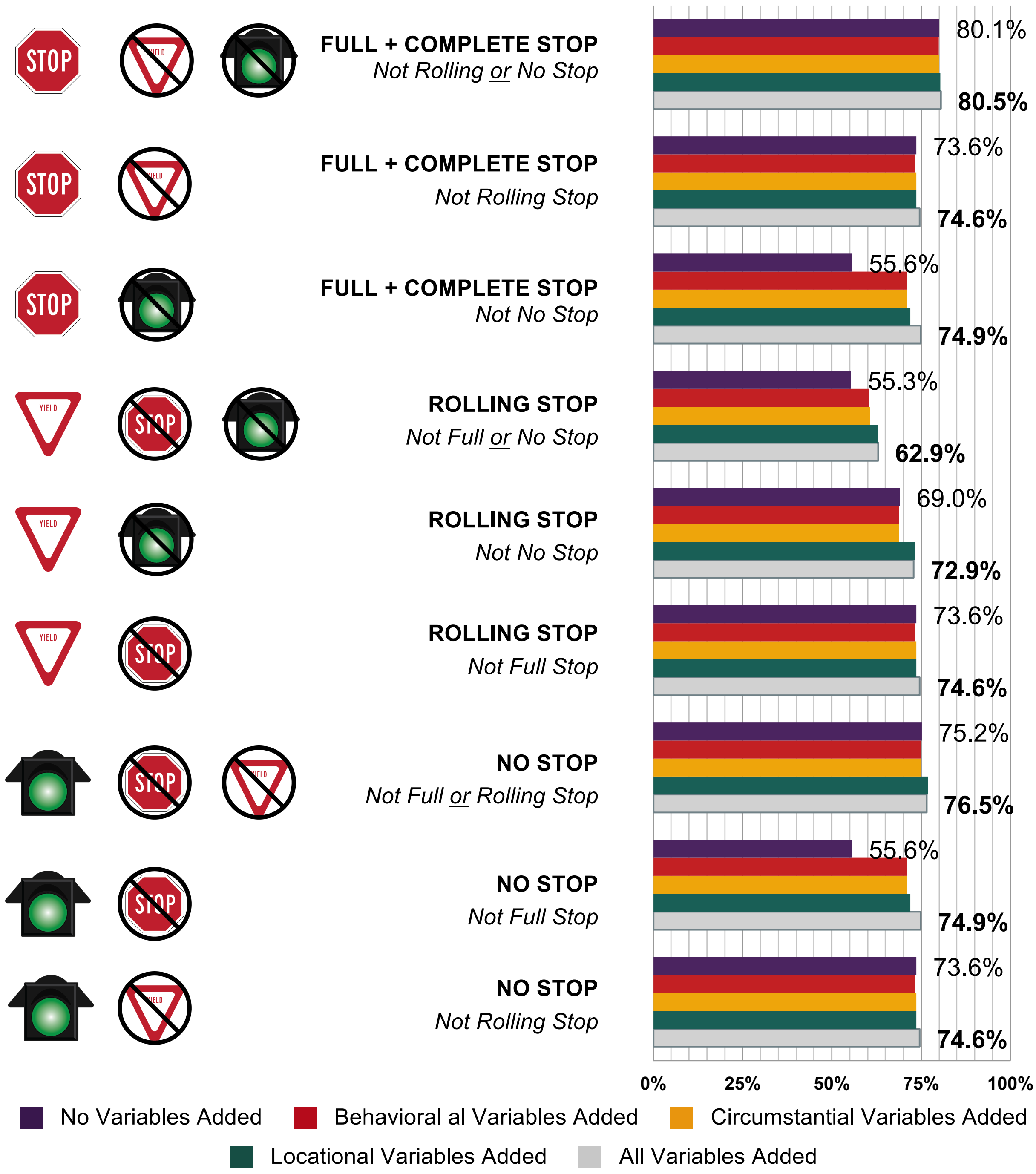


FIG. 61: Regression Model Sets B – Prediction Accuracy

PREDICTIVE POWERS REGRESSION MODEL B:
Comparison Percentage Predicted Correct by Variable Group for Regression Model Set B

VISUAL DESCRIPTION DEPENDENT VARIABLE

GRAPH OF PERCENTAGE OF ACCURATE PREDICTIONS



CORRECTNESS OF VARIABLE EXPECTATIONS

In Chapter 9 “Pilot Study Statistical Analysis Methods”, Figures 57 through 59 present lists of expectations of each how each variable might influence a bicyclist’s choice to use each of the three types of stopping behavior. Figure 62, below, provides a general overview of the accuracy of predictions. These predictions only extend to the three variables for the three defined stopping behaviors. This thesis did not document predictions for each of the dependent variables comparing stopping types one-to-one based on time and need.

FIG. 62: Lists of Accurately and Inaccurately Predicted Variable Coefficient Signs

Accurately Predicted Expectations for Stopping Behavior by Variable:
Results from Regression Model Set A & B by Coefficient and Type of Stop

Perfectly Predicted Expectations	**Partially Correct Expectations** (from most to least correct)	**Entirely Incorrect Expectations**
▪ Gender ▪ Helmet Use ▪ Left Turning Movements ▪ Temperature ▪ Uphill Topography After an Intersection	▪ Downhill Topography Before an Intersection ▪ Right Turning Movements ▪ Wind Speed ▪ Beacon Type ▪ Green Bicycle Lane ▪ Bicycle Facility Before an Intersection ▪ On-Street Parking Before an Intersection ▪ On-Street Parking After an Intersection ▪ Uphill Topography Before an Intersection ▪ Light Conditions ▪ Bicycle Facility After an Intersection ▪ Downhill Topography After an Intersection	▪ Time of Day ▪ Visibility

The regression analysis found that most expectations developed during the design of this analysis were only partially accurate. This means that the sign of the coefficient for only one or two of the dependent variables was predicted correctly before the models were run. The only two variables for which expectations were entirely incorrect are included in the group of circumstantial variables. Three of the four behavioral and subject-specific variables were predicted with perfect accuracy.

COMPILED LINEAR REGRESSION RESULTS

The findings for all variables tested using Regression Models A and B are presented in two parts. On the eight pages to follow, this thesis presents the most meaningful results for both sets of regression models developed and run using the results of this the pilot study on bicyclists' stopping behavior. The beta coefficient and significance for each variable was investigated through this statistical analysis. These figures correspond and served as the basis for the graphic representations and narrative descriptions of each variable included at the end of this chapter.

Results for Regression Model Set A are presented, followed by results for Regression Model Set B. The first model (A) includes all variables identified in Chapter 7 "Pilot Study Variables". The second model (B) analyzes the same set of variables, with the only difference being the combination of variables for locations that were observed as experiencing statistically similar patterns of bicyclists' stopping behavior.

(1) **Results for Each Separate Stopping Type** – Compares each type with all other stopping behavior types, collectively. This table also includes results for the continuous variable for the degree of a stop, from not stopping at all to using a full and complete stop.

(2) **Results for Full and Complete Stops** – Compares the behaviors of bicyclists who use full and complete stops with the behaviors of bicyclists who: **(a)** either use rolling stops and/or track stands or do not stop at all; **(b)** use rolling stops, specifically; and **(c)** fail to stop, specifically.

(3) **Results for Rolling Stops** – Compares the behaviors of bicyclists who use rolling stops and/or track stands with the behaviors of other bicyclists who: **(a)** either do not use full and complete stops or do not stop at all; **(b)** fail to stop, specifically; and **(c)** use full and complete stops, specifically.

(4) **Results for Not Stopping** – Compares the behaviors of bicyclists who fail to stop at intersections with the behaviors of bicyclists who: **(a)** either use full and complete stops or rolling stops and/or track stands; **(b)** use full and complete stops, specifically; and **(c)** use rolling stops, specifically.

Following the tables presenting results for Regression Model Sets A and B, Figures 71 and 72 present the comparison data on stopping behavior at the six count locations. This data was used to support the decision to combine results from statistically similar locations. Based on the results presented in this table, Capitol Hill and Sand Point constitute one category of locations. Therefore, The neighborhoods of Queen Anne, Greenlake, Ballard, and the University District make up the second group of locations. This grouping is used to create the binary locational variable included in Regression Model Set B.

REGRESSION MODEL A – RESULTS FOR PRIMARY STOPPING BEHAVIORS

FIG. 63: Regression Model Set A – Primary Stop Types

COMPARISON OF REGRESSION RESULTS:
Four Different Dependent Variables for Stopping Behavior

REGRESSION MODELS	Full and Complete Stop		Rolling Stop and/or Track Stand		No Stop or Yield		Continuous Variable for Stopping	
Variables	*β*	Sig.	*β*	Sig.	*β*	Sig.	*β*	Sig.
Male Bicyclist	**-.459***	.000	.147	.121	**.206****	.073	**-.083***	.000
Wearing Helmet	.411	.185	.041	.850	-.376	.117	**.049***	.001
Left Turn	**.907***	.000	-.041	.780	**-.893***	.000	.147	.380
Right Turn	-.058	.829	-.295	.134	.311	.183	**.034***	.000
Time Period	**.669***	.004	-.147	.454	**-.473****	.065	.110	.516
Lower Light	.087	.286	**-.192***	.003	**.179***	.024	**.035***	.029
Higher Temperature	-.016	.311	.021	.136	.003	.899	**-.004***	.042
Higher Visibility	**.063****	.084	-.030	.312	-.030	.423	.015	.230
Higher Wind Speed	.007	.830	**.161***	.000	**-.254***	.000	**-.013****	.057
4-Way Stop Signs	-1.437	.178	**2.862***	.004	**-3.474***	.035	-	-
Beacon Type	**.949***	.023	**-1.252***	.001	**.911****	.070	-	-
Green Lane	**-1.400***	.021	-.326	.549	**2.293***	.045	-	-
Facility Before	.123	.255	**.121****	.098	**-.233***	.007	**.018***	.037
Facility After	.104	.190	-.068	.216	.022	.727	.001	.732
Parking Before	.082	.751	.235	.288	-.445	.130	-.022	.160
Parking After	.856	.002*	.236	.288	**-1.242***	.000	.123	.431
Uphill Before	-.043	.841	.064	.649	-.041	.780	-.013	.120
Uphill After	-.313	.423	.303	.339	.254	.538	**-.115***	.008
Downhill Before	-.406	.284	.423	.188	-.111	.820	-.059	.890
Downhill After	**-.705***	.025	.037	.885	**.635****	.071	-.099	.902
Capitol Hill	-.226	.729	-.400	.499	1.804	.137	-.325	.252
Greenlake	.833	.137	**-1.489***	.004	**2.233****	.050	**.018****	.051
Ballard	-	-	-	-	-	-	-.017	.210
University Dist.	-	-	-	-	-	-	-.165	.945
Sand Point	-	-	-	-	-	-	-.298	.706
Constant	-3.752	.001	-.146	.872	.500	.672	.930	.000

* Indicates statically significant with 95% confidence interval and ** indicates a 90% confidence interval.

REGRESSION MODEL A – RESULTS FOR FULL AND COMPLETE STOPS

FIG. 64: Regression Model Set A – Full Stop to Other Stop Types

COMPARISON OF REGRESSION RESULTS FOR FULL AND COMPLETE STOP:
Four Different Dependent Variables for Stopping Behavior

REGRESSION MODELS	**Full and Complete Stop; Not Rolling or No Stop**		**Full and Complete Stop; Not Rolling Stop**		**Full and Complete Stop; Not No Stop**	
Variables	***β***	**Sig.**	***β***	**Sig.**	***β***	**Sig.**
Male Bicyclist	**-.459***	.000	**-.422***	.000	**-.575***	.000
Wearing Helmet	.411	.185	.337	.295	.840	.032
Left Turn	**.907***	.000	**.684***	.000	**1.673***	.000
Right Turn	-.058	.829	.027	.923	-.320	.355
Time Period	**.669***	.004	**.447****	.067	**1.148***	.001
Lower Light	.087	.286	.138	.108	-.087	.434
Higher Temperature	-.016	.311	-.016	.345	**-.053***	.040
Higher Visibility	**.063****	.084	.049	.202	.055	.266
Higher Wind Speed	.007	.830	**-.057****	.099	.169*	.000
4-Way Stop Signs	-1.437	.178	**-2.272***	.043	2.317	.216
Beacon Type	**.949***	.023	**1.204***	.006	-.265	.671
Green Lane	**-1.400***	.021	-.911	.145	**-2.604***	.038
Facility Before	.123	.255	.093	.263	.148	.125
Facility After	.104	.190	.041	.713	.090	.543
Parking Before	.082	.751	-.050	.851	.534	.178
Parking After	.856	.002*	**.541****	.071	**1.549***	.000
Uphill Before	-.043	.841	-.055	.809	-.123	.608
Uphill After	-.313	.423	-.329	.424	**-.953****	.092
Downhill Before	-.406	.284	-.474	.222	-.480	.450
Downhill After	**-.705***	.025	**-.568****	.072	**-2.052***	.001
Capitol Hill	-.226	.729	.100	.880	-1.127	.414
Greenlake	.833	.137	**1.214***	.035	-1.640	.178
Ballard						
University Dist.						
Sand Point						
Constant	-3.752	.001	-2.563	.032	-1.518	.332

* Indicates statically significant with 95% confidence interval and ** indicates a 90% confidence interval.

REGRESSION MODEL A – RESULTS FOR ROLLING STOPS

FIG. 65: Regression Model Set A – Rolling Stop to Other Stop Types

COMPARISON OF REGRESSION RESULTS FOR ROLLING STOP:
Four Different Dependent Variables for Stopping Behavior

REGRESSION MODELS	**Rolling Stop; Not Full or No Stop**		**Rolling Stop; Not No Stop**		**Rolling Stop; Not Full Stop**	
Variables	***β***	**Sig.**	***β***	**Sig.**	***β***	**Sig.**
Male Bicyclist	.147	.121	-.047	.696	**.422***	.000
Wearing Helmet	.041	.850	.240	.334	-.337	.295
Left Turn	-.041	.780	**.617***	.001	**-.684***	.000
Right Turn	-.295	.134	-.314	.212	-.027	.923
Time Period	-.147	.454	.323	.223	**-.447****	.067
Lower Light	**-.192***	.003	**-.215***	.008	-.138	.108
Higher Temperature	.021	.136	.000	.991	.016	.345
Higher Visibility	-.030	.312	.019	.630	-.049	.202
Higher Wind Speed	**.161***	.000	**.282***	.000	**.057****	.099
4-Way Stop Signs	**2.862***	.004	**3.774***	.030	**2.272***	.043
Beacon Type	**-1.252***	.001	**-1.145***	.034	**-1.204***	.006
Green Lane	-.326	.549	**-1.994****	.089	.911	.145
Facility Before	**.121****	.098	-.031	.628	-.093	.263
Facility After	-.068	.216	.222*	.013	-.041	.713
Parking Before	.235	.288	**.594****	.054	.050	.851
Parking After	.236	.288	**1.074***	.000	**-.541****	.071
Uphill Before	.064	.649	.045	.767	.055	.809
Uphill After	.303	.339	-.155	.722	.329	.424
Downhill Before	.423	.188	.158	.752	.474	.222
Downhill After	.037	.885	-.501	.169	**.568****	.072
Capitol Hill	-.400	.499	-1.714	.169	-.100	.880
Greenlake	**-1.489***	.004	**-2.396***	.040	**-1.214***	.035
Ballard						
University Dist.						
Sand Point						
Constant	-.146	.872	-.404	.748	2.563	.032

* Indicates statically significant with 95% confidence interval and ** indicates a 90% confidence interval.

REGRESSION MODEL A – RESULTS FOR NOT STOPPING

FIG. 66: Regression Model Set A – Not Stopping to Other Stop Types

COMPARISON OF REGRESSION RESULTS FOR NO STOP OR YIELD:
Four Different Dependent Variables for Stopping Behavior

REGRESSION MODELS	**No Stop; Not Full or Rolling Stop**		**No Stop; Not Full Stop**		**No Stop; Not Rolling Stop**	
Variables	***β***	**Sig.**	***β***	**Sig.**	***β***	**Sig.**
Male Bicyclist	**.206****	.073	**.575***	.000	**.422***	.000
Wearing Helmet	-.376	.117	**-.840***	.032	-.337	.295
Left Turn	**-.893***	.000	**-1.673***	.000	**-.684***	.000
Right Turn	.311	.183	.320	.355	-.027	.923
Time Period	**-.473****	.065	**-1.148***	.001	**-.447****	.067
Lower Light	**.179***	.024	.087	.434	-.138	.108
Higher Temperature	.003	.899	**.053***	.040	.016	.345
Higher Visibility	-.030	.423	-.055	.266	-.049	.202
Higher Wind Speed	**-.254***	.000	**-.169***	.000	**.057****	.099
4-Way Stop Signs	**-3.474***	.035	-2.317	.216	**2.272***	.043
Beacon Type	**.911****	.070	.265	.671	**-1.204***	.006
Green Lane	**2.293***	.045	**2.604***	.038	.911	.145
Facility Before	**-.233***	.007	-.148	.125	-.093	.263
Facility After	.022	.727	-.090	.543	-.041	.713
Parking Before	-.445	.130	-.534	.178	.050	.851
Parking After	**-1.242***	.000	**-1.549***	.000	**-.541****	.071
Uphill Before	-.041	.780	.123	.608	.055	.809
Uphill After	.254	.538	**.953****	.092	.329	.424
Downhill Before	-.111	.820	.480	.450	.474	.222
Downhill After	**.635****	.071	**2.052***	.001	.568	.072
Capitol Hill	1.804	.137	1.127	.414	-.100	.880
Greenlake	**2.233****	.050	1.640	.178	**-1.214***	.035
Ballard						
University Dist.						
Sand Point						
Constant	.500	.672	1.518	.332	2.563	.032

* Indicates statically significant with 95% confidence interval and ** indicates a 90% confidence interval.

REGRESSION MODEL B – RESULTS FOR PRIMARY STOPPING BEHAVIORS

FIG. 67: Regression Model Set B – Primary Stop Types

COMPARISON OF REGRESSION RESULTS:
Four Different Dependent Variables for Stopping Behavior

REGRESSION MODELS	**Full and Complete Stop**		**Rolling Stop and/or Track Stand**		**No Stop or Yield**		**Continuous Variable for Stopping**	
Variables	***β***	**Sig.**	***β***	**Sig.**	***β***	**Sig.**	***β***	**Sig.**
Male Bicyclist	**-.457***	.000	.149	.114	**.202****	.078	**-.083***	.001
Wearing Helmet	.410	.185	.040	.852	-.375	.117	.049	.381
Left Turn	**.903***	.000	-.047	.746	**-.887***	.000	**.147***	.000
Right Turn	-.060	.823	-.299	.128	.332	.153	.033	.522
Time Period	**.668***	.004	-.149	.449	**-.462****	.072	**.110***	.029
Lower Light	.088	.285	**-.191***	.003	**.180***	.023	**.035***	.042
Higher Temperature	-.016	.320	.022	.125	.001	.971	-.004	.236
Higher Visibility	**.064****	.082	-.030	.319	-.030	.422	**.015****	.057
Higher Wind Speed	.007	.843	**.160***	.000	**-.251***	.000	**-.013****	.070
4-Way Stop Signs	.243	.770	-.098	.891	.352	.730	.055	.774
Beacon Type	.060	.902	.118	.788	-.356	.585	-.032	.787
Green Lane	**-1.371***	.023	-.237	.652	**1.373****	.066	-.154	.267
Facility Before	.110	.159	-.063	.247	.012	.842	.019	.192
Facility After	.125	.247	**.122****	.095	**-.231***	.008	.001	.940
Parking Before	.075	.773	.219	.321	-.419	.154	-.024	.682
Parking After	**.841***	.003	.205	.345	**-1.168***	.000	**.119***	.039
Uphill Before	-.038	.859	.070	.619	-.048	.744	-.012	.744
Uphill After	-.294	.448	.339	.280	.178	.665	-.111	.168
Downhill Before	-.451	.203	.347	.253	.191	.694	-.065	.358
Downhill After	**-.723***	.019	.018	.943	**.683****	.055	-.101	.110
Sand Point and Capitol Hill	**-.979***	.008	**1.219***	.000	**-.859****	.093	**-.330***	.000
Constant	**-2.837***	.015	-1.433	.134	1.485	.241	**.954***	.000

* Indicates statically significant with 95% confidence interval and ** indicates a 90% confidence interval.

REGRESSION MODEL B – RESULTS FOR FULL AND COMPLETE STOPS

FIG. 68: Regression Model Set B – Full Stop to Other Stop Types

COMPARISON OF REGRESSION RESULTS FOR FULL AND COMPLETE STOP:
Four Different Dependent Variables for Stopping Behavior

REGRESSION MODELS	**Full and Complete Stop; Not Rolling or No Stop**		**Full and Complete Stop; Not Rolling Stop**		**Full and Complete Stop; Not No Stop**	
Variables	***β***	**Sig.**	***β***	**Sig.**	***β***	**Sig.**
Male Bicyclist	**-.457***	.000	**-.423***	.000	**-.571***	.000
Wearing Helmet	.410	.185	.337	.295	**.835***	.033
Left Turn	**.903***	.000	**.687***	.000	**1.679***	.000
Right Turn	-.060	.823	.029	.917	-.333	.337
Time Period	**.668***	.004	**.447****	.067	**1.151***	.001
Lower Light	.088	.285	.138	.108	-.088	.428
Higher Temperature	-.016	.320	-.016	.340	**-.053***	.040
Higher Visibility	**.064****	.082	.049	.203	.056	.262
Higher Wind Speed	.007	.843	-.057	.101	**.168***	.000
4-Way Stop Signs	.243	.770	.150	.860	-.659	.628
Beacon Type	.060	.902	.015	.976	.860	.320
Green Lane	**-1.371***	.023	-.920	.138	**-2.084***	.031
Facility Before	.110	.159	.091	.265	**.161****	.093
Facility After	.125	.247	.040	.720	.074	.621
Parking Before	.075	.773	-.046	.861	.520	.193
Parking After	**.841***	.003	**.548****	.063	**1.489***	.000
Uphill Before	-.038	.859	-.057	.800	-.121	.613
Uphill After	-.294	.448	-.340	.401	-.946	.100
Downhill Before	-.451	.203	-.453	.212	-.666	.272
Downhill After	**-.723***	.019	**-.562****	.072	**-2.199***	.000
Sand Point and Capitol Hill	**-.979***	.008	**-1.148***	.002	.896	.210
Constant	**-2.837***	.015	-1.387	.257	-2.417	.141

* Indicates statically significant with 95% confidence interval and ** indicates a 90% confidence interval.

REGRESSION MODEL B – RESULTS FOR ROLLING STOPS

FIG. 69: Regression Model Set B – Rolling Stop to Other Stop Types

COMPARISON OF REGRESSION RESULTS FOR ROLLING STOP AND TRACK STAND:
Four Different Dependent Variables for Stopping Behavior

REGRESSION MODELS	**Rolling Stop; Not Full or No Stop**		**Rolling Stop; Not No Stop**		**Rolling Stop; Not Full Stop**	
Variables	***β***	**Sig.**	***β***	**Sig.**	***β***	**Sig.**
Male Bicyclist	.149	.114	-.045	.710	**.423***	.000
Wearing Helmet	.040	.852	.241	.331	-.337	.295
Left Turn	-.047	.746	**.616***	.001	**-.687***	.000
Right Turn	-.299	.128	-.338	.178	-.029	.917
Time Period	-.149	.449	.303	.253	**-.447****	.067
Lower Light	**-.191***	.003	**-.215***	.008	-.138	.108
Higher Temperature	.022	.125	.003	.905	.016	.340
Higher Visibility	-.030	.319	.018	.638	-.049	.203
Higher Wind Speed	**.160***	.000	**.277***	.000	.057	.101
4-Way Stop Signs	-.098	.891	-.428	.692	-.150	.860
Beacon Type	.118	.788	.333	.630	-.015	.976
Green Lane	-.237	.652	-1.122	.158	.920	.138
Facility Before	-.063	.247	-.023	.722	-.091	.265
Facility After	**.122****	.095	**.222***	.014	-.040	.720
Parking Before	.219	.321	.569	.064	.046	.861
Parking After	.205	.345	**1.003***	.000	**-.548****	.063
Uphill Before	.070	.619	.052	.736	.057	.800
Uphill After	.339	.280	-.079	.854	.340	.401
Downhill Before	.347	.253	-.104	.834	.453	.212
Downhill After	.018	.943	-.549	.135	**.562****	.072
Sand Point and Capitol Hill	**1.219***	.000	**1.073***	.043	**1.148***	.002
Constant	-1.433	.134	-1.623	.226	1.387	.257

* Indicates statically significant with 95% confidence interval and ** indicates a 90% confidence interval.

REGRESSION MODEL B – RESULTS FOR NOT STOPPING

FIG. 70: Regression Model Set B – Not Stopping to Other Stop Types

Comparison of Regression Results for No Stop:
Four Different Dependent Variables for Stopping Behavior

REGRESSION MODELS	**No Stop; Not Full or Rolling Stop**		**No Stop; Not Full Stop**		**No Stop; Not Rolling Stop**	
Variables	**β**	**Sig.**	**β**	**Sig.**	**β**	**Sig.**
Male Bicyclist	**.202****	.078	**.571***	.000	**.423***	.000
Wearing Helmet	-.375	.117	**-.835***	.033	-.337	.295
Left Turn	**-.887***	.000	**-1.679***	.000	**-.687***	.000
Right Turn	.332	.153	.333	.337	-.029	.917
Time Period	**-.462****	.072	**-1.151***	.001	**-.447****	.067
Lower Light	**.180***	.023	.088	.428	-.138	.108
Higher Temperature	.001	.971	**.053***	.040	.016	.340
Higher Visibility	-.030	.422	-.056	.262	-.049	.203
Higher Wind Speed	**-.251***	.000	**-.168***	.000	.057	.101
4-Way Stop Signs	.352	.730	.659	.628	-.150	.860
Beacon Type	-.356	.585	-.860	.320	-.015	.976
Green Lane	**1.373****	.066	**2.084***	.031	.920	.138
Facility Before	.012	.842	**-.161****	.093	-.091	.265
Facility After	**-.231***	.008	-.074	.621	-.040	.720
Parking Before	-.419	.154	-.520	.193	.046	.861
Parking After	**-1.168***	.000	**-1.489***	.000	**-.548****	.063
Uphill Before	-.048	.744	.121	.613	.057	.800
Uphill After	.178	.665	.946	.100	.340	.401
Downhill Before	.191	.694	.666	.272	.453	.212
Downhill After	**.683****	.055	**2.199***	.000	**.562****	.072
Sand Point and Capitol Hill	**-.859****	.093	-.896	.210	**1.148***	.002
Constant	1.485	0.241	2.417	0.141	1.387	0.257

* Indicates statically significant with 95% confidence interval and ** indicates a 90% confidence interval.

STOPPING BEHAVIOR COMPARISON BY COUNT LOCATION

FIG. 71: Games-Howell Post Hoc Test for Comparing Means – Degree of Stop

Games-Howell Post Hoc Test for Comparing Means Among Locations						
COUNT LOCATIONS	**Capitol Hill**	**Queen Anne**	**Greenlake**	**Ballard**	**University District**	**Sand Point**
Capitol Hill		-.3887	-.4358*	-.4149*	-.1550*	-.0863
Queen Anne	.3887		-.0471	-.0262	.2337	.3024
Greenlake	.4358*	.0471		.0209	.2808*	.3495*
Ballard	.4149*	.0262	-.0209		.2599	.3286*
University District	.1550*	-.2337	-.2808*	-.2599		.0687
Sand Point	.0863	-.3024	-.3495*	-.3286*	-.0687	

* Indicates statistically significant differences exist among the means with 95% confidence interval, no asterisk indicates. No statistical difference is found.

FIG. 72: Games-Howell Post Hoc Test for Comparing Means – All Stop Types

Games-Howell Post Hoc Test for Comparing Means Among Locations							
		Capitol Hill	**Queen Anne**	**Greenlake**	**Ballard**	**University District**	**Sand Point**
Capitol Hill	Full Stop		-.287*	-.272*	-.262*	-.004	-.043
	Rolling Stop		.204	.327*	.306*	.302*	.087*
	No Stop		.083	-.055	-.045	-.298*	-.044
Queen Anne	Full Stop	.287*		.014	.025	.282*	.244
	Rolling Stop	-.204		.123	.102	.098	-.117
	No Stop	-.083		-.138*	-.127	-.380*	-.127*
Greenlake	Full Stop	.272*	-.014		.011	.268*	.229*
	Rolling Stop	-.327*	-.123		-.021	-.025	-.240*
	No Stop	.055	.138*		.010	-.243*	.011
Ballard	Full Stop	.262*	-.025	-.011		.257*	.219*
	Rolling Stop	-.306*	-.102	.021		-.005	-.220*
	No Stop	.045	.127	-.010		-.253*	.001
University District	Full Stop	.004	-.282*	-.268*	-.257*		-.039
	Rolling Stop	-.302	-.098	.025	.005		1.215*
	No Stop	.298*	.380*	.243*	-.253*		.253*
Sand Point	Full Stop	.043	-.244	-.229*	-.219*	.039	
	Rolling Stop	-.087*	.117	.240*	.220*	.215*	
	No Stop	.044	.127*	-.011	-.001	-.253*	

* Indicates significant differences exist among the means with 95% confidence interval and ** a 90% confidence interval. No asterisk indicates no statistical difference is found.

Variables Type A:

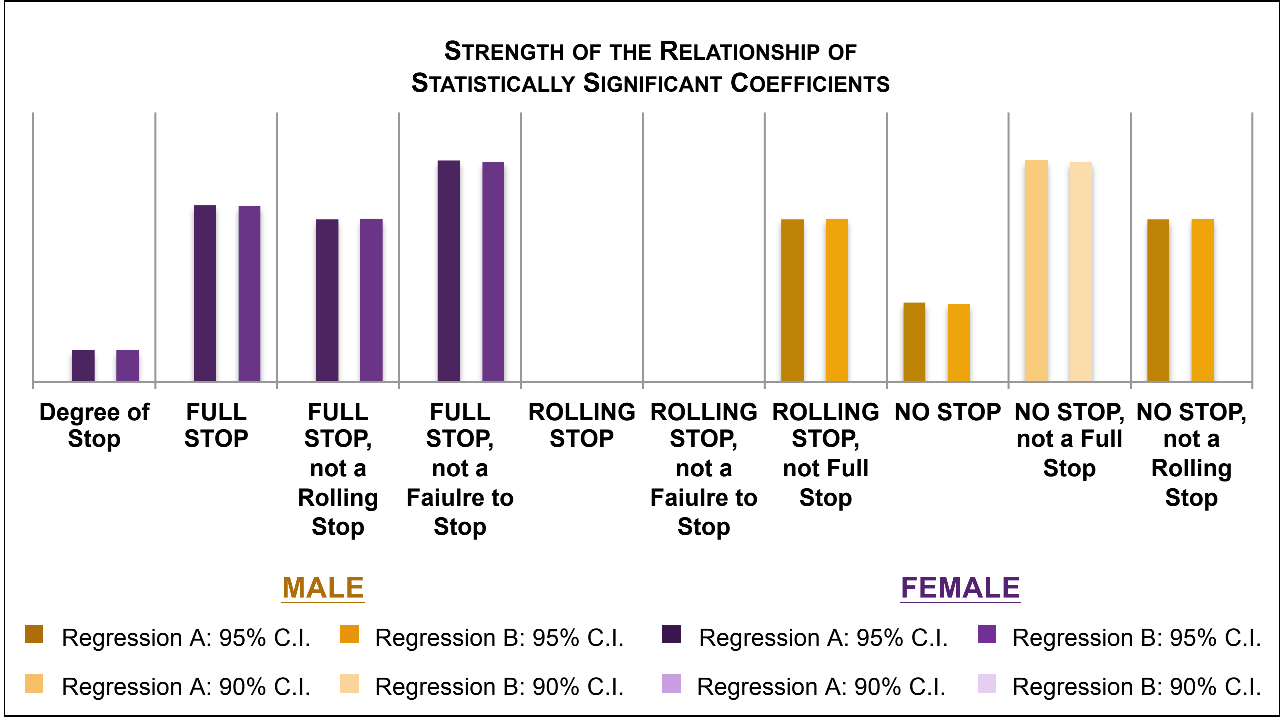
BEHAVIORAL AND SUBJECT-SPECIFIC VARIABLE RESULTS

A1 – BICYCLISTS' GENDER

The findings of both sets of regression models show that male bicyclists, more than female, chose not to stop at intersections. Male riders are also found to choose rolling stops over coming to a complete stop. Female bicyclists, however, are more likely to come to a full and complete stop at intersections. No significant results for female bicyclists were found for any other stopping behaviors. The models treating stopping behavior as continuous and measurable—increasing from not stopping, to rolling stops, to full stopping behaviors—likewise shows that women are slightly more likely to engage in increasingly law abiding behaviors. Looking at an average of the results from each

FIG. 73: Regression Model Comparison Results – Gender

INFLUENCE OF BICYCLISTS' GENDER ON STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals



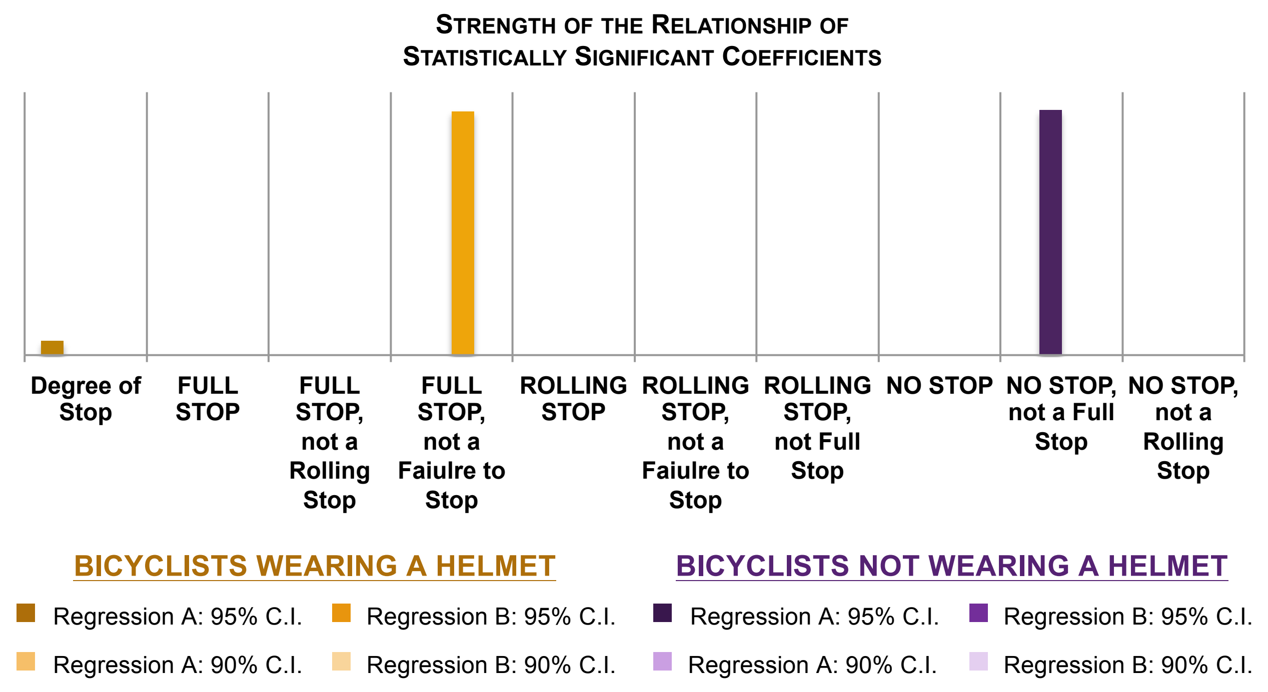
regression model set, the characteristic of being male is the variable that has the fifth strongest negative association with the use of full stops as well as fourth strongest positive relationship with rolling stops and not stopping (Fig. 73). Concerning the correlation of all variables included in the two sets of regression models, the characteristic of being male is negatively correlated with full stops (-0.77*) and positively correlated with not stopping rather than using a rolling (.081*) or full stop (.104*).

A2 – BICYCLISTS' HELMET USE*

The results on Figure 76 demonstrate that wearing a helmet shows positive results in two paired stopping behavior decisions. Bicyclists wearing a helmet are more likely to use a full stop, rather than not stopping at all. Echoing this, bicyclists not wearing a helmet are more likely to bicycle through an intersection without stopping rather than

FIG. 74: Regression Model Comparison Results – Helmet Use of Bicyclists

INFLUENCE OF BICYCLISTS' HELMET ON STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals

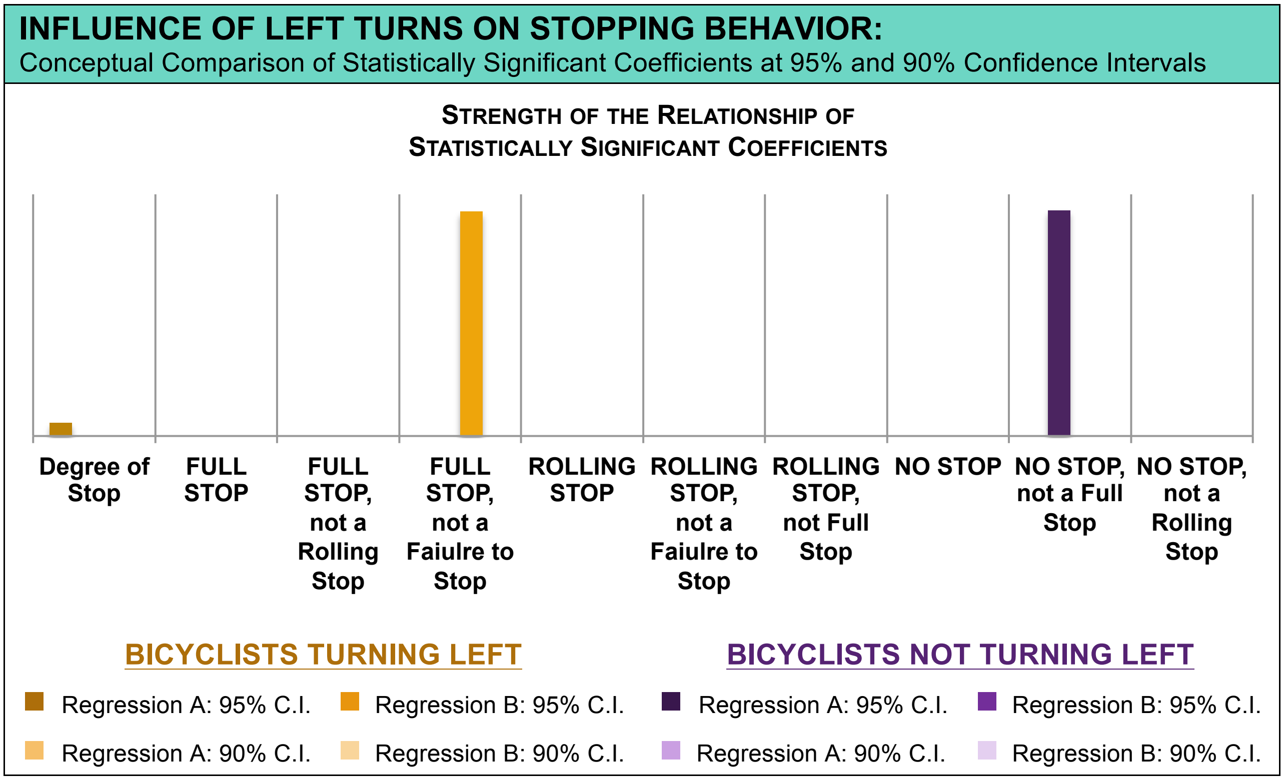


coming to a complete stop. No further useful findings regarding stopping behavior are seen using complete stop. No further useful findings regarding stopping behavior are seen using the variable for bicycle helmet use. This may be due to the fact that 97.3% of all bicyclists observed through the pilot study were wearing a helmet. Overall, the decision to wear a bicycle helmet has the third strongest positive significant relationship with the use of stopping behavior other than making no attempt to stop before entering an intersection (Fig. 74). Possibly due to the near ubiquitous use of bicycle helmets, no significant correlations between helmet use and stopping behavior are found.

A3 – BICYCLISTS' TURNING MOVEMENTS

No significant results were found for right turning movements. This indicates that the pilot study did not yield data able to reliably describe the stopping behavior of bicyclists turning right. The action of turning left at a stop sign controlled intersection, on the other hand, has the strongest average positive relationship with the use of full and complete stops, out of all variables included in the two specifications. Mirroring this finding, left turning movements have the second strongest negative relationship with the decision to not stop before crossing an intersection. As is shown in Figure 75 below, full stops are particularly favored over not stopping by bicyclists making left turns after stop signs. Those bicyclists who did not turn left at the intersection—either turning right or traveling straight—are more likely to travel through the intersection without stopping than are left turning bicyclists. In both regression model sets, a positive relationship is found between left turns and the decision to use rolling stops rather than not stopping. Left turns are, however, negatively associated with the use of rolling stops rather than the use of full and complete stops.

FIG. 75: Regression Model Comparison Results – Left Turning Movements



A4 – SAFETY OF BICYCLISTS' MANEUVERS

This is the only behavioral variable not included in the regression analysis. The reason for this is that, unlike the other more concrete variables in this category, the data collected on the safety of bicyclists' maneuvers are purely descriptive. Of all other variables, it is the most likely that data collectors will have recorded with slight variance the safety of maneuvers employed by the bicyclists observed. This thesis, therefore, does consider this data to be valid for the purposes of statistical analysis.

The correlation matrix describing all variables in the pilot study does, however, exhibit statistically significant relationships between the safety of bicyclists' maneuvers and their stopping behavior. Rolling stops and/or track stands as well as full and complete stops both share the same positive correlation (.182*) with increasing levels of safety.

The action of not stopping at a stop sign, however, is negatively correlated (-.378) with safer bicycling maneuvers. Based on these results, the data collected through this pilot study describe safer bicyclists as being more law abiding than more reckless riders.

Variables Type B:

CIRCUMSTANTIAL VARIABLE RESULTS

All data recorded in this pilot study were collected over a three-day period of time in the month of November, in 2014. As is discussed in Section C “Methodology for Scheduling Counts”, the count schedule used is modeled after the methodology used for the statewide bicycle and pedestrian documentation project conducted in Washington State. This means that counts occurred twice daily, on a Tuesday, Wednesday, and Thursday, from 7:00-9:00 to 16:00-18:00. The largest proportion of observations, 44.6%, was made on Thursday, and an average of 60.7% of bicyclists were recorded during the morning period.

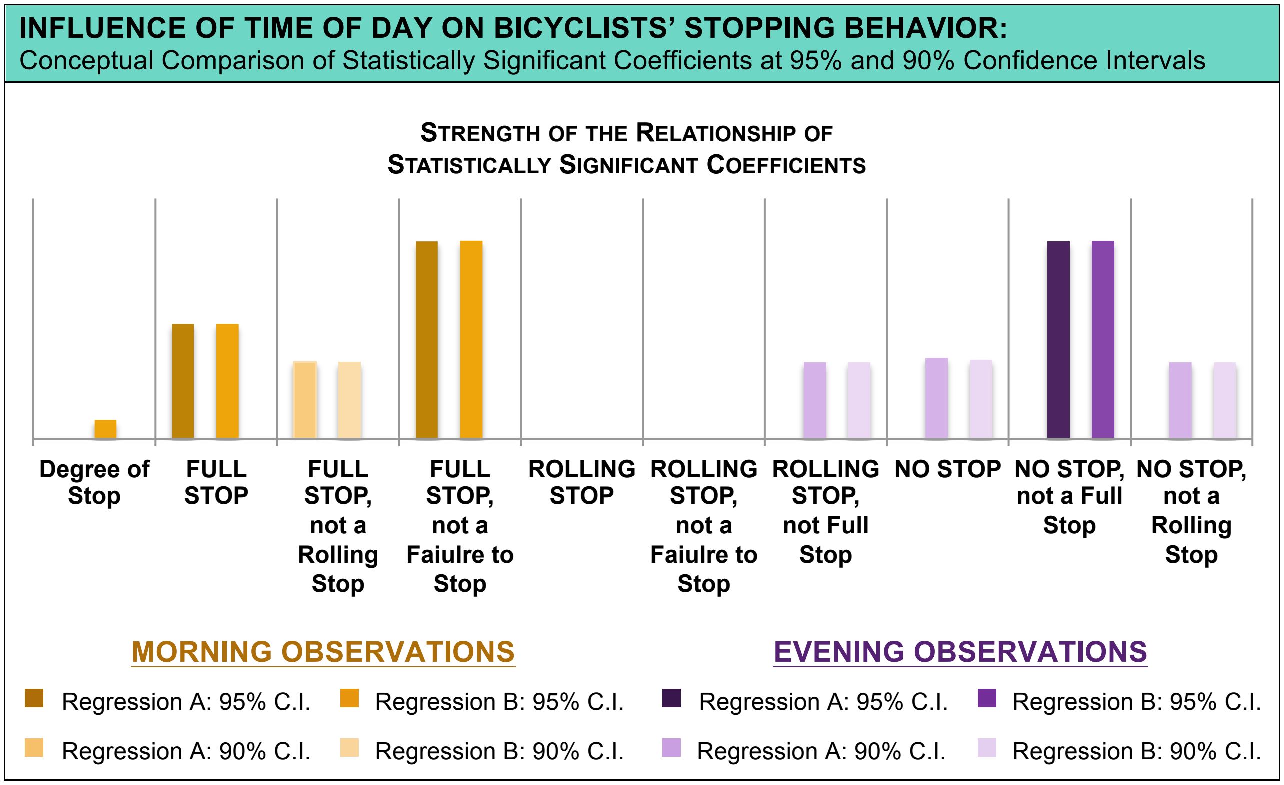
Weather conditions during the morning counts were clear and dry each day, with freezing temperatures experienced at several count locations the first two mornings of the pilot study. Overall, due to the low temperatures experienced during this pilot study, 79.6% of observations were made under weather conditions defined as “poor” by the National Bicycle and Pedestrian Documentation Project.

No rain was experienced during the pilot study, with the exception of light rain experienced at the end of the evening count period on the third day of observations. This rain did not result in perception above 0.0 inches and was included as a variable in this regression analysis.

B1 – TIME PERIOD*

Recognizing that the data for this variable are unbalanced, the regression analysis results depicted in Figure 76 above show clear statistical differences between observations made during the morning and during evening count periods. The use of full and complete stops shares a statistically significant relationship with the morning count period, and a failure to stop is significantly related to the evening count period, albeit at a lower confidence interval (Fig. 76). The morning count period is positively correlated (.060*) with the act of using a rolling stop rather than failing to stop. Rolling stops and/or track stands (-.045**) and failure to stop (-.051*) are both negatively correlated with the observations made from 7:00 to 9:00 AM.

FIG. 76: Regression Model Comparison Results – Time of Day

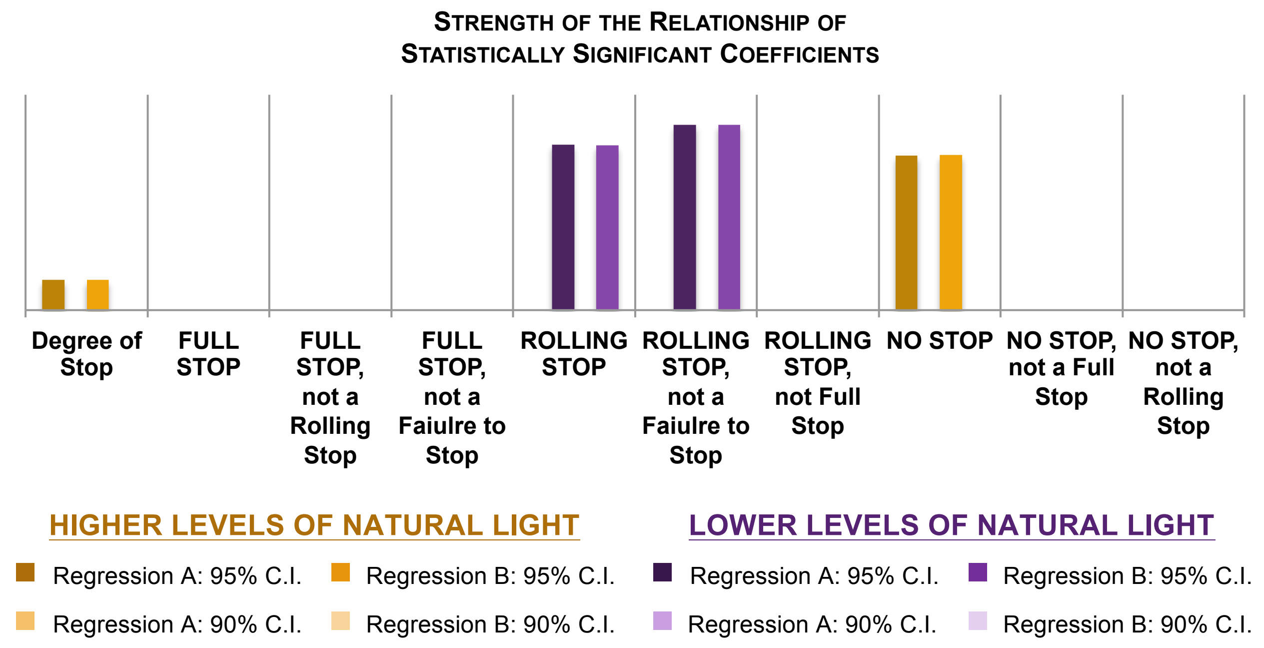


B2 – NATURAL LIGHTING CONDITIONS

As was hypothesized in the list of assumptions, this analysis finds a statistically significant relationship between lower levels of natural light and rolling stops, as well as twilight and rolling stops. The largest variation is seen in the total percentages recorded for rolling stops and/or track stands. The highest percent of bicyclists, 60%, were recorded using rolling stops and/or track stands during sunset and sunrise. Only 51.9% performed the same action during nocturnal twilight. This difference is explained by a shift in behavior, with 7.1% fewer bicyclists coming to a full and complete stop during sunset and sunrise than during the latest hours recorded during the pilot study (Fig. 77). No significant correlations were observed between this variable for the levels of natural light and the set of dependent variables describing stopping behavior.

FIG. 77: Regression Model Comparison Results – Natural Light Conditions

INFLUENCE OF NATURAL LIGHT CONDITIONS ON BICYCLISTS' STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals

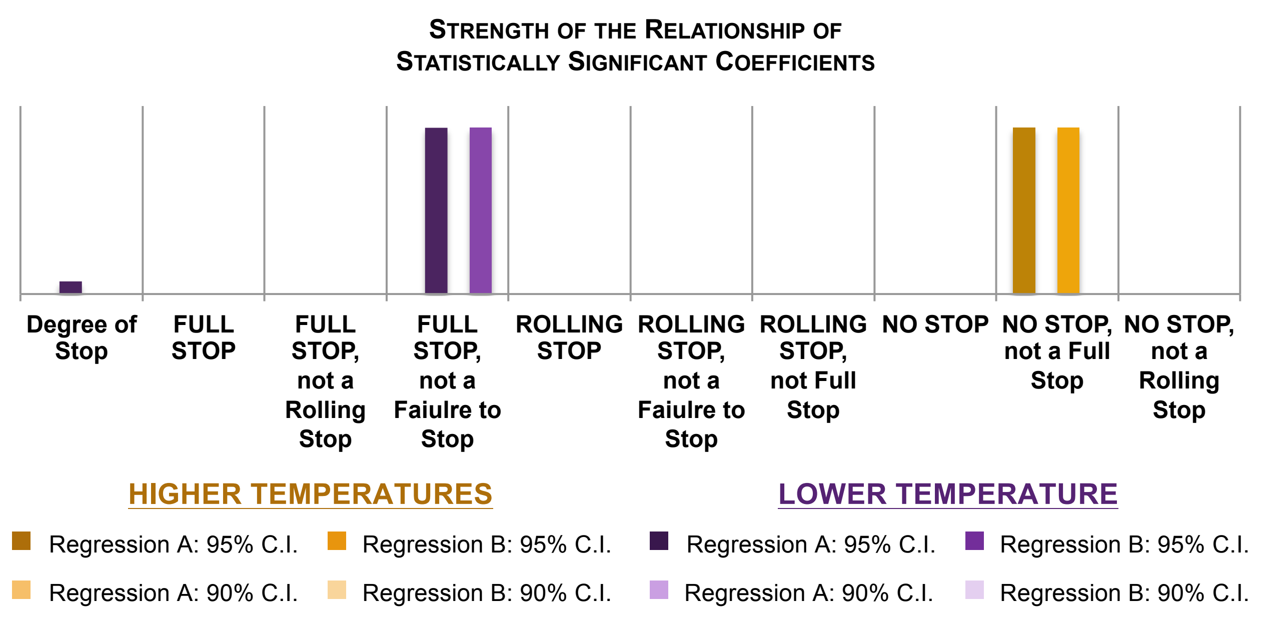


B3 – TEMPERATURE (in degrees Fahrenheit)

Similar to the descriptive results for temperature, results from the regression analyses likewise shed little light on the influence of temperature on bicyclists' behaviors. The only statistically significant results show two paired findings for the variable describing temperature as a range from high to low. These results suggest that higher temperatures encourage the decision to not stop over using a full and complete stop, and lower temperatures result in the opposite, with full and complete stops used in greater proportion than not stopping at the intersection. Despite the limited utility of these descriptive and analytical statistics, statistically significant correlations are found with temperature. Higher degrees of temperatures are positively related to the failure to stop and negatively correlated with the use of full and complete stops (-.058*).

FIG. 78: Regression Model Comparison Results – Temperature

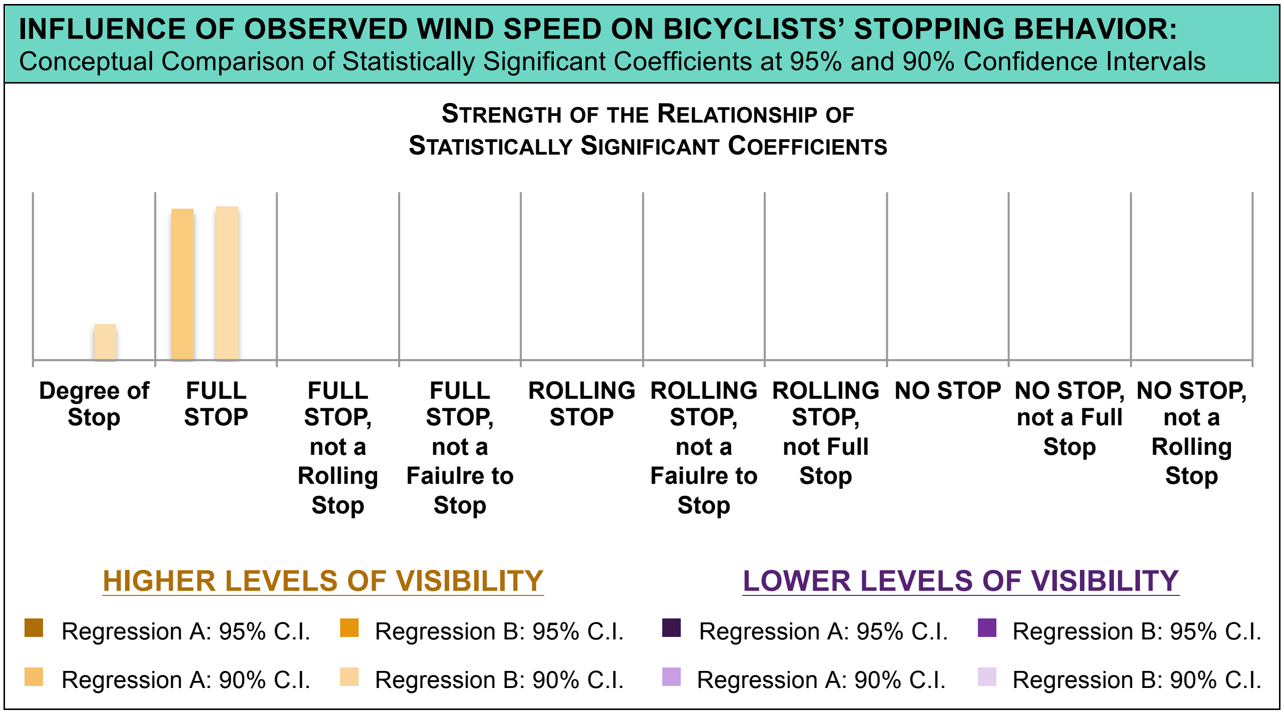
INFLUENCE OF OBSERVED TEMPERATURES ON BICYCLISTS' STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals



B4 – VISIBILITY

Reflecting this behavior, full stops are positively correlated (.080) with higher levels of visibility, and negative correlation is seen for visibility and rolling stops (-.038), as well as not stopping (-.030) at an intersection. Despite these correlations, the only statistically significant results were found for only one dependent variable, and this was only significant with 90% confidence interval. When the number of miles of visibility is higher, bicyclists are statistically more likely to use a full and complete stop at stop signs. To a lesser degree, however, high levels of visibility also share a relationship with the stopping behaviors increasingly non-compliant to the law (Fig. 79). Unfortunately, no other statistically significant findings were discovered for visibility. This is more likely to be a function of the limitations of the weather statistics than a true representation of the influence visibility has on bicyclists' stopping behaviors. Further study designed to

FIG. 79: Regression Model Comparison Results – Visibility



INFLUENCE OF OBSERVED WIND SPEED ON BICYCLISTS' STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals

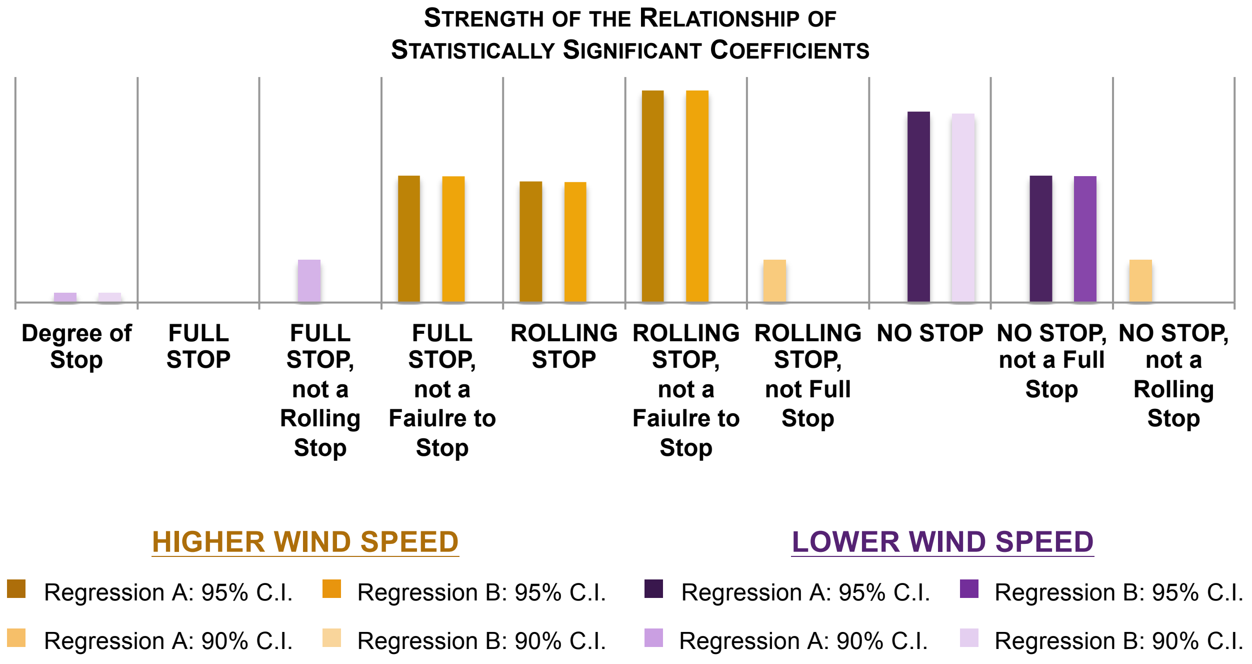
target a broader spectrum of visibility conditions is required for a more nuanced understanding of this relationship.

B5 – WIND SPEED

Higher wind speeds are related to the use of rolling stops, as well as to the use of full stops and rolling stops over a failure to stop. With a 90% confidence interval, lower wind speeds have a statistically significant relationship with the action of not stopping at stop sign controlled intersections Fig. 80). Lower wind speeds are also associated with a decision not to stop over coming a complete stop. Statistically significant correlations show that higher wind speeds are positively associated with both rolling stops and/or track stands (.081*) and complete stops (.048**). A failure to stop, however, is negatively correlated with higher wind speeds (-.137*).

FIG. 80: Regression Model Comparison Results – Wind Speed

INFLUENCE OF OBSERVED WIND SPEED ON BICYCLISTS' STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals



Variables Type C:

LOCATIONAL VARIABLES

The largest proportions of bicyclists observed during the pilot study were seen in the University District and Greenlake neighborhoods, representing 37.15% and 24.4% of all bicyclists observed. This means that over half of the observations were only made at a third of count locations With this being the case, the data collected for each of the locational variables is skewed toward the representation of these particular count locations, rather than representing a general population of locations.

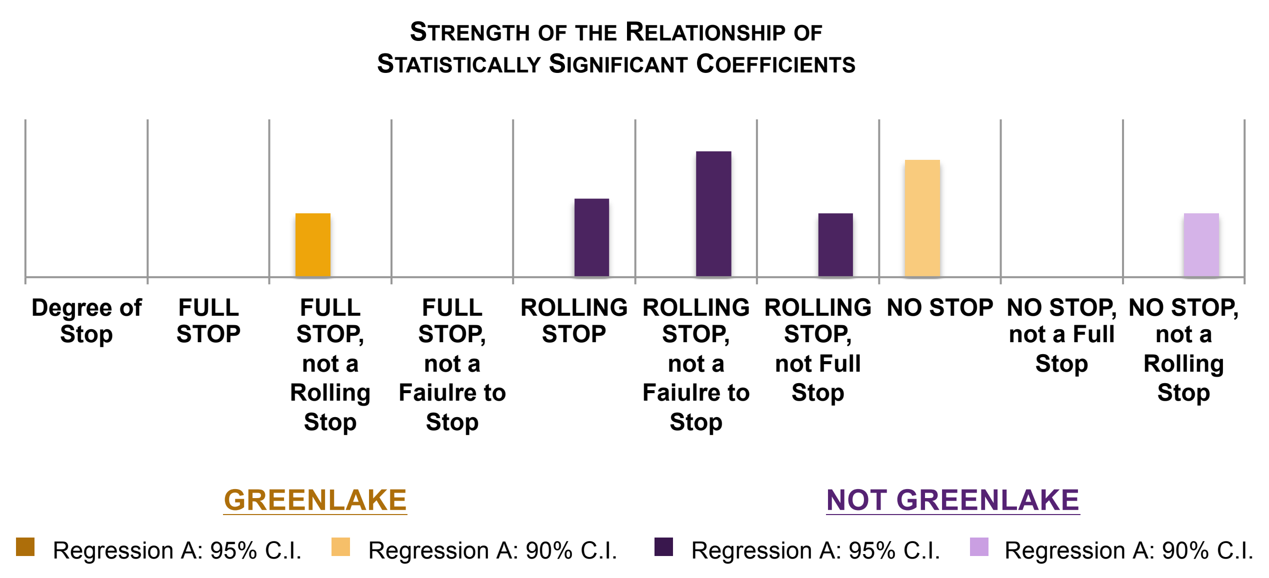
As locational variables are the most easily impacted by policy, planning, and traffic engineering fields, it is important that the data set be recognized as imperfect; these results are not well developed enough for credible application to decision-making. This is especially important, as three of the four most significant findings, discussed earlier in this chapter, are locational variables that would be easily adjusted through facilities design changes.

C1 – LOCATION OF OBSERVATION

With the locational variables included in Regression Model Set A, a failure to stop is negatively correlated with all count locations, with the exception of the location in the University District (.293*), which suggests that this is the one location where breaking the stopping law might be expected. Greenlake (-.125*) and the University District (-.129*) both share negative, statistically significant correlations with the use of rolling stops and track stands. Using Regression Model Set B, the neighborhoods of Queen Anne, Greenlake, Ballard, and the University District collectively share a positive,

FIG. 81: Regression Model Comparison Results – Location: Greenlake

INFLUENCE GREENLAKE ON BICYCLISTS' STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals

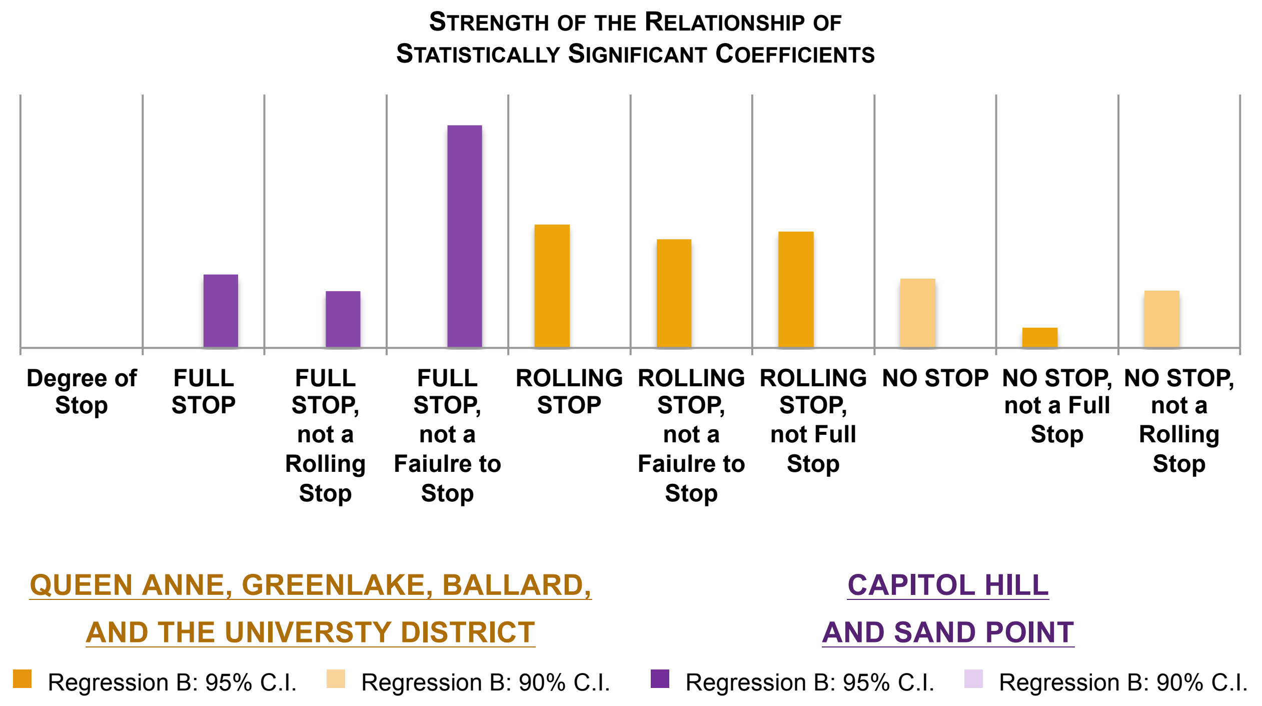


statistically significant correlation (.250*) with the practice of using a rolling stop. Negative correlations exist, however, with both full and complete stops (-.194*), in addition to making no attempt to stop or yield (-.183*) before crossing.

Regardless of these correlations, the count location in Greenlake is the only one for which Regression Model Set A yielded statistically significant results. When treated as separate variables, no significant results are found in describing the count locations in Capitol Hill, Ballard, the University District, and Sand Point. Partially based on the limitations of these results and the drawback of the data collected for locational variables, the binary variables describing the individual locations were grouped into two categories of two statistically similar groups of locations.

FIG. 82: Regression Model Comparison Results – Location: Grouped Categories of Locations

INFLUENCE GROUPED LOCATIONAL VARIABLE ON STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals



The significant results for Greenlake exhibit a negative relationship with rolling stops and track stands, indicating that these two similar behaviors are significantly associated with all other location variables with a 95% confidence interval. Results further indicate that bicyclists in Greenlake will choose a full stop over using a rolling stop or track stand. With a 90% confidence interval, a stronger association was found between Greenlake and the failure to stop at an intersection (Fig. 82).

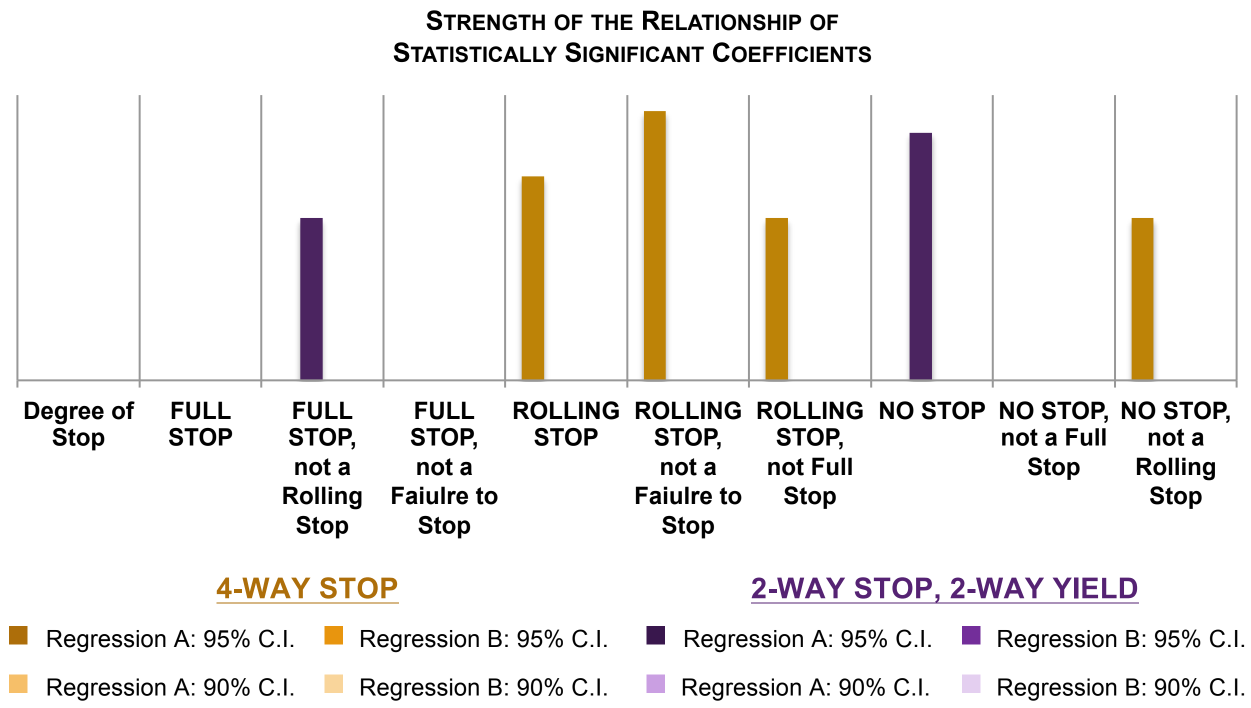
By grouping variables that are statistically similar (Fig. 71 and 72), statistically significant results describe Queen Anne, Greenlake, Ballard, and the University District as sharing a relationship with the practice of using a rolling stop or track stand at a stop sign. The action of failing to stop is also associated with these four groups, at a confidence interval of 90%. The count locations in Capitol Hill and Sand Point share a mild affiliation with the use of full and compete stops. The strongest relationship is the preference for full stops over failing to stop in this second grouped set of variables.

C2 – INTERSECTION STOP SIGN CONFIGURATION

A statistically significant negative correlation (-.118*) exists between the configuration of a four-way stop and the action of using a rolling stop. The action of not stopping, conversely, is positively correlated (.109*) with intersections controlled by four-way stop signs. Under analysis, results for this variable are only significant when running Regression Model Set A. When the data for statistically similar locations is combined in

FIG. 83: Regression Model Comparison Results – Intersection Stop Sign Configuration

INFLUENCE OF STOP SIGN CONFIGURATION ON BICYCLISTS' STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals

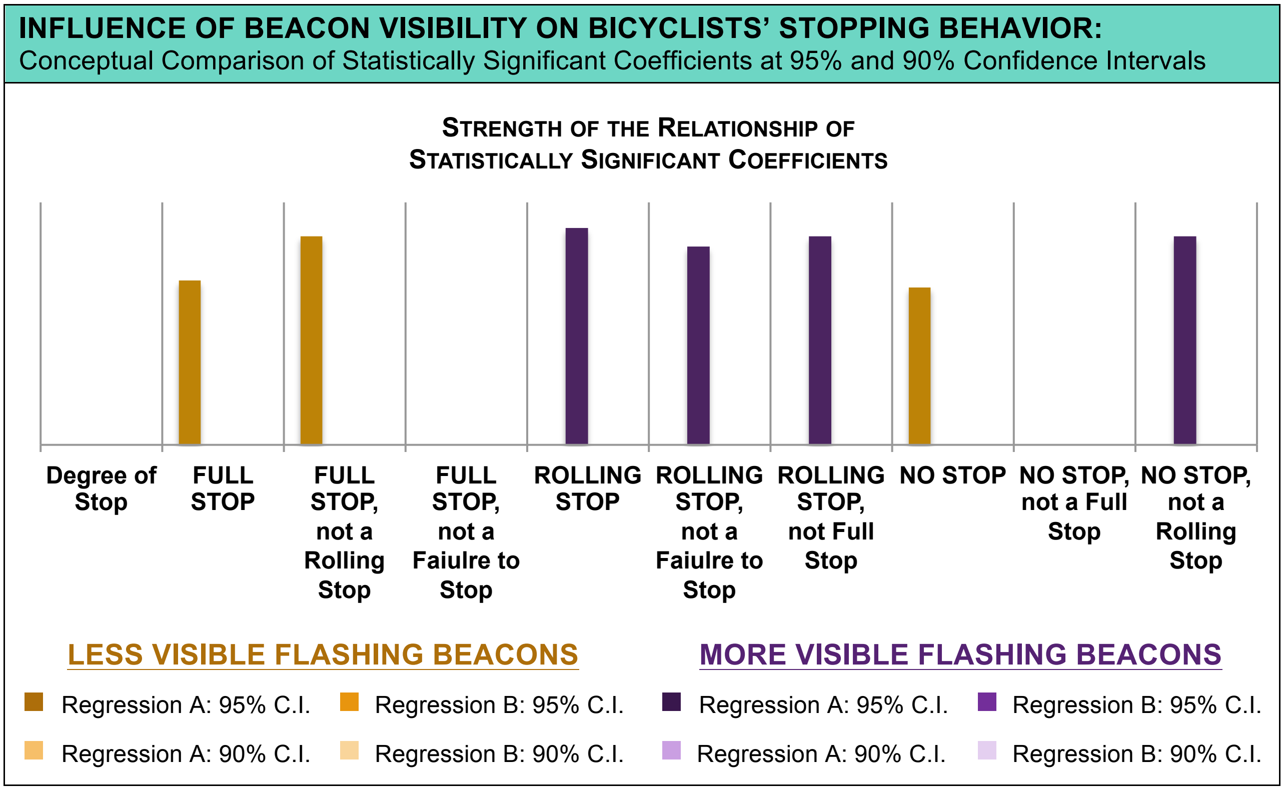


Regression Model Set B, the results for the variable describing the stop sign configuration are no longer significant for any type of stopping behavior. A statistically significant relationship exists between four-way stop sign controlled intersections and the action of using a rolling stop and/or track stand. Results also indicate that bicyclists are more likely not to stop than to use a rolling stop or track stand at four-way stops. The failure to stop, however, is associated with two-way stops, two-way yields, rather than with four-way stops as the simple correlations suggested. Significant results were also found by connecting two-way stop, two-way yield intersections with a preference for full stops over using a rolling stop or track stand.

C3 – FLASHING BEACON

Both the statistical correlations (-.149*) and the regression analysis show that rolling stops and track stands are used more where flashing beacons are more visible (Fig. 86). Full and complete stops, on the other hand, are associated with flashing beacons that are more visible at a distance. At a lower confidence interval, increasing visible beacons are related to the act of not stopping. A failure to stop, likewise, shares a statistically significant positive correlation (.203*) with more highly visible flashing beacons. No statistically significant results were found using Regression Model B.

FIG. 84: Regression Model Comparison Results – Flashing Beacon

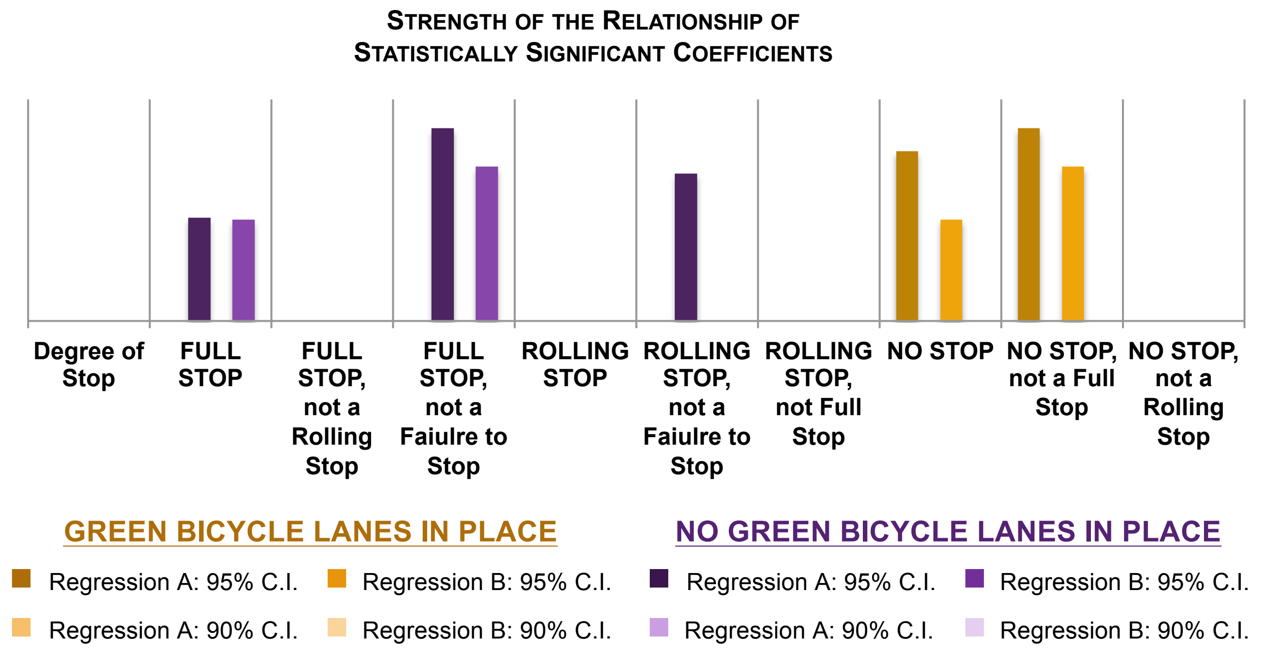

INFLUENCE OF BEACON VISIBILITY ON BICYCLISTS' STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals

C4 – GREEN BICYCLE LANES

The presence of green bicycle lanes is significantly negatively correlated with the use of rolling stops and track stands (-.129*) as well as full and complete stops (-.156*). A positive correlation (.293*) exists between not stopping and green bicycle lanes. These correlations are confirmed by the regression analysis results, which find statistically significant relationships between green bicycle lanes and not stopping, as well as between full stops and a lack of green lanes in an intersection. Statistically significant findings further show that where green bicycle lanes are not installed, full stops are preferred over no stops, with the opposite also being true (Fig. 85). In regard to rolling stops, Regression Model A found rolling stops to be preferred over no stops, where green bicycle lanes are not in place.

FIG. 85: Regression Model Comparison Results – Green Bicycle Lanes

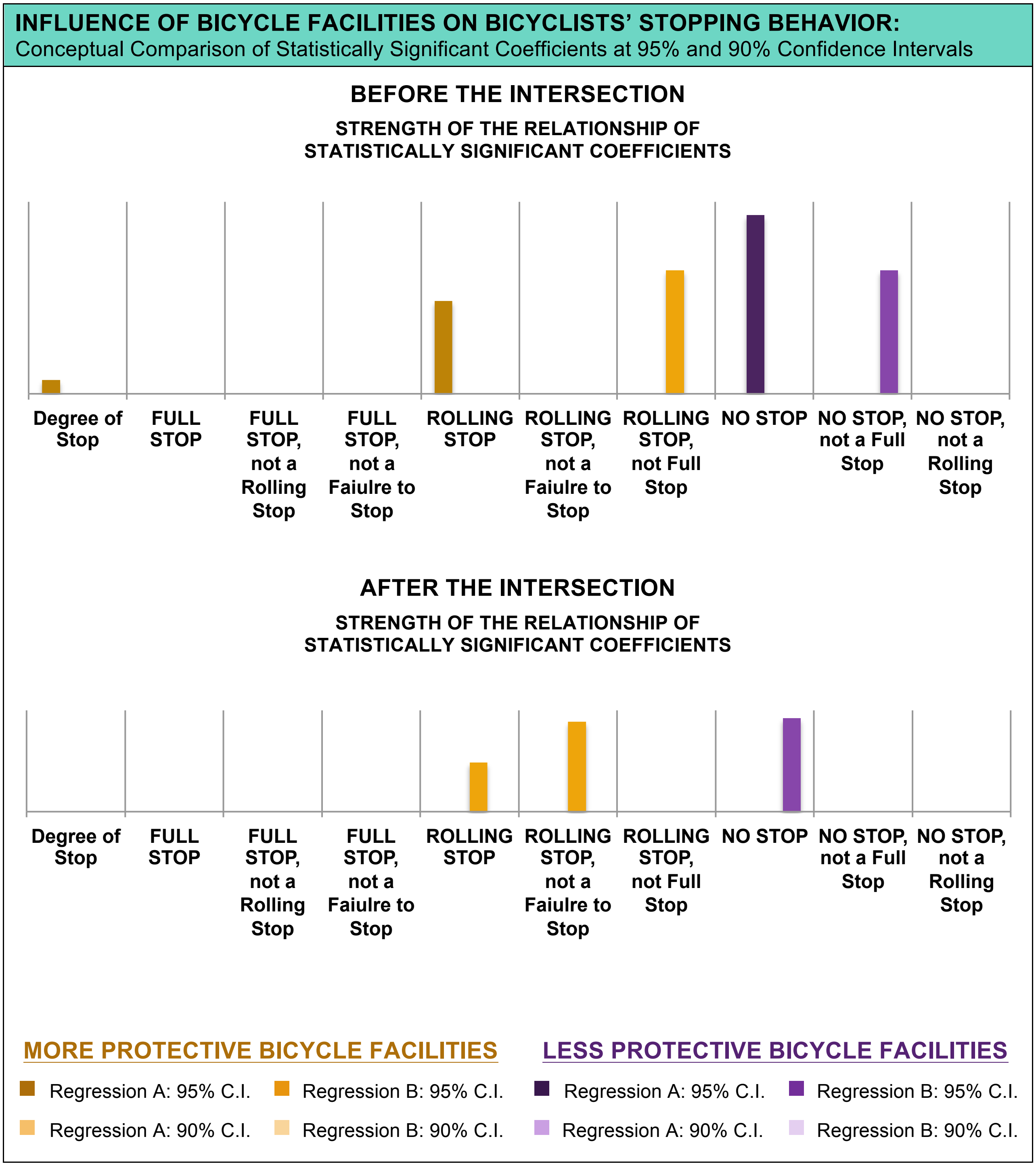
INFLUENCE OF GREEN LANES ON BICYCLISTS' STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals



C5 – TYPE OF BICYCLE FACILITY

Increasingly protective bicycle facilities before (.095*) and after (.212*) the intersection are positively correlated with non-compliance with the traffic law to stop at stop signs. Statistically significant negative correlations, however, are seen between the presence of more protective facilities before (-.112*) and after (-.102*) crossings and the action of coming to a full and complete stop. The regression analysis, however, suggests that these correlations inaccurately depict these relationships. Different from the correlations, results show that rolling stops before an intersection are increasingly common with more protective facilities. Regression Model Set A confirmed this finding for bicycle facilities on the approach, and Regression Model B for facilities on the roadway along which a bicyclist departed an intersection. Results also show an association between not stopping and roadways where less protective facilities are in place.

FIG. 86: Regression Model Comparison Results – Level of Protection of Bicycle Facilities

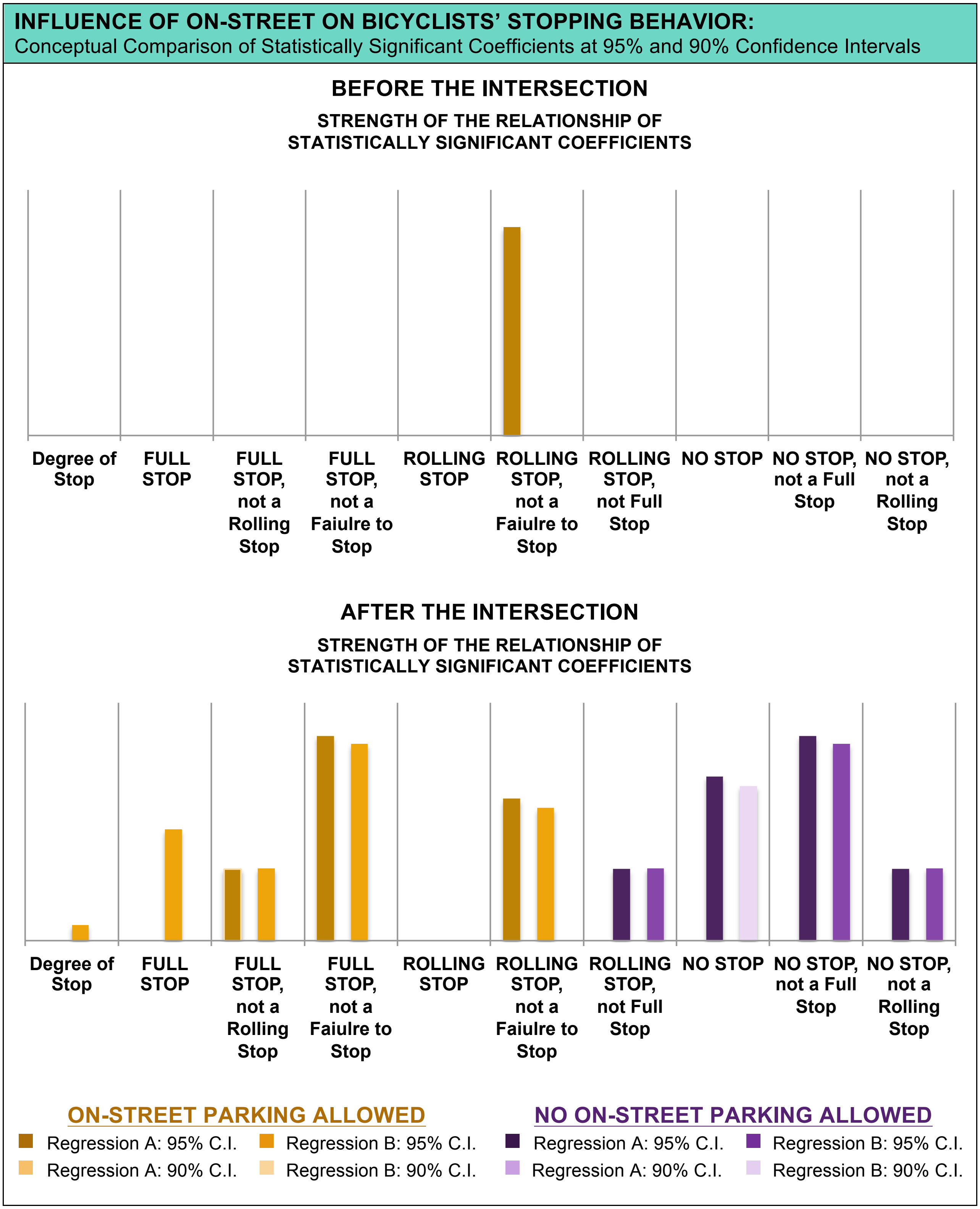


C6 – ON-STREET PARKING

The regression analysis revealed only one statistically significant result for the allowance of on-street parking on the roadway from which bicyclists approach an intersection. Regression Model A found that rolling stops are preferred over a failure to stop, where on-street parking is present before the intersection (Fig. 89). Statistically significant results, however, are found through both Regression Model Sets for the presence of on-street parking on the roadway after an intersection. A failure to stop at a stop sign is more common where on-street parking is not allowed after the crossing, and full stops are significantly more likely where on-street parking is allowed. Results for rolling stops are less conclusive, with the action of using a rolling stop preferred over not stopping when on-street parking is present, as well as being preferred over full stops where on-street parking is not allowed after the crossing (Fig. 87).

These results partially reflect the significantly significant correlations found between the variables of stopping behavior and on-street parking. The action of crossing an intersection without stopping or yielding is negatively correlated with the presence of on-street parking before (-.1.50*) and after (-.120*) a stop sign controlled intersection. Rolling stops, on the other hand, are positively correlated with the presence of on-street parking before (.162*) and after (.078*) the crossing. Lastly, a statistically significant negative correlation was also found for full and complete stops and on-street parking located on the roadway before (-.40*) the intersection.

FIG. 87: Regression Model Comparison Results – On-Street Parking



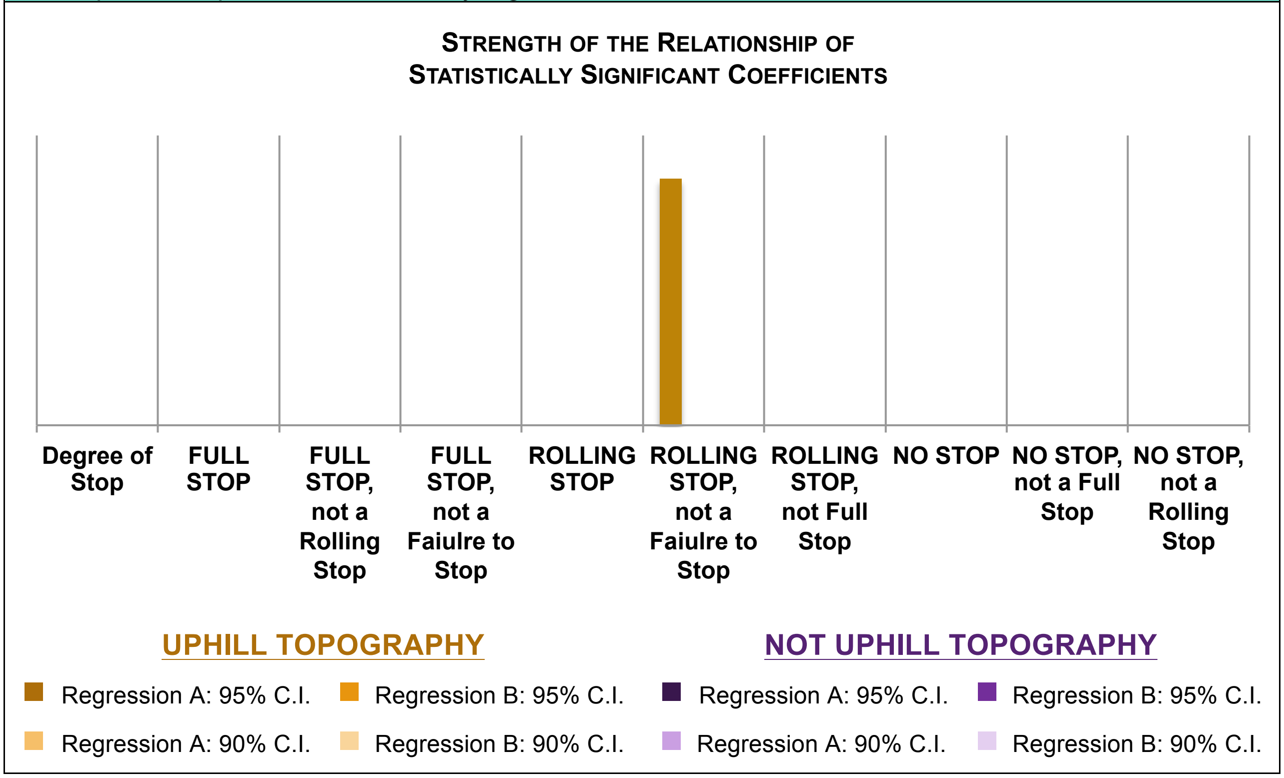
C7 – DIRECTIONAL TOPOGRAPHY

The practice of using of full and complete stops is negatively correlated with both uphill (-.105* and -.044**) and downhill (-.094 and -.107*) topography, before and after crossings. Rolling stops share a statistically significant negative correlation with uphill topography before the intersection (-.071), and a positive correlation with downhill topography before (.166*) and after (.148*). Regarding a complete failure to stop or yield, positive correlations exist with uphill topography and negative correlations with the presence of downhill topography.

FIG. 88: Regression Model Comparison Results – Uphill Topography, After the Intersection

INFLUENCE OF UPHILL TOPOGRAPHY AFTER AN INTERSECTION ON BICYCLISTS' STOPPING BEHAVIOR:

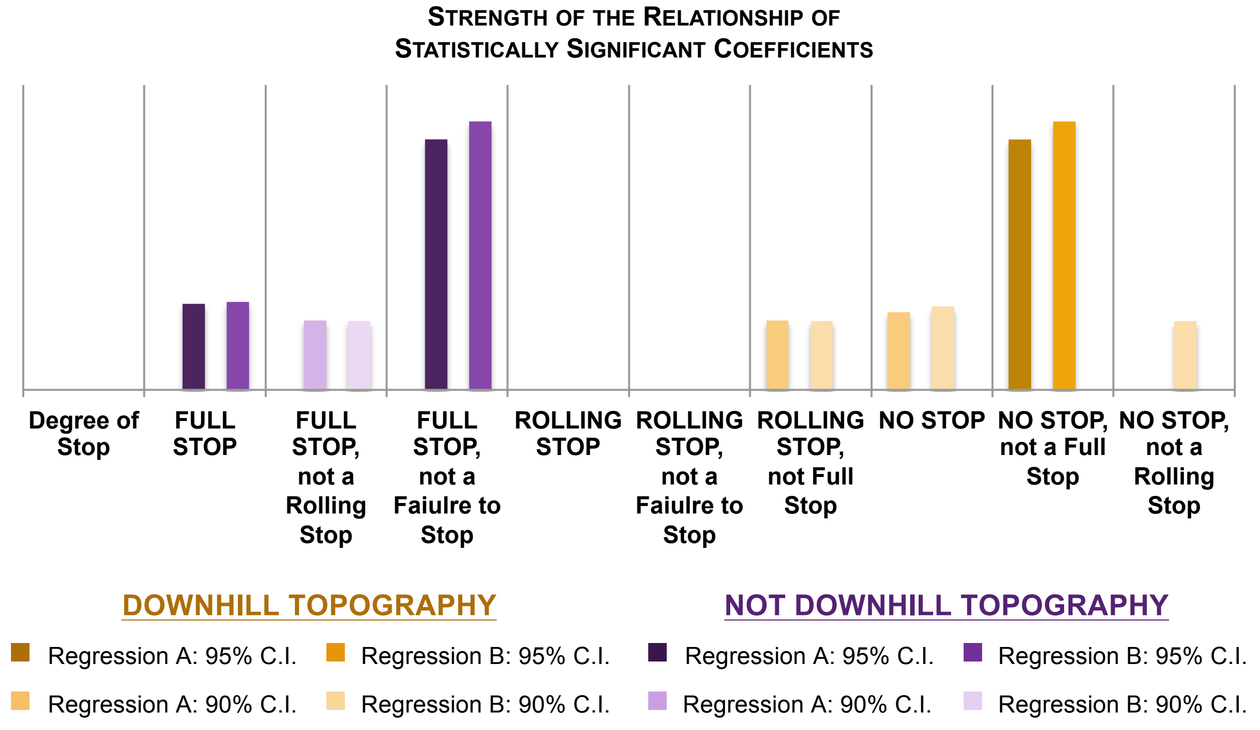
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals



Despite these many significant correlations, neither regression model found significant results for the presence of topography before an intersection. Results, however, do indicate significant results for topography after crossings. Regression Model A found that bicyclists are more likely to fail to stop, rather than using a full stop, when an uphill slope is present after an intersection. The reverse is also true, with full stops being used over not stopping when a bicyclist does not travel uphill after crossing (Fig. 89). Beyond this, however, this analysis did not yield any other statistically significant information on how uphill topography might influence bicyclists' behaviors.

FIG. 89: Regression Model Comparison Results – Downhill Topography, After the Intersection

INFLUENCE OF DOWNHILL TOPOGRAPHY AFTER AN INTERSECTION CROSSING ON BICYCLISTS' STOPPING BEHAVIOR:
Conceptual Comparison of Statistically Significant Coefficients at 95% and 90% Confidence Intervals



Statistically significant results for downhill topography after an intersection are more comprehensive than for uphill (Fig. 89). These results indicate that when bicyclists travel down a hill after crossing an intersection, they will choose not to stop, over using a full stop. At a lower confidence interval of 90%, downhill slopes are associated with full and complete stops. Results at this confidence interval also indicate that bicyclists will choose not to stop over using a rolling stop and use a rolling stop over a full stop, when downhill topography is present after the intersection. Full and complete stops are used when downhill topography is not present after a crossing, and to a much greater extent, bicyclists will choose a full and complete stop over failing to stop at a stop sign.

CHAPTER 11:

RESEARCH CONCLUSIONS

To conclude this research on bicyclists' stopping behavior, the four research questions identified in the Introduction are examined with reference to the observational, theoretical, and methodological research presented in this document.

BICYCLISTS' STOPPING BEHAVIOR

The primary research focus of this thesis is to answer the question:

(1) Do bicyclists in the City of Seattle use rolling stops or track stands at intersections controlled by stop signs and/or flashing beacons?

In Washington State, all bicyclists riding on the public right-of-way are required to adhere to the same set of traffic rules and obey traffic control devices in the same manner as users of other modes of transportation (Washington State Legislature 1975) . Several different variations of Idaho's rolling stop law for bicyclists at stop signs and traffic signals are used across the country. Under Washington State law, all persons are obligated to come to a "complete stop" at a stop sign (Washington State Legislature 2010b). As this question suggests, however, this thesis was developed with the expectation that bicyclists in the City of Seattle use rolling stops more often than coming to a complete stop at stop sign controlled intersections, despite policies in place. This is because rolling stops are considered more efficient for bicyclists, as the practice allows a rider to maintain some speed and conserve energy, rather than needing to start from a full and complete stop (Fajans and Curry 2001, 31).

To answer this question, this thesis presented the exploration of theoretical and methodological frameworks for approaching the documentation of bicyclists' stopping behaviors. Chapters 4 through 7 document the development of an observational pilot study for investigating bicyclists' activities at stop signs, with Chapters 8, 9, and 10 presenting a thorough analysis of these results. Of the 2,616 bicyclists included in the dataset produced through the pilot study, a total of 1,446 bicyclists were observed using rolling stops. This total represents 55.3% of all observations. Full and complete stops were used by 19.9% of riders observed and 24.3% disobeyed the traffic control device entirely.

These results clearly show that, yes, bicyclists in the City of Seattle do use rolling stops at intersections controlled by stop signs and/or flashing beacons.

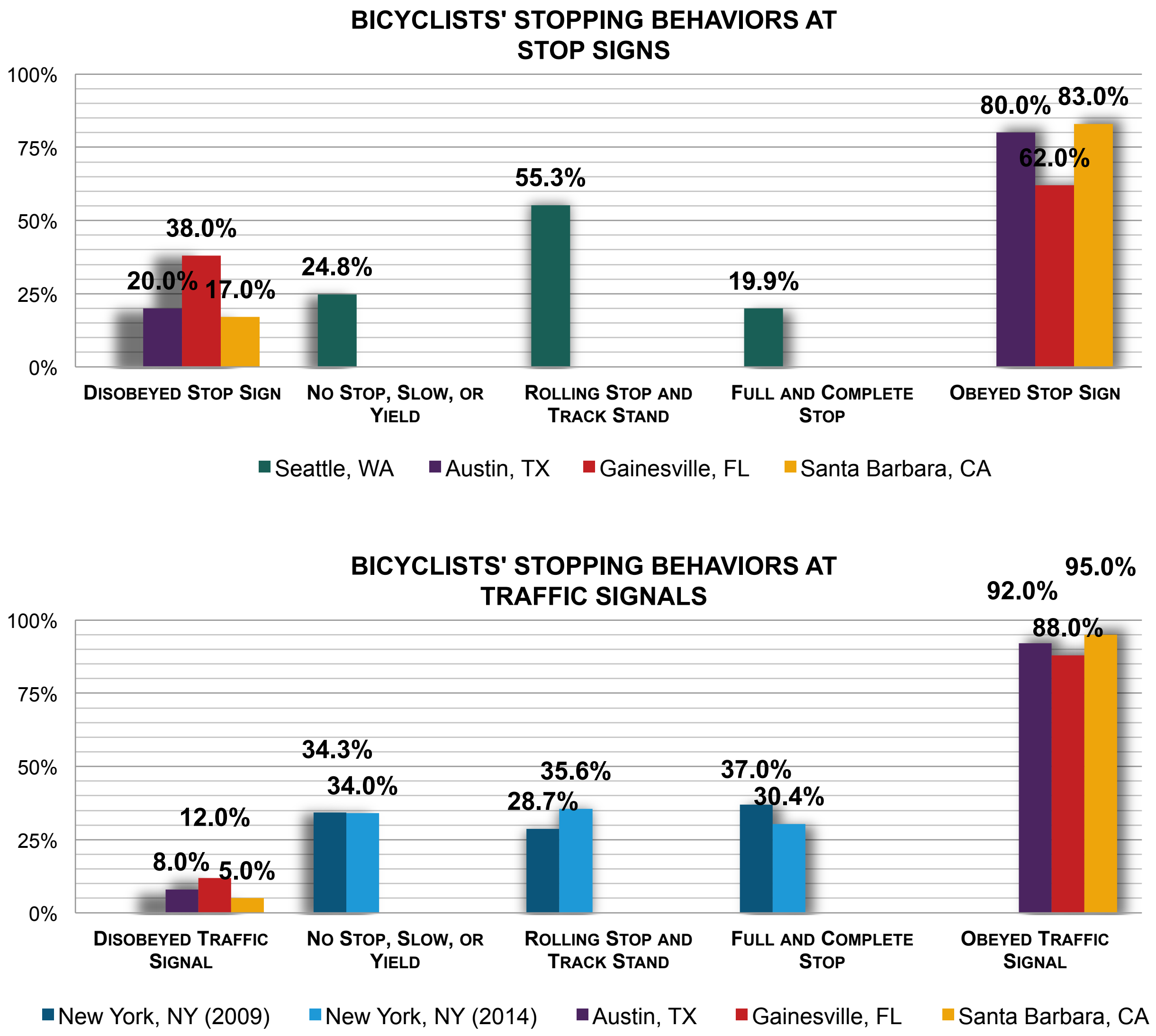
COMPARISON TO NATIONAL AVERAGES

In comparison to the findings from the case examples produced by researchers at the National Highway Research Safety Center and faculty and students at Hunter College, the stopping behaviors observed through this pilot study are similar to patterns seen in other U.S. cities that do not have rolling stop laws. Figure 90 shows the pilot study results along side findings from these other studies investigating behaviors at stop signs and traffic signals.

The tri-state study published in 1999 finds that an average of 25.3% of bicyclists did not stop or yield at a stop sign, which is nearly identical to the 24.8% non-compliance observed throughout the pilot study (Hunter et al. 1999, 30). In New York City, rolling stops were included as a variable and were used by an average of 32.2% of bicyclists, during two unrelated studies conducted by the same researchers, in 2009 and in 2014 (Tuckel and Milczarski 2009, 7; Tuckel and Milczarski 2014, 8). It is not surprising that rolling stops would be used less frequently at traffic signals, as signalized intersections

FIG. 90: Comparison of American Stopping Behavior Research

BICYCLSITS' STOPPING BEHAVIOR PATTERNS AT STOP SIGNS IN U.S. CITIES:
By Percentage within each City



DATA SOURCES:
Seattle (n=2,616) | 2014 Pilot Study (Silva)
New York, NY 2009 (n=) | (Tuckel and Milczarski 2009, 7)
New York, NY 2014 (n=) | (Tuckel and Milczarski 2014, 8)
No Actual Total Reported by National Highway Research Center Study | (Hunter et al. 1999, 30, 68)

inherently experience higher vehicular traffic volumes and therefore require greater caution when crossing. This greater degree of compliance to traffic signals is suggested through the findings that the tri-state average of disobedience to signals is only 8.4%, which is only one-third the total observed running stop signs (Hunter et al. 1999, 30).

SIGNIFICANT STOPPING BEHAVIOR FINDINGS

To the benefit of the practical applications of the pilot study's results, many of the most significant findings are related to the locational variables that are potentially influenced by policy and planning decision-making. With a sincere consideration for the limitations of these findings discussed in Chapter 10 "Pilot Study Regression Results", the results of the four variables with the most significant findings are presented in the sub-sections below.

Stop Sign Controlled Intersections

One of the strongest statistically significant results found was for the variable explaining the configuration of traffic control devices at the intersection. Findings show a statistically significant negative correlation (-.118*) between the uses of rolling stops and track stands at four-way stop sign controlled intersections. The results also show a positive, significant correlation (.109*) between failure to stop and intersections controlled by stop signs in two directions and yield signs in the perpendicular direction. This particular finding could be directly impacted by a shift in policy and local traffic engineering decision-making. Another option that might be considered is allowing rolling stops, which may encourage those formerly non-compliant riders to slow down and respect a new, more liberal law.

This thesis strongly recommends, however, a consideration for other important factors in making such changes to local or state traffic control management. For example, no accidents or near-incidences were observed during the pilot study, which indicates that this significant non-compliance at two-way stops, two-way yields may not be an exceptionally important issue. This significant finding was also only found in Regression Model Set A.

Green Bicycle Lanes Installed Across The Intersection

The results of from both Regression Model Sets A and B found the variable describing the presence of green bicycle lanes to have a positive, statistically significance correlation (.293*) with the failure to stop at a stop sign. Results also show a statistically significant correlation (-.156*) between the action of coming to a full and complete stop and intersections that do not feature green bicycle lanes. At a glance, these results appear to indicate that green bicycle lane cause bicyclists to break Washington's traffic law. However, what this represents is the set of circumstances and conditions at one particular count location.

As is discussed in Chapter 7 "Pilot Study Variables", a total of 37.1% of bicyclists were observed at the count location in the University District. This location is one of two included in the pilot study where green bicycle lanes are installed across the intersection, which was implemented in concert with a bicycle lane. The intersection observed along the Neighborhood Greenway in Ballard also features green bicycle lanes, but only 2.1% of observations were made at this location. This is a strong indication that the results regarding green bicycle lanes represent conditions in the

University District. Findings for this variable, therefore, cannot reasonably be applied to locations that do not share the same set of characteristics as this count location.

On-Street Parking After The Intersection

The results from Regression Model Set A find that where on-street parking is allowed on the curb of the roadway onto which a bicyclist travels after an intersection, a statistically significant relationship was found with a full and complete stop. A slightly stronger negative, statistical correlation (-.120*) was found for the action of not stopping at a stop sign, meaning that more bicyclists fail to stop where on-street parking is not allowed. To a much lesser extent, Regression Model Sets A and B both exhibit a significant correlation (.078*) between on-street parking after the crossing and the use of rolling stops and/or track stands.

These results suggest that allowance curbside parking, after crossing an intersection, actually inspires more obedient stopping behaviors for bicyclists. Bicyclists may be responding to a feeling of decreased security, slowing down as they check to confirm that parked or parking cars are aware of the bicyclist's presence. No similar finding was discovered for on-street parking in place on the approach. This thesis recommends future study of this variable. By design, the pilot study included locations with varying levels of on-street parking available. This notwithstanding, 57.2% of all observations were made at two locations with no or very little on-street parking. The nature of the data collected, therefore, strongly influences the results for this particular variable.

Left Turning Movements

The action of turning left has a positive, statistically significant correlation (.198*) with the act of coming to a full and complete stop in both Regression Model Sets A and B. On the other end of the spectrum, a negative correlation (-.120*) exists for the failure to stop, indicating a significant relationship between not turning left and not stopping at the stop sign. These findings are not surprising, as it is logical that left turning bicyclists will stop more often, as they need to yield to more lanes of traffic than do bicyclists turning right or traveling straight. The potential policy applications of this behavioral finding are limited to the stronger enforcement, targeting bicyclists traveling straight or turning right.

PERCEPTION OF SAFETY

The second research question identified in this thesis explores the safety of decision-making and perception capabilities of bicyclists by asking:

(1) Are bicyclists capable of accurately perceiving whether or not conditions afford the safe use of rolling stops or track stands, rather than coming to a full stop and bringing at least one foot to the ground?

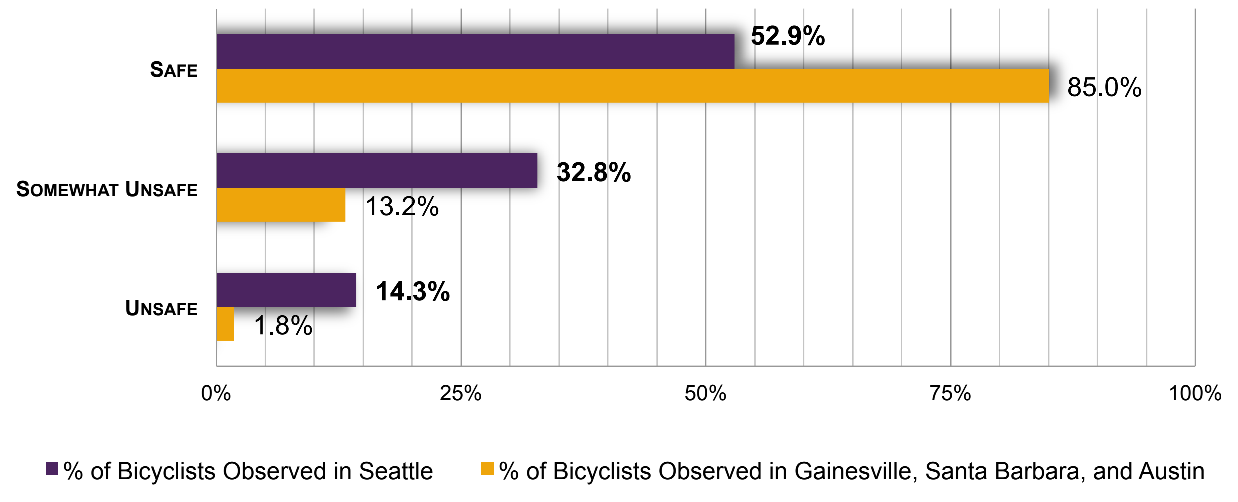
This is first approached through the application of three theoretical models relevant to a discussion of behavioral mobility. The theory of affordances suggests that a bicyclist's mobile practices are a reflection of what they perceive their environment safely affords, based on the individual's skills and knowledge of the physical setting (Gibson 1979, 225). Stern and Portugali synthesize the theories purported by several models to describe mobile decision-making, including the consideration of spatial knowledge and the decision field theory. This work highlights that the risk avoidance deliberation process becomes more refined as an individual becomes more familiar with a given route or geographic area (Stern and Portugali 1999, 102, 436). The theory of geosemiotics applies this discussion of mobile perception to human interactions with signs in the public realm. Addressing stop sign behavior explicitly, Scollon and Scollon's theory argues that signs have meaning based on where they are in the physical world and their relationships with other semiotic devices. This meaning is further embedded in the processes contributing to whether or not, or how, a person traveling down a roadway responds to a sign—i.e., do they choose to see and take the sign's advice or do they continue on, backgrounding the meaning and existence of the sign? (Scollon and Scollon 2003, 205). Based on this appreciation for individual perception and preference, geosemiotics explicitly accepts the notion that users of different modes will respond to semiotic devices differently (Scollon and Scollon 2003, 183).

Collectively, the theoretical sources referred to in this research suggest that all mobile individuals are capable of perceiving and practice safe mobile behaviors. In order to approach an examination of the truth of this assertion, with regards to bicyclists' stopping behavior, one subjective variable describing the safety of bicyclists' maneuvers is included in the pilot study. The inclusion of this variable was inspired by this national study, and is considered for all types of stops to supplement and inform the larger policy discussion of this thesis. As in the examination of stopping behaviors observed in the two studies, the safety of maneuvers observed in 1999 and 2014 share somewhat similar patterns. Unlike this pilot study, the USDOT study only reports the safety of stopping maneuvers for bicyclists who disobey the stop sign.

A comparison of perceived safety levels among those bicyclists who do not stop at stop signs shows that the largest proportion of riders observed during both studies safely maneuver while passing the sign. This proportion is highest among the average of riders observed through the national study, of which 85% use safe maneuvers, only 52.9% of law-breaking bicyclists in the City of Seattle using safe maneuvers (Hunter et al. 1995, 30). In the City of Seattle, only 52.6% of bicyclists failing to stop at the stop sign were documented as using safe maneuvers and another 32.8% were behaving somewhat unsafely (Fig. 91). Descriptively and with a consideration for the limited validity of this qualitative variable, these results support the theoretical assertion that bicyclists are capable of making safe decisions regarding rolling stop. An important

FIG. 91: Comparison of the Safety of Bicyclists Not Stopping at Stop Signs

STOPPING BEHAVIOR OF BICYCLISTS AT STOP SIGNS:
By Percentage of Stopping Behaviors Observed in Two Unrelated Studies



Bicyclist' Maneuver at Intersection	Safe	Somewhat Unsafe	Unsafe
Bicyclists Disobeying Stop Sign in Seattle			
Total Count	344	213	93
% of Bicyclists Observed	**52.9%**	**32.8%**	**14.3%**
Bicyclists Disobeying Stop Sign in Gainesville, Santa Barbara, and Austin			
Total Count	187	29	4
% of Bicyclists Observed	**85.0%**	**13.2%**	**1.8%**

follow-up question to this finding, however, is whether or not this perceptive ability justifies behavior that is reasonably considered a disobedience of Washington State's traffic laws. This point is addressed in further detail in the discussion surrounding the final research question examined through this research.

DOCUMENTATION METHODOLOGY

The most pragmatic research question addressed in this research seeks to determine best practices and methodological approaches for developing the pilot study. This question simply asks:

> **(2)** What methods should be used to document bicyclists' stopping behaviors?

A total of four primary case examples were referenced in the process of developing a data collection approach, with each described in detail in Chapter 3 "Methodological Case Examples". Two are directly related, one being the National Bicycle and Pedestrian Documentation Project model developed by Alta Planning and Design and the Institute of Transportation Engineers (ITE) Pedestrian and Bicycle Council and the other is the statewide counts preformed by the Washington State Department of Transportation. The methods used in Washington State are largely based on NBPDP methods, with the primary difference being the count periods observed.

Observational studies following the NBPDP methods typically yield data on the total number of bicyclists of the mail and female gender, as well as frequency of helmet use by gender. Such data might be used in arguments regarding the efficacy of a particular advocacy campaign or policy option targeted at expanding or reducing services for bicyclists, for example. The national data collection methodology does not, however, produce a data set suitable for a robust analysis of bicyclists' behaviors on streets, sidewalks, or trails. Beyond the provision of foundational data for understanding bicycle traffic volumes and the prevalence of bicycle use, this methodology affords no further exploration into the practices of bicyclists.

In order to fill this methodological research gap, two academia-based studies were reviewed in concert with these practical studies. The first is a pair of studies produced by faculty and students at Hunter College in New York City and the second is tri-state study of bicyclists' behaviors conducted by the National Highway Research Center housed at the University of North Carolina at Chapel Hill. Of the numerous behavioral studies identified in the course of this research, these two studies were selected as they both included an investigation of bicyclists' stopping behavior. As little research has been done in this area, it was critical to consider the existing body of work and in order to learn from and expand on past research.

Methodologies used in observational studies of bicyclists' behavior often share qualities with the NBPDP, but there is no collaborative effort to systematically build a consistent, observation-based dataset describing the behavioral practices of bicyclists in America. Leaning on the methods developed for the NBPDP and observational studies of bicyclists, the pilot study developed through this thesis is intended as a model for collecting such data. To that end, this thesis exhibits a method for approaching observational research yielding quantitative information on the behavior, conduct, and lawfulness of bicyclists.

The three key elements of the methodology developed for the pilot study include:

(1) Behavioral and Subject-Specific Variables describing the bicyclists observed, including their personal characteristics and behavioral practices;

(2) Circumstantial Variables describing the atmospheric conditions occurring at the time of data collection; and

(3) Locational Variables describing the physical setting, specifying the qualities specific relevant to bicyclists or that might indirectly impact bicyclists' principles.

These three variable typologies are based on the variables included in the four methodological case examples. By breaking down the variables into these categories, identifying the general implications of any variable in a study or model is simplified. Variables included in the first category are either unchangeable or are potentially regulated by law, depending on whether they are subject-specific or behavioral in nature. Circumstantial variables represent a group of unpredictable, uncontrollable conditions that cannot be regulated but the effects might be mitigated by facilities design. Lastly, and perhaps most importantly, the locational variables primarily represent conditions that can be impacted by planning and regulation decisions. This framework was used in this pilot study to home in on the most salient variables under each category in order to develop a well-rounded investigation of the many factors influencing stopping decisions.

For a complete list of the variables included in this study and recommendations for data collection practices, see Chapter 6 "Pilot Study Data Collection Methods" and Chapter 7 "Pilot Study Variables".

PRACTICAL APPLICATION OF RESEARCH STUDY

The final research question explored through this master thesis is intended to identify the practical applications of the findings of the pilot study investigating bicyclists' stopping behaviors, asking:

(4) Should the Washington State Legislature consider adjusting bicycle traffic laws, transportation design guidelines, or other policies based on the findings of this study?

The findings of this pilot study and thesis research are preliminary and not examined to their fullest capacity. At present, this thesis therefore does not recommend the application of the data reported in this document for decision-making purposes. This is, in part, due to the inadequacy of existing data on bicyclists' behaviors and traffic data for performing a cross-state comparison of bicycle safety under the conditions of the varied stopping laws used across the United States. Without the possibility of a reliable and comparable assessment of bicycle safety in other states, this thesis research is unable to determine whether a rolling stop law has a positive or a negative impact on safe transportation environment. A more focused evaluation of the most recent data reported in Washington State does, however, provide bicycle traffic safety information relevant to the concluding discussion to follow.

Addressed in the context of the primary research question of this thesis, the findings of this pilot study show that over half of the bicyclists observed in the City of Seattle use a rolling stop or track stand before crossing an intersection controlled by a stop sign and/or flashing beacon. On the surface, an immediate reaction to this finding may be to assert that most bicyclists in the city are scofflaws who disregard the law and that greater policy enforcement or higher citation fees should be implemented. Such assertions, however, would be premature and made without consideration for the various factors contributing to this behavioral practice. From a policy perspective, the most critical issue related to the topic of stopping behavior is the slight ambiguity in laws regulating such behavior.

At issue is the fact that the Washington State Legislature does not actually define what a "complete stop" is for different modes of transportation. For the purposes of this research, this made difficult the decision for where to draw the line between a rolling stop and the legally allowed complete stop. Moreover, there is no guidance for identifying whether a track stand represents a rolling stop or complete stop. Without any legal foundation to support the categorization of stopping behaviors, this thesis coded track stands as rolling stops and defined a full and complete stop as the action of a bicyclist removing at least one foot from its pedal and touching it to the ground. This thesis, however, could just as easily have categorized track stands as full stops, under the premise that both wheels come to a full stop, despite the fact that the bicyclists' feet remain balanced on the pedals.

With state law not providing a more vivid description of the legal definition of a "complete stop", a grey area exists for defining stopping types. This not only applies to the coding developed for this pilot study, but also has implications for the behaviors practiced by bicyclists on the state's public rights-of-way. With the inability of this focused research study to establish an infallible definition for a complete stop, the assumption is made that similar confusion exists among the many bicyclists riding in Washington State. Nevertheless, this potential for confusion does not appear to manifest itself in unsafe transportation situations at stop sign controlled intersections. In Chapter 1 "Background Research", the most recent statewide bicycle traffic data revealed that a disregard of stop signs only 3% of all reported bicycle accidents in 2013 (WSDOT 2013, 15). While further research is needed to assess the true safety of bicyclists' stopping behaviors at stop signs, this statewide accident report and pilot study results do not indicate that current practices employed by bicyclists at stop signs as a priority safety concern.

The state's law currently appears to operate with a certain degree of flexibility for both practice and enforcement. Given that two-thirds of bicyclists observed in this pilot study did not come to a full and complete stop, this research suggests that most bicyclists respond to stop signs depending on the circumstances at the time of their crossing. These observed behaviors align well with the theoretical concepts suggested by the field of geosemiotics and decision field, assuming that these stopping behaviors are the result of human perception and risk avoidance decision making. Considering this high incidence of non-compliance with the strictest definition of a "complete stop" and no evidence found to suggest a concerted effort to cite bicyclists failing to stop, this research further suggests that this strictest definition is not enforced. Therefore, similar to the practices engaged in by bicyclists, a suggestion can be made that police officers likewise use their personal judgment to assess the need to issue a citation to bicyclists engaging in varying types of stopping behaviors. From this perspective, despite that Washington Sate may not allow rolling stops and track stands by the letter of the law, the use of these alternative types of stopping behaviors is not expressly disallowed. Unless or until the Washington State Legislature is concerned that these stopping behaviors are commonplace for bicyclists at stop sign controlled intersections, the best policy recommendation of this research may simply be to maintain the status quo. Rather than developing a more thorough definition of “complete stop” or considering the legal adoption of rolling stops for bicyclists, an equally credible option is not to disrupt the system in place with a continued allowance for perception to play a part in the movements within a mobile environment.

APPENDICES

PILOT STUDY DATA COLLECTION MATERIALS

The first portion of this appendix exhibits the flyer used to advertise the need for data collection volunteers. This flyer was sent out to the email listserves for students enrolled in the Master of Urban Planning Program and students seeking a Master in Public Administration, in addition to social media groups also linked to these communities.

Following this flyer, example data collection materials are presented. This is includes the list of instructions provided to data collection volunteers and the actual data collection sheet used during observation periods.

APPENDIX A: Volunteer Outreach Flyer

BICYCLE DATA COLLECTION VOLUNTEERS ARE NEEDED...

NEXT WEEK!!

Volunteers are needed to assist a graduate student at the UW collect data describing bicyclists' behaviors in order to answer this question:

DO BICYCLISTS STOP AT STOP SIGNS?

COUNT PERIODS

November 18th, 19th, and 20th

7-9 am and **4-6 pm**

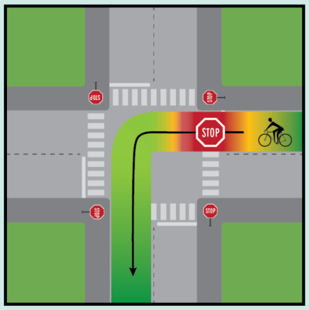
COUNT LOCATIONS

- U-District
- Greenlake
- Ballard
- Sand Point
- Capitol Hill
- Queen Anne

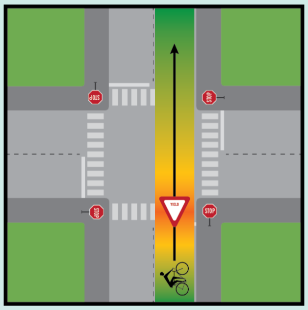
Please **sign up to volunteer** or learn more by emailing: catsilva@uw.edu

OR...you can register to volunteer through **Cascade Bicycle Club** here: http://www.cascade.org/volunteerportal

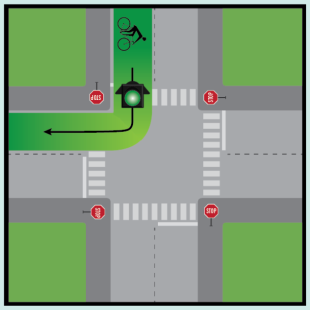
HOW DO BICYCLISTS BEHAVE AT STOP SIGNS?



COMPLETE STOP



ROLLING STOP



NO STOP

The data collected will be used to inform a masters thesis investigating bicycle policy and traffic control devices by Cat Silva, a graduate studying urban planning and public administration at the University of Washington.

(I need your help! Thank you to all who volunteer!)

APPENDIX B: Example Data Collection Sheet

A Study of Bicyclists' Behaviors at Stop Sign by Catherine Silva

Data Collectors' Name: ____________ **Date:** ___________ **Time Period:** _____________

Count Location: ____

Weather Conditions: ____

Instructions for Observations:

- Be inconspicuous and do not interact with observed bicyclists;
- Do not record information on bicyclists who appear under the age of 14 years old (best judgment);
- Record each bicyclists' behaviors in an individual row on the chart below;
- Count the number of bicyclists, not the number of bicycles. Multiple riders on one bicycle are recorded in different rows;
- Count bicyclists using the roadway, any type of bicycle facility or infrastructure, and/or the sidewalk; and
- Record counts in 15-minute increments of time.

Instructions on Using Count Sheet

- Mark an "**X**" in the "**Time**" column to indicate that an observation is the first made during a new 15-minute time period (this column should only be marked once at the start of a new 15-minute period);
- Mark an "**X**" over "M" or "F" in the "**Gender**" column to indicate the observed bicyclists' gender (using best judgment for assigning gender as male or female).
- Mark an "**X**" over "Y" or "N" in the "**Helmet Use**" column to indicate whether an observed bicyclist is or is not wearing a bicycle helmet.
- Mark an "**X**" over "N", "S", "E", or "W" in the "**Direction of Travel**" column to indicate in which direction the observed bicyclist is heading as they approach the intersection, before making any turning movements.
- Mark an "**X**" over "FS", "RS", or "NS" in the "**Stopping Behavior**" column to indicate if the observed bicyclist came to a full and complete stop, used a rolling stop or track stand, or did not stop or yield in any way at the intersection.
- Mark an "**X**" over "L", "S", or "R" in the "**Turning Movement**" column to indicate if the observed bicyclist turned left or right, or went straight through the intersection;
- Mark an "**X**" over "S", "SUS", or "US" in the "**Safety of Maneuver**" column to indicate whether the observed bicyclists' action at the intersection was generally safe, somewhat unsafe, or decidedly unsafe for themselves or other road users; and
- Use the column labeled "**Conditions**" to make notes on-going notes on environmental changes occurring during each count (i.e., note when the daylight comes or goes, when rain starts and stops, etc).

For detailed guidelines and instruction for collecting this data and using the chart on the following pages, please refer to the *Bicycle Observation Guidelines.*

Time	Gender	Helmet Use	Direction of Travel	Stopping Behavior	Turning Movement	Safety of Maneuver	Conditions (weather, light)
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
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15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	
15	M F	Y N	N S E W	FS RS NS	L S R	S SUS US	

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