Examining the Cycle: How Perceived and Actual Bicycling Risk Influence Cycling Frequency, Roadway Design Preferences, and Support for Cycling Among Bay Area Residents

By

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Abstract

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This dissertation investigates the connection between perceived and actual bicycling risk, and how they both affect and are affected by one's attitudes, knowledge, behavior, and experiences. Understanding bicycling risk has gained importance as efforts by the U.S. Department of Transportation, the Environmental Protection Agency, the Centers for Disease Control & Prevention, and others have urged communities to increase cycling for its health, environmental, and social equity benefits. Research has identified numerous barriers to increased bicycling in the U.S., including topography, weather, and trip distance, but the barrier that appears most consistently between studies is the perceived hazard associated with cycling near motorists. Yet, little research has fully explored the concept of risk to understand its component parts, including how 1) various driver actions affect perceived and actual cycling risk, 2) reported crash statistics reflect perceived and actual risk, 3) roadway design preferences are affected by perceived risk, and 4) attitudes toward cycling and cycling risk—especially among drivers—influence support for bicycling in one's community. A deeper understanding of perceived and actual risk is critical for knowing how to address it, and, ultimately, to encourage more people to bicycle. To begin to answer these questions and demystify bicycling risk, this dissertation employs three main methods: focus groups, an online survey (n=463), and an analysis of reported crash data from the San Francisco Bay Area, one of the regions at the forefront of cycling efforts in the U.S.

My findings confirm that perceived and actual cycling risk influence the decision to bicycle, but indicate that the causal pathways are more nuanced than previously understood. First, my data suggest that cyclists experience two types of roadway risk: *pervasive risk* in the form of near misses that occur frequently, and *acute risk* that occurs when a cyclist is struck—a less frequent, but more injurious incident. Both types—but particularly near misses—significantly affect perceived risk for cyclists and their family and friends, yet we lack systematic data on near misses and are therefore almost completely ignorant about the extent and effect of their occurrence. Routinely-collected reported crash data provide only limited insight into the type and extent of risk cyclists experience.

Second, roadway design preferences are significantly related to perceived risk, and particularly important for attracting new cyclists. Surprisingly, drivers and cyclists both prefer roadway designs with separated space for bicyclists, particularly if barrier-separated, regardless of cycling frequency. Shared space designs are less popular among drivers and much less

popular among cyclists, particularly for people who might consider cycling but do not currently do so: only a tiny fraction of potential cyclists feel comfortable sharing space with drivers on commercial streets.

Third, perceived cycling risk extends beyond fear of danger for oneself, and is significantly related to support for cycling in one's community. Structural equation models of perceived cycling risk, attitudes, and behavior revealed that respondents are affected by their perceived risk as cyclists, but also as drivers sharing the roadway with cyclists they view as "scofflaws", and the risks they project onto other cyclists—particularly those cycling with children. This multi-pronged belief in cycling risk significantly negatively affects bicycling support, including support for new bicycle facilities and public funding to encourage cycling.

Based on these findings, I propose a revised theoretical framework for conceptualizing cycling risk and its influences. I conclude the dissertation with policy recommendations for addressing perceived risk.

This dissertation is dedicated with love to my parents, Cindi and Roger Sanders,
and my daughter, Vivian Sanders Carlton.

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Preface

I chose to investigate bicycling risk as my dissertation topic because it is a topic near and dear to my heart. I began bicycling in Texas, where the streets are wide and drivers generally had no idea how to drive around me—and I was unsure how to bicycle around them. It was scary, and I often wondered why something as good and healthy as bicycling seemed an option only to those willing to risk their comfort and safety, or worse, to those who had no other choice.

When I moved to California, I bicycled more, and learned how to properly bicycle in mixed traffic. I felt grateful for the bicycle lanes and boulevards that communicated to me that I belonged on the roadway, and I decided to further explore bicycling and traffic safety through graduate work in City Planning at Berkeley. While working toward my Master's degree, I found that perceptions of bicycling and bicycling risk were not well-studied, and I decided to pursue a PhD to contribute to closing that knowledge gap..

As I explain in the dissertation, there are many reasons people choose to bike or not, but the one that seems the most consistent—both in my personal experience and in the literature—is fear of being hurt, particularly in a crash with a car. In the process of conducting this research, I often felt like a participant observer. I have been buzzed more times than I can count, even, alarmingly, while bicycling with my daughter in a bright orange child's seat on the back of my bicycle. Through my research, I have also talked to many non-bicycling drivers and gained a deeper understanding of the fear and uncertainty they experience on the roadway with cyclists. My findings have convinced me that there is much that can be done to increase predictability and safety for all roadway users, and I hope that it will be done—for as much as we need cars to perform certain tasks that make our lives richer, we need people to have options other than driving. Bicycling is not a panacea, nor is it for everyone, but it is a viable option for a lot of people to make a lot of trips—if they feel safe and comfortable doing so. It is my hope that this research furthers the possibility of safe and comfortable bicycling.

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There are also those who have patiently supported me outside of the academic sphere. To my father and sister, thank you for a lifetime of love and encouragement. I feel grateful and lucky to count you as mine, and to have had your support. Susan and Mike, my in-laws, I owe you my deepest gratitude for your help and love, especially this last year. And to our community of friends, thank you for love and support. I love you all.

Finally, I am indebted to my nuclear family. Vivian, mi princesa: you bless me abundantly. Though having you made this infinitely harder and more complicated, you were and are worth every strain. The work in this dissertation is dedicated to you—may you always feel safe and welcome bicycling and walking, and may yours be a healthier future because of my efforts. And to my partner, Ian Carlton—you are a gem. I am humbled and grateful for the countless hours of discussion and review, and for your love, exhortation, and patience in stressful times. I am a lucky woman indeed. I love you both more than words can say.

Chapter 1 – Introduction

This dissertation investigates the perceived and actual risk of bicycling, and how it is affected by attitudes, knowledge, behavior, and experiences. Understanding bicycling risk has gained importance as—in the face of national efforts by the US DOT, EPA, CDC, and others to increase cycling (American Academy of Pediatrics, 2009; CDC, 2009; EPA, 2009; Lynott et al., 2009)—studies have repeatedly shown the influence of perceived risk on the decision to bicycle (Dill and Voros, 2007; Emond et al., 2009; Sener et al., 2009). These agencies have all endorsed bicycling for transportation as a way to improve health, reduce emissions and energy usage, and inexpensively provide mobility—yet still the percentage of cyclists remains very low in all but a handful of cities. As of 2009, utilitarian bicycle trips (i.e., not recreational) in the U.S. had increased to 1% (up from 0.70%), and bicycle commute trips to 0.49% (up from 0.40%) since 1994 (Flusche, 2010).

Studies examining barriers to bicycling have found many, including topography, weather, and trip distance—though these vary by city in terms of importance (Cervero and Duncan, 2003; Dill and Carr, 2003; Dill and Voros, 2007; Sener et al., 2009). The one consistent barrier found in these studies is perceived risk, yet little research has fully explored the concept of risk to understand its component parts. For example, no research has explored how various driver and cyclist behaviors affect perceptions of risk for their counterparts on the roadway, and little research has examined how perceived risks reflect statistical risk. In addition, we do not know how attitudes toward cycling affect perceived risks or support for bicycling improvements in one's community—all potentially critical pieces of information to understand and begin to address the barrier of perceived risk.

This dissertation aims to address these and related questions, in the hopes of demystifying bicycling risk and contributing to effective planning and policymaking.

Defining Risk

This dissertation focuses on perceived and actual bicycling (traffic) risk. I define these two types of risk based on the definitions from the Dutch SWOV[1] Institute for Road Safety, but have modified the terminology to better reflect the nature of the concepts. SWOV defines traffic risk as the number of fatalities or serious road injuries divided by the distance traveled, for example, 1 fatality per 100 miles (SWOV Institute for Road Safety Research, 2012a). Because traffic risk applies to both perceived and actual or statistical risk, I use the term "actual risk" when discussing reported traffic risk in this dissertation. SWOV differentiates between actual (traffic) risk and subjective safety, the latter of which is defined as "personal feelings of being unsafe in traffic" or "anxiety regarding hazardous traffic situations for (a person) and/or others" (SWOV Institute for Road Safety Research, 2012b). As subjective safety describes how unsafe people feel, it is somewhat of a misnomer. For this reason, I use the term "perceived risk" in this dissertation to describe the concept of feeling unsafe and worrying about safety or danger while bicycling or considering bicycling. The term "perceived risk" also better conveys the effects of outside influences on a person's thoughts or feelings about cycling risk.

[1] SWOV stands for Stichting Wetenschappeliijk Onderzoek Verkeersveiligheid, which is translated from Dutch to English as Institute for Road Safety Research.

The Cycle of Bicycling Risk

Studies have repeatedly found that the perceived risk of bicycling is a significant barrier to utilitarian and recreational bicycling (Dill and Voros, 2007; Winters et al., 2010; Xing et al., 2008). There is, furthermore, an inverse relationship between the rate of bicycle collisions and the number of cyclists per city—that is, the more people bicycle, the fewer collisions there are per person, an effect known as "safety in numbers" (Jacobsen, 2003). Other reports have found a clear positive correlation between the total length of on-street bicycle facilities (in particular, bicycle lanes or boulevards) and the number of people bicycling in annual counts (New York City Department of Transportation, 2013; Portland Bureau of Transportation, 2013) and in Census data (Dill and Carr, 2003). Taken together, the increase in ridership and decrease in collisions per person indicates an inverse relationship between the miles of bicycle infrastructure and the crash rate at the city level, and recent research on bicycle lanes has corroborated a lower crash risk—particularly when the lanes are physically separated (Lusk et al., 2011; Teschke et al., 2012). Not surprisingly, participants in stated preference studies routinely request separation from drivers to feel safer while bicycling (Parkin et al., 2007; Tilahun et al., 2007; Winters and Teschke, 2010). These feedback loops are illustrated by the Cycle of Bicycling Risk[2], as pictured in Figure 1.

Figure 1. Established Cycle of Bicycling Risk

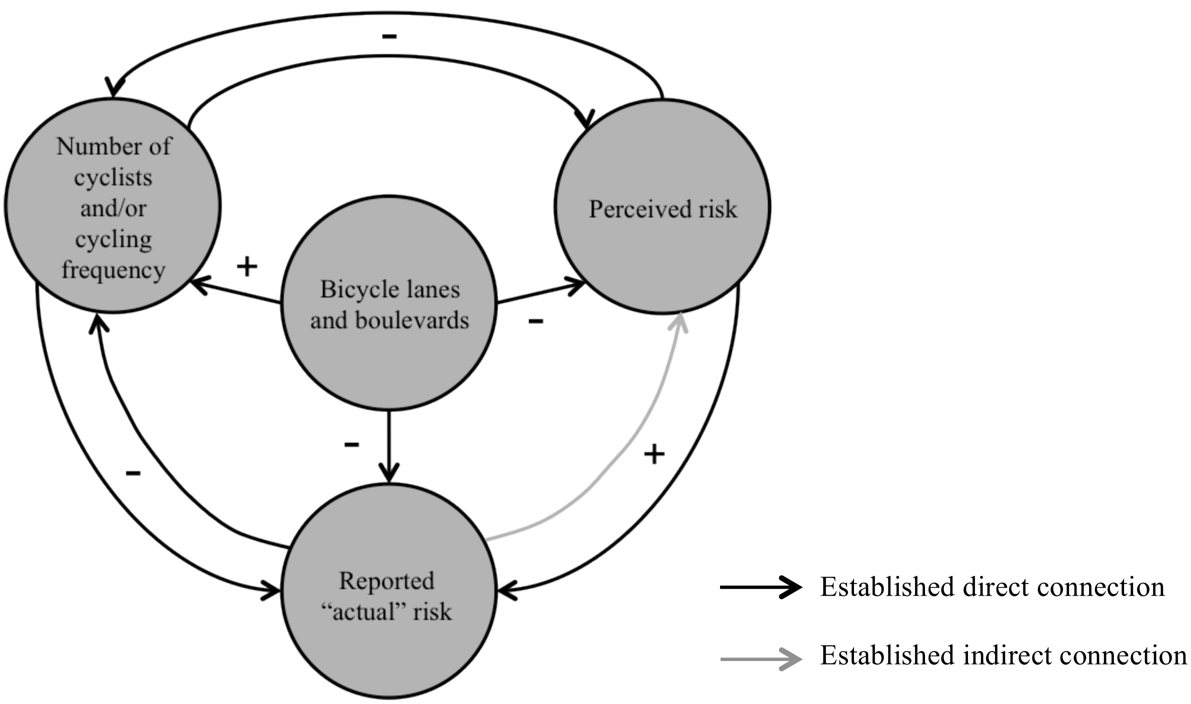


Figure 1 includes several categories that together construct the Cycle of Bicycling Risk. The category at the top of the figure, Roadway Characteristics, theoretically includes roadway slope,

[2] Cycling risk is also affected by vehicle volumes and speed, built environment characteristics such as land use patterns, slope, and street width, and other factors. For the sake of keeping these figures relatively digestible, they are limited to the concepts studied in this dissertation, including, in this case, reported crash risk and bicycle-specific infrastructure (but not a detailed analysis of the roadway and driver characteristics for each crash).

number and width of travel lanes, presence of on-street parking, lighting, presence, width, quality, and placement of bicycle infrastructure, etc. However, with the exception of research on bicycle faculties—which overwhelmingly suggests that people want to bicycle on and seek out roadways with such facilities—there is very little research on how all of those roadway characteristics together affect bicycling willingness, frequency, and safety. Thus, this theoretical model focuses on the role of on-street bicycle facilities such as bicycle lanes and boulevards.

The middle-left category combines the concepts of cycling frequency and cycling mode share. These are self-contained concepts, but quite related, so for the purpose of this diagram, they are combined in the same circle. As described above, research has established the connection between miles of bicycle infrastructure and the number of cyclists in a city. Little research has examined the correlation between the network density of bicycle facilities and cycling frequency, but my data show a significant correlation between the percentage of people who report living within a few blocks of a bicycle lane and how often they report bicycling.

The remaining two categories in Figure 1 deal with reported, or "actual" cycling risk and perceived risk. Actual risk theoretically includes factors such as cyclist and motor vehicle volume and motor vehicle speed, but little thorough research on actual risk exists, as crash statistics are known to be biased downward, and, as will be explained in Chapter Nine, are often missing key information for understanding crash trends.

The category perceived risk exemplifies the findings that people are scared to bicycle, which affects who bicycles and how often, and the crash risk on the roadway. The missing link from the picture of perceived risk is an understanding of what, exactly, makes bicycling seem so dangerous. Without knowing the degree to which various aspects of bicycling are seen as dangerous—for example, does the risk of being struck by someone opening a car door worry cyclists as much as the risk of being hit while crossing an intersection?—practitioners and policymakers will be limited in their ability to address the perceived risk. In addition, we lack a thorough understanding of perceived risk from the driver's point of view, and know little about how drivers' beliefs are correlated with actions that may increase harm for bicyclists on the roadway. We also do not know which aspects of cycling are deemed the most worrisome, and therefore do not know the extent to which official crash statistics capture perceived bicycling risk. Finally, in the wake of recent anti-bicycle lane demonstrations in several U.S. cities (Goodman, 2010; Gootman, 2011; Stehlin, 2013), it is clear that we lack an understanding of how perceived risk and other factors affect bicycling support within communities.

This dissertation uses focus groups, an online survey (n=463), and an analysis of reported crash data to examine the topic of bicycling risk in order to better understand its component parts. In particular, the results presented here address:

1. How driver and bicyclist attitudes, behaviors, and experiences affect and are affected by perceived bicycling risk;
2. How perceived risk is—or is not—reflected in official bicycle crash statistics; and
3. How perceived risk affects support for bicycling among survey respondents.

Dissertation Outline

This chapter provides an overview of the entire dissertation. I describe my attempts to answer these research questions and my findings through the remaining chapters, as follows:

- Chapter 2 provides a brief history of bicycling in the U.S. and an overview of the literature on bicycling risk and ridership, including gaps where more research is needed.
- Chapter 3 describes the background and research approach, and elaborates on the limitations of the data.
- Chapter 4 describes the findings from the focus groups and how they influenced the survey design
- Chapter 5 examines the survey population and explores summary statistics to paint a picture of the attitudes, behavior, experiences and personal characteristics of the sample.
- Chapter 6 describes findings about the roadway design preferences of drivers and cyclists for shared roadways.
- Chapter 7 explores perceptions of bicycling risk in various scenarios and how various factors affect those perceived risks
- Chapter 8 examines how perceived bicycling risk and other variables influence support for bicycling in one's city.
- Chapter 9 examines reported crash data to understand how reported risk compares to perceived and real-but-unreported risk.
- Chapter 10 concludes the dissertation with a discussion of the findings and their implications for policy, as well as next steps for research.

Overview of Findings

My cumulative findings corroborate and strengthen the results of previous bicycling research, and suggest that bicycling risk significantly influences attitudes and behavior among the survey respondents in the following ways:

Perceived Risk is a Serious Barrier to Bicycling

I found that perceptions of traffic risk affect the decision to bicycle as much as commonly cited barriers such as hilly topography and a lack of secure bicycle parking. While fundamental barriers like trip distance and the belief that cycling is impractical influenced more occasional and potential cyclists, there is evidence that these barriers are also affected by perceived traffic risk, underscoring the importance of addressing perceived risk to encourage more people to bicycle and to do so more often.

We Do Not Know or Comprehensively Measure the Full Extent of Bicycling Risk

The self-reported collisions and near misses[3] in Chapter Nine suggest that bicyclists in my survey population experienced near misses to a much greater extent than actual crashes. The near misses are problematic, as they represent risks for bicyclists that are often not reflected in official crash statistics—and may therefore not be considered serious from a policy perspective, but clearly influence perceptions of traffic risk, which in turn influence how often people bicycle. The data show that the near miss and collision experiences of friends and family also influence a person's perceptions of risk.

[3] I have defined a "near miss" as an incident in which the person almost hit, but escaped unscathed.

Crash Statistics Paint an Incomplete Picture of Risk
Reported crash data only partially reflects the risk that cyclists experience. While actual crashes are better represented than near misses, neither is well reflected. Similarly, perceived risks are not systematically reflected in either the severity or frequency of reported crashes.

Drivers and Bicyclists Prefer the Same Roadway Designs
My survey found clear and strong agreement among drivers and cyclists for roadway designs that provide physical separation between cyclists and drivers on multi-lane roadways. These preferences were consistent across bicycling experience levels and type of cycling (i.e., recreational versus utilitarian). Both drivers and cyclists preferred roadway designs with the following features, in descending order:

1. Physical (barrier) separation of space
2. No on-street car parking
3. Fully painted, separated space (even if not physically separated).
4. Striped, delineated space

Without some type of separated (i.e., not shared) space, few current bicyclists felt even slightly comfortable bicycling, and almost no infrequent or non-cyclists felt comfortable. A small majority of drivers still felt at least moderately comfortable in shared space, but many fewer than those who felt comfortable with separated space.

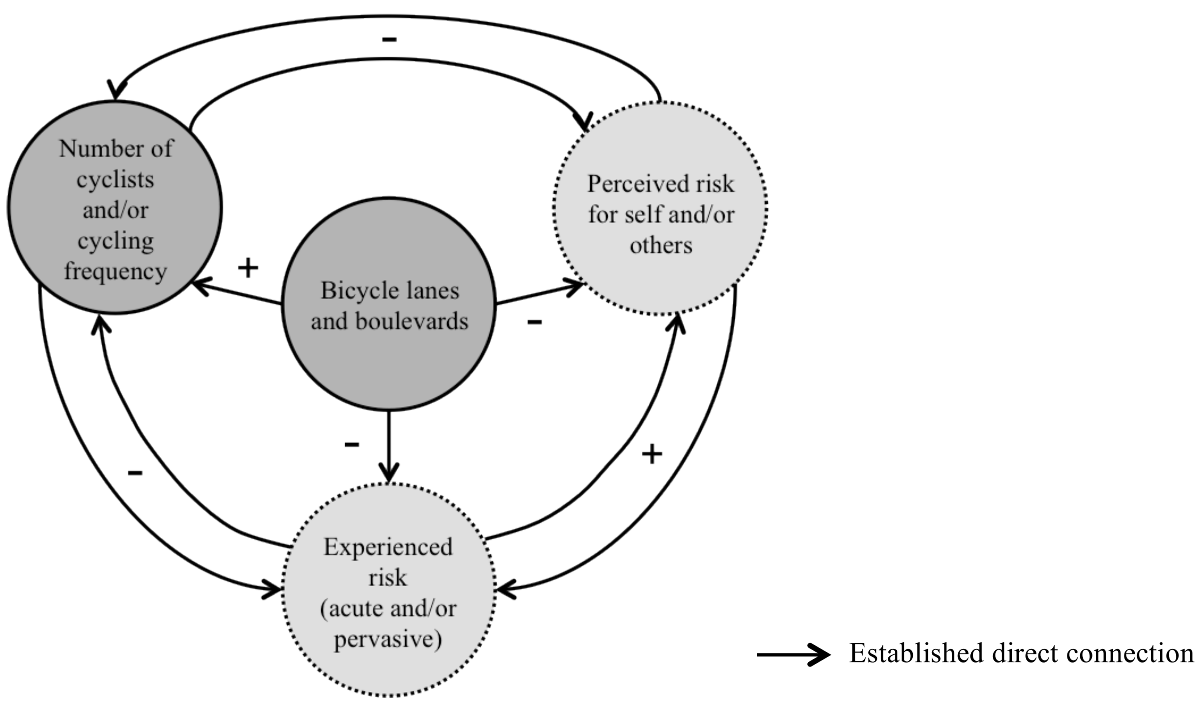
Striped Bicycle Lanes Received Mixed Reviews
My research found that a large majority of the sample believed that bicycle lanes conferred benefits to bicyclists and drivers in the form of predictability, legitimacy, and space. However, some respondents, particularly non-cyclists, also believed that bicycle lanes conveyed the message that bicyclists were restricted to certain streets—a finding that may mitigate some of the potential benefits if it leads to driver confusion or frustration when bicyclists use streets that don't have bicycle lanes or facilities..

Support for Bicycling Significantly Affected by Perceived Risk
Because roadway design seems to play such a critical role in increasing both numbers of cyclists and decreasing perceived and actual bicycling risk, it is imperative that we understand which factors influence the provision of bicycling infrastructure, and how we can address those factors. Bicycling support—which in this dissertation includes support for bicycling infrastructure—among the survey respondents was significantly affected by perceptions of risk for one's self and for others, bicycling frequency, the proximity of a bicycle lane to one's home, the practicality of bicycling for the respondent, whether one has had a negative experience driving near a bicyclist, the population density of one's home, sex, and parenthood.[4] Of all of these factors, perceived risks for self and others were the dominant categories. These findings underscore the importance of understanding perceived risk, as such risk directly impacts community support for bicycling and the potential to address the risks therein.

[4] Support for bicycling was determined by summing the following scores: 1) one's desire to see more bicyclists in her city, 2) one's willingness to use public funding to encourage cycling, and 3) one's willingness to give up car parking to provide space for bike lanes on major streets.

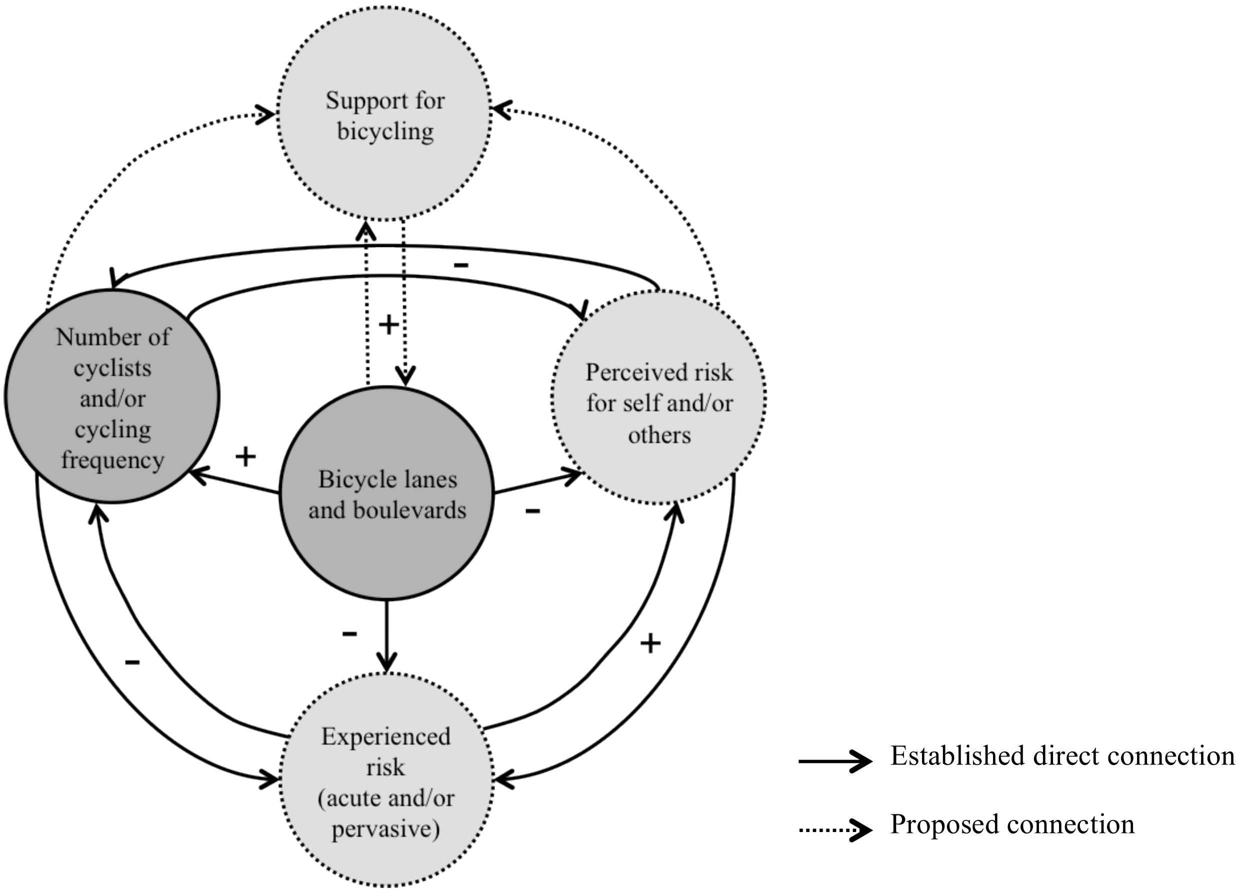
Rethinking the Cycle of Bicycling Risk
The findings presented above suggest that, while the connections in Figure 1 hold true, they are more nuanced than previously documented. For example, my data suggest that perceived risk is not a monolithic category, but instead seems to be composed of perceived risk for oneself and perceived risk for others. My findings also indicate that reported crash risk does not fully reflect the extent or type of risk ("experienced risk") cyclists face on the roadway. Cyclists seem to face acute risk in the form of collisions, and considerable pervasive risk in the form of near misses. Neither the acute nor the pervasive risk is well-captured by reported crash statistics. My data also provide evidence for the direct connection between experienced risk and perceived risk, in contrast to the original theoretical cycle. I therefore propose modifying the cycle to include two categories of perceived risk (for self and for others) and replace reported risk with two categories of experienced risk (acute and pervasive), as indicated by the light gray circles with hashed outlines in Figure 2.

Figure 2. Revised Cycle of Bicycling Risk



My findings also provide evidence that both perceived cycling risk and cycling frequency significantly influence support for bicycling in one's city—a construct that is becoming increasingly important as more people bicycle and more infrastructure is demanded and provided. Therefore, I propose adding the construct of bicycling support to the cycle, as shown by the third light gray circle in Figure 3.

Figure 3. Proposed Cycle of Bicycling Risk



I do not claim to have exhausted the topic of bicycling risk; on the contrary, many of my findings indicate that the subject is deeper than previously thought, and deserve further study. I hope that my findings, in addition to the proposed theoretical model encapsulating the findings and showing their relationship to previous research, can help guide future research, and equip practitioners and policymakers to better understand the complexity of the subject and accomplish their goals of increased bicycling and improved bicycling safety.

Policy Implications and Future Research

Key findings and their related policy implications are described in detail in Chapter Ten. My findings are summarized as follows:

1. Perceived risk is commensurate with other commonly cited impediments like topography and lack of bike parking regarding its influence on bicycling. Perceived risk may be even more important than the data indicate, given its permeating influence on other barriers.
2. For multi-lane, commercial roadways, drivers and cyclists both prefer designs with separated space, especially barrier-separated space, regardless of cycling frequency.
3. So few potential cyclists feel comfortable with shared space designs on commercial streets—including shared lane markings—that they are essentially useless in attracting

new riders. Just a small minority of current cyclists feels comfortable riding on multi-lane commercial roadways where cyclists and drivers share space.

4. Striped bicycle lanes were viewed ambivalently. On the one hand, the majority of drivers and cyclists believed that striped bike lanes increased cyclists' legitimacy and predictability on the roadway. However, they were also seen as increasing the risk of being hit by a car door and communicating to some respondents that cyclists did not belong on streets without bicycle lanes.
5. Cyclists experience two types of risk on the roadway: *pervasive risk* in the form of near misses that happen or threaten to happen frequently, and *acute risk* that occurs when a cyclist is struck—a less frequent, but more injurious occurrence. Both of these risk types significantly affect a cyclist's perceptions of risk for herself and within her social network.
6. Data on near misses are not captured in any systematic way, resulting in near complete ignorance of the extent of their occurrence. In addition, data on reported crashes provide only limited insight into the near misses and even the collisions cyclists experience.
7. Perceived cycling risk is broader than previously imagined. Cycling is seen as dangerous not just for oneself, but also for other cyclists and even for drivers who share the roadway with cyclists. This holistic belief in the danger of cycling significantly negatively affects support for bicycling, and is countered only seriously by utilitarian cycling frequency.

Chapter 2 – Background and Motivation

This chapter provides the background and motivation for this dissertation through a summary of the history of bicycling in the United States, followed by a literature review describing the current understanding of bicycling and cycling risk. I then identify knowledge gaps and discuss the limitations of previous research. I conclude with a brief description of my efforts to address several of the gaps in knowledge through my various chapters. The following chapter summarizes the theories and methods framing the study.

History

Bicyclists were introduced to public streets in large numbers in the 1890s with the development of the "safety" bicycle (Herlihy, 2004). Early proponents of cycling emphasized the potential health benefits for an "increasingly sedentary population", while others touted the freedom it brought to women (Herlihy, 2004). While many saw the bicycle as the culmination of a long search for human-powered transport, however, others saw bicyclists as reckless and dangerous. Bicyclists who sped through the streets were known as "scorchers" for their propensity to scare and even hurt pedestrians, and were prohibited from using the sidewalk due to the difference in speed (Herlihy, 2004; Mionske, 2007). This prohibition was a constant source of tension between cycling proponents and pedestrians, as cyclists were physically sensitive to poor roadway quality and therefore preferred the smoother sidewalks for travel, and cycling proponents worried that refusing to let cyclists ride in comfort would be the death knell for the bicycle. This conflict eventually led to the "good roads" movement, which called for roadways to be paved for bicycle travel (Herlihy, 2004). Little would cyclists have guessed the role that this triumph would play in enabling automobile travel.

The shift from planning separately for pedestrians and bicyclists began as early as the 1890's in some places (Macdonald, 2012), but in most U.S. cities and suburbs, it began in earnest with the widespread adoption of the automobile around 1920-1930 (Herlihy, 2004). Taken with the convenience and freedom of the automobile, American adults abandoned the bicycles they had ridden with enthusiasm around the turn of the century, and spent their time in and money on the automobile, with bicycles largely relegated to children's recreation. From the 1930's on, with the exception of wartime, the automobile remained the most desirable mode of transport in the United States. Buoyed by inexpensive gas, highly subsidized roadways, and housing policies that enabled development in the U.S. to spread outward, increasing numbers of people shifted to personal motorized travel. As they did, the demand for time, resources, and space devoted to the private automobile only increased, creating a negative spiral for walking and bicycling as transportation.

Earlier tension between drivers and pedestrians was settled through the creation of sidewalks and separated facilities that conferred safety for pedestrians, but bicyclists were usually restricted to the roadway. The perceived (and many times actual) danger of bicycling near automobiles only served to make bicycle travel even less attractive than it had already become, further dampening the market. By the time of the 1973 oil embargo, bicycling for transportation among adults had declined to 1%. The embargo seemed to provide an opportunity to rethink transportation in the United States, but did not last long enough to provide meaningful change as far as alternative modes of transportation. In addition, by that time in U.S. history, the majority of urban spaces had already been carved out, mostly for the automobile. Any effort to get more people to bicycle was going to face an uphill battle.

With the carving of spaces for the automobile came a steady decrease in road safety for pedestrians and bicyclists ("non-motorized users"). Bicyclists, by virtue of their traveling in the road versus on the sidewalk, were keenly affected by this trend in a way that pedestrians were not. Decreased roadway safety discouraged bicycling, which had the unfortunate effect of further decreasing bicycling safety, as transportation departments built roadways meant for motorized vehicles that encouraged relatively high speeds and high throughput—two factors consistently related to crashes (Helak et al., 2013). In addition, the principle of "safety in numbers" argues that as fewer bicyclists took to the roads, drivers became less aware of them. Thus began a vicious cycle that bicyclists would face for decades to come—that not planning for bicyclists led to fewer people bicycling, which led to decreased bicyclist safety, which further discouraged people from bicycling.

In 1990, however, things began to change for bicycling when the U.S. Congress passed a transportation infrastructure bill with flexible funding that could be used for bicycling and walking improvements (Federal Highway Administration, 1999). The Federal Highway Administration issued the National Bicycling and Walking Study (NBWS), and the U.S. Department of Transportation set a goal to double the percentage of walking and bicycling trips in the U.S. from 7.9% to 15.8% of all trips. The fifteen-year NBWS status report showed 50% change in the percentage of all walking and cycling trips, suggesting fair progress toward the goal—although for cycling, this translated to a rise from 0.7% to 1% of all trips (Pedestrian and Bicycle Information Center, 2010). With widespread knowledge of global climate change and skyrocketing rates of chronic health disease, the Centers for Disease Control and Prevention (CDC) and the Environmental Protection Agency (EPA) joined the US DOT in promoting increased bicycling and walking trips for the American people. In separate efforts, the American Academy of Pediatrics (AAP) and the American Association of Retired People (AARP) also lent their support.

Behind all of the federal policy efforts to generate more bicycling trips, there were people still bicycling in cities around the U.S. In a few circumstances (most notably, Davis, California), the city's bike treatments were shaped by people who brought ideas about designing roadways to accommodate bicyclists from visits to bicycle-friendly countries like the Netherlands (Buehler, 2007). In most cities, however, the decision about roadway design rested with local engineers, who tend to follow the guidance of the American Association of State and Highway Transportation Officials ("AASHTO"). AASHTO began publishing its Guide to Bicycle Facilities in the early 1980's, basing it on the California DOT ("Caltrans") bicycle design guidelines (Mapes, 2007). In contrast to the strategy in the city of Davis, Caltrans' strategy was heavily influenced by the philosophy of a group known as "vehicular cyclists." Informally led by a civil engineer named John Forester, vehicular cyclists advocated against bicycle facilities of all types on the basis that these facilities at best did not address bicycle safety, as they were along the roadway and most crashes occurred at intersections, and at worst decreased bicycle safety, as they conveyed safety to bicyclists when it did not, in fact, exist (Forester, 2001; Mapes, 2007). Instead, these bicyclists argued, cyclists must be taught to operate their bicycle as if they were driving a car, taking the center of the lane and behaving like a car driver. These cyclists also believed that separate bicycle facilities subordinate bicyclists.

While the vehicular cyclists may have been correct that the majority of bicycle crashes happen at intersections, this argument should never have been advanced against installing a bicycle lane, for the two treat different aspects of bicycling. Bicycle lanes have always been about making people feel safer and more comfortable riding. Data for the cities examined in Chapter Nine of this dissertation suggests that in many cities, a higher percentage of pedestrian crashes than bicycle crashes occur at intersections, yet it would seem nonsensical[5] to pull up the sidewalks because they channel pedestrians into the crosswalk instead of the roadway. Society recognizes that there is value in the sidewalk beyond preventing intersection collisions. Yet this is exactly the argument vehicular cyclists advanced against bicycle lanes. In addition, the transportation system generally seeks to provide comfort and smooth passage for pedestrians and drivers, so why would this not also apply to cyclists? Forester has acknowledged that he does not care if bicycling is not more widely attractive—he does not think bicycling will ever be a mass mode, and he is purely interested in maintaining his right to the road (Mapes, 2007).

Over the next thirty years, little progress was made for bicycling except for in a few cities that went beyond the AASHTO guidelines and built networks of bike facilities. Cities that invested in bicycle infrastructure have seen large increases in cycling (League of American Bicyclists, 2013). For example, cycling to work dramatically increased in the following cities from 1990 to 2011:

- Portland, Oregon – increase of 443%
- Washington, D.C. – increase of 315%
- San Francisco – increase of 258%
- Philadelphia – increase of 210%
- Denver – increase of 183%

In these cities, bicycling is now well above the national average of 1%, and the gender split tends to be more even. For example, Portland, Oregon, boasts a bicycling mode share of 6.3%, while San Francisco and Minneapolis report mode shares of 3.4%, and Washington, D.C. reports a mode shares of 3.2% (League of American Bicyclists, 2013). In cities where no or only haphazard bicycle facilities were provided (the majority), in contrast, bicycling remains below the average, and there are uniformly more men (often about three times as many) than women. While the vehicular cyclists stuck to their ideological guns and exercised their power, cities kept expanding and an increasing number of people who might have bicycled instead drove, took transit, or walked. Meanwhile, cities like Copenhagen and Amsterdam in Western Europe began a congenial competition to be the most "bike-friendly" city, with some of them boasting bicycle mode shares of 40%, evenly split between men and women (City of Amsterdam, 2008; City of Copenhagen, 2009).

Beginning in the late 1990's and spurred by federal policy meant to encourage walking and bicycling, researchers began to investigate preferences for roadway design. Uniformly, these studies showed that people generally preferred to be separated from traffic (Dill and Voros, 2007; Landis et al., 1997). Other research showed that bicycle lane miles were positively associated with a higher percentage of bicyclists at the city level (Dill and Carr, 2003). As the evidence mounted, the debate about bicycle facilities was reignited and fairly quickly moved in favor of advocates for bicycle lanes and treatments. As I will show in my review of previous

[5] A similar claim was made with regard to pedestrian planning in the 1990's, when a San Diego study found that most pedestrians were hit in marked crosswalks (as compared to unmarked crosswalks). This finding (which did not account for exposure) prompted the city engineers to remove all marked crosswalks, only to see increased pedestrian crashes in other locations. The city has spent the last few years restriping the crosswalks it removed.

research, the evidence was overwhelming that people generally wanted to be separated from traffic, to the chagrin of the vehicular cyclists.

Since 1999, the bicycle design guide of the American Association of State and Highway Transportation Officials ("AASHTO") bicycle design guide has included designs for bicycle lanes (AASHTO Task Force on Geometric Design, 1999). The latest version includes designs for striped and painted bicycle lanes, as well as intersection treatments like bike boxes. The guide still does not treat cycle tracks, the curb- or barrier-separated bicycle lanes found in many other countries, but the recent design guide published by the National Association of City Transportation Officials ("NACTO") does include such guidance, almost ensuring that the AASHTO guide will in the future (National Association of City Transportation Officials, 2011).

While the ideological debate about bicycle facilities may be considered settled from the bicycling advocacy side, practical issues have kept bicycle lanes from being consistently built. Roadway space is often limited, forcing transportation planners to decide between removing parking or a travel lane to provide a separate bicycle facility, installing shared-use markings in a travel lane, or maintaining the current design. These decisions are sometimes fraught with controversy, as seen in high-profile cases of citizens and neighborhood groups resisting bicycle lanes in San Francisco (Goebel, 2010), New York City (Goodman, 2010; Gootman, 2011), and Portland, Oregon (Stehlin, 2013). If bicycle lanes of any type are considered to only benefit bicyclists, they may be easily dismissed as a good design option for streets—particularly in cities where the bicycling mode share is low. However, little research has examined drivers' preferences for driving on various roadway designs with bicycle traffic. The effects of bicycle lanes on other roadway users—particularly drivers—seems important to understand when considering how to allocate roadway space.

Another important aspect of the roadway design debate is how to handle shared space, or space where no bicycle facility can be installed. My research and other studies (Dill, 2013; Winters and Teschke, 2010) have shown a clear preference for separated space, but less is known about shared space except that our current system—in which bicyclists can technically share roadway space on most roads in all cities—does not produce many bicyclists. In order to know how to properly design for this space (i.e., whether to install sharrows, no treatment, etc.), it is important to understand which aspects of bicycling compose "bicycling risk" and how those aspects are related to individual characteristics such as bicycling experience and environmental characteristics such as roadway design.

This dissertation aims to contribute to these two debates by 1) examining how drivers' experiences, demographics, attitudes, and behaviors affect their perceptions of comfort for various roadway designs and their opinions about bicycle lanes, and 2) disaggregating bicycle traffic risk into its component sub-risks and exploring how these sub-risks are related to individual and built environment characteristics.

Previous Work on the Topic

Research on bicycling has covered the gamut from barriers to benefits, case studies to analysis of aggregated data. In this section, I cover a cross-section of the literature and discuss how previous findings have contributed to our current understanding of cycling habits and risk, as well as which gaps remain to be filled.

Bicycling at the Ecological Level

Several studies have looked at bicycling from the "ecological", or community level to determine if there are quantifiable benefits to increasing the number of cyclists in one's city. Several studies have documented that cities with higher numbers of cyclists also tend to be safer—and not just for the cyclists. For example, Marshall & Garrick (2011) compared the safety of bicycling, walking, and driving in twenty-four cities with varying levels of bicycling mode share in California. They found that crashes in the cities with higher bicycling mode shares had lower injury severity levels for all users, which they attributed to street network density, as well as the higher percentage of non-motorized travel. In an international comparison, Pucher, Buehler, et al. (2011) examined trends in cycling demographics, amounts, safety, trip purposes, and funding in the United States and Canada, with a specific focus on nine case cities. The researchers found that targeted efforts to increase cycling were positively associated with cycling numbers and cycling safety.

Jacobsen (2003) examined pedestrian and bicyclist injuries, mode share, and trip data for four different analyses: 68 cities in California, 14 European countries, 8 European countries, and 47 Danish towns. In each case, he found an exponential decrease in the number of injuries as the amount of bicycling increases—an effect he titled "safety in numbers." Following in Jacobsen's footsteps, Robinson (2005) also found evidence of "safety in numbers" through her analysis of fatalities and amounts of cycling in Australia in the 1980's; fatality and injury rates over time; and serious injuries and fatalities before and after Victoria instituted a helmet law. Her analysis indicated that risk per kilometer falls as cycling increases, and vice versa. Elvik (2009) analyzed the results of multiple "safety in numbers" studies to determine thresholds for the effect with regard to transferring motorized trips to bicycling and walking. His findings suggest that risk decreases non-linearly upon researching certain thresholds of drivers switching to other modes, but cautioned that additional study is necessary to better understand the interaction.

Barriers to Bicycling

Interest in cycling ranges from the recognition that it is a mode of transport for those too young to drive, to the potential health benefits to all people, young and old alike. However, while the potential for cycling to benefit U.S. cities has garnered attention through exceptional successes (e.g., Portland, Oregon) and various federal efforts to increase cycling trips, substantial progress will likely be hindered as long as major barriers to bicycling remain unaddressed – particularly, perceived and actual traffic risk.

Physical Barriers

Research on North American cities has revealed that there may be many barriers to bicycling, but they tend to be context-specific, and vary in intensity by amount of cycling experience, trip purpose, and alternative travel options, among other things. Perhaps due to the influence of context, studies aiming to tease out the effects of influential factors, such as urban form, availability of alternative travel options, weather, income, a large student population, and topography, have consistently failed to account for more than 40% of the variation in cycling between cities and suggested a wide variation in acceptable conditions (Dill and Carr, 2003). For example, in their study of regional travel data on utilitarian bicycling and walking in hilly San Francisco, California, Cervero and Duncan (2003) found that land use diversity and street connectivity increased the likelihood of bicycling, while increased slope decreased the likelihood. In their telephone survey of Portland, Oregon residents, Dill and Voros (2007) found hilly topography to be a barrier to less than one-third of respondents who wanted to cycle more for transportation. This may reflect greater comfort with the hills, better routes around them, or the fact that Portland's topography is not as challenging as San Francisco's.

Looking at U.S. cities with a population over 250,000, Dill and Carr (2003) found that, although the average number of days of rainfall was negatively correlated with bicycle commuting, some of the top bicycling cities were frequently cold and wet, including Portland, Oregon, and Minneapolis, Minnesota. This, again, may be context-dependent: in the Bay Area, where rain is limited to the winter season, Cervero and Duncan (2003) found that rainfall did not discourage bicycling. However, in their online survey of current Texas bicyclists, Sener, Eluru et al. (2009) found that inclement (winter) weather was the largest deterrent for bicycling. These results, while intuitive, were limited by the survey methodology (online with a self-selected sample of people who bicycle) and perhaps influenced by an overall lack of bicycle accommodations in that state. Rainfall in the Dill and Carr (2003) model was not as significant or powerful of a predictor as the presence of bicycle lanes per square mile, suggesting that the influence of weather may be mitigable. In their mixed-methods survey of 1400 Vancouver residents who bicycled or owned a bike and would consider bicycling in the future, Winters, Davidson, et al. (2010) found that rainy weather, the presence of ice or snow along a route, and surfaces that become slick when wet or cold are three of the ten largest deterrents to bicycling in Canada—although rain is less of a deterrent the more one bicycles. As part of the major research effort Cycling in Cities, this survey covered people who currently bicycled or owned a bike and would consider bicycling—it did not include the 70% of the population who did not currently own a bicycle.

Trip distance has also had mixed effects: while a distance over two miles is a barrier for many, dedicated cyclists regularly commute by bicycle over much longer distances (Sener et al., 2009). Dill and Voros (2007) also found that less than one-quarter of their survey respondents thought that trip distances were too great to bicycle. The inverse has also been found to be true: shorter trip distances were seen to encourage bicycling for all types of cyclists in Canada (Winters et al., 2010). Flexible work schedules have also been cited as enabling cycling, although this has been attributed mostly to the reduced interaction with motorists due to bicycling outside of rush hour (Sener et al., 2009).

Psychosocial Barriers

Not surprisingly, studies exploring psychosocial factors affecting adult bicycling have found some correlation between perceived benefits of bicycling and the likelihood of bicycling. In their survey of residents in four medium-sized California cities and comparable cities in Oregon and Colorado, Xing, Handy, and colleagues found that enjoyment of bicycling was significantly correlated with bicycling, although the sample was biased toward current cyclists and had a low response rate (Emond et al., 2009; Xing et al., 2008; Xing et al., 2009). Sener, Eluru, et al. (2009) found similar perceived benefits from cycling within their sample of Texas bicyclists: 88% bicycled for fitness or health concerns, and 87% bicycled for pleasure or enjoyment. In their study of motivators and deterrents of bicycling, Winters, Davidson, et al. (2010) also found that positive experiences can motivate cycling: taking a route separated from traffic noise and pollution, and riding along a route with beautiful scenery were the top two motivators for cycling among the Vancouver survey respondents.

Basford et al. found the inverse to be true, as well: cyclists and drivers in the UK who don't enjoy bicycling are less likely to do so (Basford et al., 2003). Emond et al. (2009) found that the perception that bicyclists are poor was significantly negatively associated with whether someone had ridden a bicycle in the last week. Other barriers may include perceptions of personal safety while bicycling. Winters, Davidson, et al. (2010) found that a concern about the potential for crime negatively affects the decision to bicycle (although it is not a top deterrent to bicycling). Only 21% of current Texas cyclists reported feeling worried about personal security, but these were all people who currently bicycle (Sener et al., 2009). Some bicyclists in the 2002 National Survey of Pedestrian and Bicyclist Attitudes and Behavior also reported feeling scared of loose animals (Royal and Miller-Steiger, 2008). However, these fears do not seem to be among the top barriers to cycling.

Perceived Traffic Risk

No research has comprehensively identified how many people do not bicycle due mainly to traffic safety concerns, but survey results clearly demonstrate that such concerns form a substantial barrier. Several studies have shown that people are discouraged from bicycling or are unwilling to bicycle due to multiple safety concerns, including traffic volume and speed, roadway conditions, and driver behavior. In their study of medium-sized cities in California, Oregon, and Colorado, Emond et al. (2009) found that the having "safe destinations" to which to bike was significantly correlated with whether one had bicycled in the past week. Moreover, feeling "comfortable" bicycling was the largest predictor of whether the women in the sample had bicycled in the last week. Sener, Uluru et al. (2009) found that nearly 70% of the current bicyclists in their study felt at least somewhat unsafe bicycling because of traffic risk.

In their Portland survey, Dill and Voros (2007) found that nearly 65% of respondents in their Portland survey wanted to cycle more for transportation, although the authors noted that the sample, although random, was not necessarily representative of greater Portland. Of that group, 56% cited "too much traffic" as a barrier to doing so, while 37% cited a lack of bicycle lanes and trails. Xing, Handy, and Buehler (2008) found a clear positive association between perceptions of safety and the frequency of cycling in their survey of several mid-sized communities in California, Oregon, and Colorado. Likewise, in their survey of Texas bicyclists, Sener, Uluru, et al. (2009) found that, while a large majority of respondents perceived bicycling with traffic to be dangerous, those who believed it to be safer were more likely to bicycle more often.

In their survey of Vancouver residents, Winters, Davidson, et al. (2010) found that 3 of the top 5 deterrents to bicycling were related to traffic safety for cyclists of all experience levels, and the 6th-ranked deterrent was related to traffic safety for all but "regular" bicyclists. These deterrents included (in order) high amounts of car, bus, and truck traffic; vehicles driving faster than 50 kph (31 mph); the risk of motorists not knowing how to drive safely near cyclists; and the risk of injury from car-bike collisions. The 2002 National Survey of Pedestrian and Bicyclist Attitudes and Behavior found that 13% of respondents who bicycled felt threatened by motorists on their last bicycling trip (Royal and Miller-Steiger, 2008)—a finding that, given its focus on only one trip, may underestimate the prevalence of such feelings among people who bicycle in traffic. The survey also found that nearly 28% of respondents did not have access to a bicycle, which previous research has found to be related to fear of cycling (Beck and Immers, 1994; Xing et al., 2008).

In addition, research has consistently shown that people do not like to bicycle with auto traffic, in part because they perceive it to be unsafe. Haworth and Schramm (2011) found that utilitarian bicycle riders in Queensland, Australia, particularly if they were new to bicycling, were hesitant to ride on the roadway and often road on the sidewalk when they didn't feel comfortable.

Bicycling Risk by the Statistics

The perceived lack of cycling safety is not completely unfounded, as bicyclists repeatedly comprise 2% of national fatalities and injuries, while making less than 1% of all trips (National Highway Traffic Safety Administration, 1997-2007). Analyzing safety on a per-trip basis, Beck, Dellinger et al. (2007) found bicycling to be more dangerous than all other modes except motorcycling. Comparing risk per hour of various modes in California, Guler, Grembek et al. (2012) found that bicycling is an average of 6.1 and 6.25 times more dangerous on a per-minute basis than walking or driving, respectively. Studies measuring risk-per-kilometer have found similar trends (Joshi et al., 2001).

Bicycling risk is not limited to crashes with cars. Several studies have found that bicyclists are frequently injured by falling or straining muscles, joints, and other body parts (Washington et al., 2012). However, these types of injuries are typically much less impactful on the cyclist's overall perception of bicycling risk, perhaps because of their perceived control regarding the injury (i.e., the cyclist can ride less and rest her muscles, but cannot control a car driver who is not paying attention and swerves into her lane).

Near Misses

In addition, little research has examined what is potentially a key aspect of bicycling safety—the "near miss" (when someone is almost hit, but escapes unscathed). As these incidents by their very nature do not end in a crash, there is no formal mechanism for reporting them (as well as no judicial action to be taken if reported), and they are therefore only investigated through targeted research, such as the diary study by Joshi, Senior et al. (2001) of risk perceptions among 291 road users near Oxford, England. In this study, the researchers asked participants, including pedestrians, bicyclists, and car and bus drivers, to record all trips for one week, noting any incidents (defined as events causing the person to take evasive action and/or causing worry or annoyance) or near misses that occurred and grading them on a 4-part scale level of threat and level of annoyance. The data indicated that cyclists, on average, experienced one incident every 5.59 miles within Oxford City, as compared to one incident every 41.67 miles for drivers (a 7.5-fold difference). As discussed by the authors, examining these incidents "gives insight into the experiences that road users have on regular journeys. Such risk perceptions are likely to be relevant to the choices road users make between various forms of transport, and for the choices made on behalf of others…" Although the study is potentially limited by self-selection and recall bias, it provides strong evidence that traffic risk figures more prominently into bicyclists' journeys than it does for car drivers, and that it is not fully captured through reported crash statistics.

Perceived Safety Inextricably Linked to Bicycle Roadway Facilities

Until fairly recently in most cities, bicyclists have been expected to share roadway lanes with drivers traveling much faster than they and possibly holding attitudes counter to cyclists' rights to the road. In the United States, vehicular cycling advocates—who believe that bicyclists should have the same rights, responsibilities, and behaviors as a car—resisted bicycle lanes for many years in the belief that cyclists need only assert their rights to be safe and accepted on the roadway (Forester, 1984; Forester, 2009; Furth, 2012). However, there have been no conclusive studies comparing the safety of riding in bicycle lanes and the safety of practicing vehicular cycling. In fact, only recently have studies found that bicycle lanes contribute to a lower crash risk (Lusk et al., 2011; Reynolds et al., 2009; Teschke et al., 2012). For years, little defensible research existed on the subject.

In contrast, the evidence overwhelmingly indicates that most people prefer to bicycle on streets with bicycle facilities (Broach et al., 2012; Dill, 2013; Landis et al., 1997; Tilahun et al., 2007; Winters and Teschke, 2010). Research examining preferences may take the shape of 1) surveys examining general trends in preferences for bicycle facilities, 2) stated preference techniques that present survey participants with a range of facilities to choose from and adapt the survey around their preferences as it progresses, and 3) revealed preference research that examines real-life choices about facilities and makes inferences about the value of those facilities. Studies about general preferences are relatively uncomplicated to conduct and can inform the reader about how trends in preferences relate to characteristics of the survey participants. Like stated preference research, studies about general preferences have the advantage of presenting a broad range of facilities to the survey participant, including roadway types or bicycle facilities that may not exist in the participant's frame of reference. However, only stated preference research goes further to investigate the value of the facility characteristics in terms of time. This extra benefit makes the study much more complicated to conduct. The main limitation of stated and general preference studies is that there is no tie to actual behavior, and the preferences may not manifest in reality.

Revealed preference studies, on the other hand, observe where people actually ride their bicycles and infer facility preferences from that data. Revealed preference studies have the advantage of reporting data that reflect real choices, but are limited by the fact that the data are all revealed and thus cannot reflect preferences about facilities unavailable to the research participants.

Descriptive Statistics

Several surveys have asked respondents their preferences for roadways, but without necessarily requiring the trade-offs that generally accompany stated preference studies. These surveys are helpful for understanding a baseline of what is popular or unpopular among certain cyclist types, and can be used as the basis for future stated or revealed preference work.

For example, in their online survey of Texas cyclists, Sener, Uluru, and Bhat (2009) found that nearly 80% of respondents characterized the overall quality of bicycle facilities in their communities as "inadequate" or "very inadequate." In their telephone survey of Portland residents, Dill and Voros (2007) found that 37% of those who wanted to bicycle more reported that there were not enough bike lanes or trails near where they want to go.

In a particularly thorough study, Winters and Teschke (2010) conducted a mixed-methods survey using phone and visual aids over the internet to evaluate the roadway design preferences of 1,402 cyclists of all experience levels (including potential cyclists). Of the sixteen road types shown to survey participants, off-street paths were the most preferred by all cyclist types, while major city streets without bicycle facilities were the least preferred. As expected, the presence of on-street parking reduced the attractiveness of any particular route type, and the presence of bicycle facilities increased the attractiveness. One benefit of this study is that it asked about bicycle facilities not common in North America, finding that barrier-separated cycle paths next to major streets were the fourth-ranked option for potential and occasional cyclists, and ranked second and third, respectively, for regular and frequent cyclists. A comparison of the preference rankings to the respondents' current riding patterns suggests that cyclists do not have the full range of options they would like for cycling. A recent telephone survey from Portland, Oregon, found similarly strong preferences—particularly among potential cyclists and women—for separated bicycle facilities (Dill and McNeil, 2012).

Stated Preference

In their adaptive stated preference survey of 167 members of a convenience sample from the University of Minnesota, Minneapolis, Tilahun, Levinson, et al. (2007) presented participants with ten-second videos featuring routes along two roadways with different bicycle facilities, as well as an associated amount of travel time. As the respondents chose between the two roadways, a computer program presented them with different options until a final value for the facility was reached (four iterations total). A utility model of the data revealed that, on average, the respondents were willing to travel the farthest to avoid a street with on-street parking but no bike lane. In general, the presence of a bicycle lane had a much greater impact on the odds of choosing the higher quality facility than did the elimination of on-street parking or the presence of an off-road facility. The tendency to choose the higher quality facility was magnified among women, and cycling experience did not significantly influence the rankings.

Parkin, Wardman, et al. (2007) also used video to present their 144 survey participants with various route options for bicycling in Bolton, United Kingdom. Models created from user ratings of the facilities, although resulting in a relatively low R^2 (maximum of 0.275), suggested that the presence of on-street parking increased perceived risk along residential roads, while the presence of a bicycle lane on any road type decreased perceived risk. However, the effect of a bicycle lane was less powerful for busy roads due to the increased perceived risk from traffic. Overall, users clearly felt safer bicycling on off-street and adjacent paths than they did on the roadway with traffic.

Revealed Preference

Landis, Vattikuti, et al. (1997) conducted one of the first revealed preference studies by recruiting volunteers to ride and grade sections of a set route in Orlando, Florida. The participants' grades were then used to model preferences for facility design. The model results showed that the presence of a bicycle lane significantly improved the perceived level-of-service (LOS) of the street segment, irrespective of other street characteristics (including traffic volume and posted speed limit). As with all of the studies in this section, this one was limited to the facilities on the ground and the participants, who all bicycle currently and therefore do not necessarily represent the preferences of a potential bicyclist.

Winters, Teschke, et al. (2011) used reported routes from 74 of the participants in their Vancouver bicycling study to examine the distance people detour from the shortest path to use a bicycle facility. The researchers found that bike trips were significantly more likely to occur along routes with enhanced bicycle facilities including traffic calming, stencils, and signage; while only 21% of trips would be along designated bike routes in a shortest path scenario, on average, 49% of actual trip distance took place along a bike route. The researchers also found that participants who reported that the risk of injury from car-bike crashes deterred them from cycling were more likely to detour, although the small sample size limits the generalizability of the results.

Broach, Dill, et al (2012) used GPS monitors to gather data on the routes of 164 cyclists over several days in Portland, Oregon. They were then able to build a model based on revealed, real-time preferences that could account for trade-offs in topography, traffic volumes, and street network characteristics. They found that cyclists travel out of their way to reach bicycle infrastructure, particularly bicycle boulevards, which comprised 1% of the network, but carried 10% of all utilitarian bicycle travel.

Cycling Risk and Bicycle Facilities

For decades, bicycle lanes were fought using data from studies about bicycling on sidewalks and "sidepaths", which were essentially sidewalks. The data in the studies indicated that riding on sidewalks or sidepaths increased crashes at intersections, which was generally assumed to occur because cyclists had been removed from the motorist's field of vision. This data was used to argue against bicycle lanes because they, too, put the cyclist to the right of the motor vehicle and therefore removed him from the center of a driver's field of vision. For example, in their study of sidewalk bicycling, Aultman-Hall and Adams (1998) found that cyclists who ride on the sidewalk experience a higher rate of dangerous events than cyclists who do not ride on the sidewalk, despite the fact that the sidewalk events were rarely reported. Wachtel and Lewiston (1994) analyzed intersection crashes between bicyclists and motor vehicles in Palo Alto and found that sidewalk riding was twice as risky as roadway riding.

What these studies failed to report, however, was overall crash comparisons—including crashes that occur on the street segment, rather than just the intersection. When the data from Wachtel and Lewiston's (1994) study was later reanalyzed by Lusk et al. (2011) to include non-intersection crashes, the increased risk of sidewalk riding disappeared. In fact, Lusk and her colleagues found that sidewalk riding, as long as it was consistent with the direction of traffic, was associated with the fewest incidents in the data set.

As increasing numbers of bicycle lanes have been built in response to community demand, more studies have been conducted to augment and reshape the debate about bike lanes and objective risk. A recent meta-analysis looking at 25 studies of bicycling safety on various facility types concluded that bicycle lanes provide some additional safety (Reynolds et al., 2009). Although the researchers struggled with the lack of exposure data in many of the cities, they believed that the overall trend was clear that bicycle facilities improved safety. Along the same lines, Chen, Chen et al. (2012) conducted a case-control evaluation of bicycle lanes in New York City and concluded that bicycle lanes seemed to improve safety. On roadway segments where bike lanes were installed, the researchers found that crashes for vehicles and pedestrians decreased, while crashes for cyclists increased an insignificant amount ($p < 0.05$). Intersection crashes on those roadways also decreased for vehicles, but increased for pedestrians and bicyclists—although again not significantly ($p < 0.05$). A major limitation of this study is that the researchers did not control for volume; however, since research has consistently shown that people prefer to ride in bicycle lanes, the volumes of bicyclists on roadways with bike lanes should theoretically have increased, and thus would explain at least some of the increase in crashes for cyclists.

As part of the Canadian Cycling in Cities research effort, Teschke et al. (2012) conducted a case-crossover study with 690 injured cyclists (via a fall or collision with a fixed object or motor vehicle) in Vancouver and Toronto. All participants were injured seriously enough o have been admitted to a hospital emergency room, but not so seriously that they couldn't remember details from the day they were injured. The researchers interviewed each cyclist and had them trace the route they were riding when they were injured. Each injury site was matched to two randomly-selected control sites along the cyclist's route. Data on each location was gathered and used to classify the site as a certain facility type (data gatherers were blind to whether it was the injury site or a control). Subsequent analysis of each facility type along the route suggested that certain facilities, particularly facilities that do not mix traffic and speeds (i.e., a bike-only path rather than a shared use path, a local street rather than a major street) had a much lower odds of being associated with an injury than facilities with a higher speed differential and/or more modal mixing. In particular, the cycle track was found to have one-ninth the adjusted odds of being associated with an injury as a major street with parked cars, although the small number of cycle track locations in the study may have biased this number.

These findings matched fairly well with findings of a preference study conducted by Winters and Teschke (2010), such that the objectively safest facility types were also the most preferred facility types, with the exception of shared-use paths, which are highly preferred, but only about 0.7 times as objectively dangerous as major streets with parking. In addition, the findings on objective safety matched fairly well with the interviewees' perceived risks associated with each facility type, with two major exceptions (Harris et al., 2013). Cycle tracks were thought to be more dangerous than the statistics suggested, while shared-use paths were thought to be less dangerous than in reality. The cycle tracks finding again may be biased due to the small sample size of locations, or it may reflect biases with the sample population. The discrepancy regarding multi-use paths may reflect a lack of understanding about how dangerous the paths are, the difference in magnitude of fear about colliding with a motor vehicle versus someone or something on a bicycle path, the greater perceived control when separated from traffic, etc.

Regardless of the studies, the statistics show that the vast majority of Americans have chosen to refrain from cycling for utilitarian purposes. The 2002 National Survey of Pedestrian and Bicyclist Attitudes and Behaviors (the most current data available) found that 27% of Americans aged 16 and older bicycled for recreational purposes (Royal and Miller-Steiger, 2008), but recreational bicycling tends to be off-street and therefore does not inspire changes to roadway design in the way that many utilitarian cyclists would like. The limited on-road bicycling has also likely contributed to increased actual traffic risk through lower overall numbers of cyclists on the roadway (the principle of "safety in numbers") (Jacobsen, 2003), and lower number of drivers who also bicycle and are therefore more tolerant of bicyclists while driving (Basford et al., 2003; Granville et al., 2001). As long as traffic risk for cyclists is not fully understood, it is likely to remain a significant barrier for bicyclists in the United States. And as long as it is a significant barrier, the percentage of bicycling trips in the U.S. is likely to remain small. This research addresses the issue of bicycle traffic risk by further exploring some of the roots of bicycling risk and fears about bicycling, as well as how facilities address safety, in order to illuminate potential strategies for increasing the perceptions and actual safety of bicycling.

Limitations of Research

The studies and reports reviewed in this section represent the most thorough and most reliable research on cycling today. Yet they are not without limitations, many of which are endemic to the types of studies conducted. First, very few cities regularly collect volume data on cyclists, so studies examining the risk associated with cycling must rely upon absolute numbers that may misrepresent the actual safety or danger of a certain intersection, cyclist type, bicycle facility, etc. Even fewer individual studies have the resources to collect such data, leading to conclusions that are not always as substantiated as researchers or interested parties would like. Second, official crash records, at least in California, code crashes to nearest intersection, so researchers don't necessarily know where on the block the crash occurred. These records also lack information about basic street features such as whether there is a bike lane, on-street parking, number of lanes, etc. There is also evidence, as will be seen in Chapter Nine, that crashes are recorded inconsistently, and perhaps too broadly or vaguely for a researcher to detect important factors leading to the crash.

Finally, it is often difficult to learn about cycling habits, issues, opinions, etc. in the general population. The major transportation surveys at the national level tend to ask questions about motor vehicles, or limit questions about bicyclists such that reasons for cycling or not cycling are not sought (e.g., Do any adults in the household own a bicycle? Is the bicycle well-maintained?), and context-specific factors affecting decisions or opinions about cycling (e.g., topography, weather, etc.) are ignored. The result is that researchers have had to conduct surveys specifically about bicycling to develop any understanding of who bicycles, how often, and why. Yet so few people in the general population bicycle for utilitarian purposes, that even these studies may have difficulty getting a large enough response rate to be valid. Only in the last few years have researchers who are curious about the majority of people who don't bicycle been able to generate enough of a response rate to contribute to any real understanding of who doesn't bicycle, and why they don't. As with every survey, there is still the potential for response bias.

Summary of Findings from Literature Review

The research covered here has contributed greatly to a deeper understanding of factors that affect the decision of whether and where to bicycle. Several studies have investigated barriers to bicycling such as trip distance, topography, weather, and land use. Other studies have contributed that attitudes toward cycling and cyclists can discourage cycling and affect one's behavior toward cyclists while driving.

In particular, we have a more thorough understanding of the complex relationship between perceived and actual cycling risk, and the presence and type of bicycle facilities available. Worries about cycling arose as a barrier in several studies, and research on the statistical risk of cycling suggests that it is more dangerous than walking or driving a car, whether using a time-based or a distance-based measure of risk. In addition, the risk of almost being hit, while not captured in any official crash statistics, was found to affect perceptions of cycling safety.

Research has also documented a clear and strong preference among the general population for greater separation from drivers while bicycling. This has been demonstrated in general surveys, as well as stated and revealed preference studies. Research examining whether cyclists are actually safer when separated from traffic has found that, indeed, they are. This has born out at the ecological level, as well: cities where more people bicycle have a lower per-capita crash rate for bicyclists, and cities with a lower crash rate for cyclists also have a lower crash rate for drivers and pedestrians.

Given the preponderance of evidence, it seems clear that traffic risk is an issue that must be addressed if cycling is to increase in the United States. However, while these findings paint an overall picture of bicycling risk, they do not provide insight as to which aspects of cycling make it dangerous, how they may differ for different types of cyclists, or how they relate to perceived risk—critical knowledge if the risk is to be addressed.

Through this dissertation, I aim to address some of the gaps in the collective knowledge about cycling and cycling risk. Specifically, little research has sought to incorporate the perspective of non-cycling drivers who share the roadway with bicyclists. Presumably, their attitudes and behavior are important to understand when moving toward a more multi-modal system. In addition, while perceived cycling risk has been clearly documented as a barrier to cycling, we have sparse knowledge of what, exactly, that means for cyclists. For example, are there particular actions by drivers that cyclists fear more than others? Correspondingly, we lack a thorough understanding of how perceived risk relates to actual risk on the roadway.

Research Contributions

This dissertation focuses on exploring these knowledge gaps in the following ways:

First, I explore how attitudes, knowledge, and behavior among cycling and non-cycling drivers relate to perceived risks and beliefs about cycling.

Second, I examine roadway design preferences among drivers and bicyclists to understand how facility preferences compare between the two groups, and relate to perceived risks.

Third, I examine various types of bicycling risk to understand which aspects of bicycling with traffic are considered worrisome, and how those perceptions differ between cyclists of various experience levels and demographics.

Fourth, I explore how perceived risk compares to non-traffic-risk barriers to cycling.

Fifth, I investigate "near misses" and collisions among the sample population to understand how these experiences influence perceived risks and mirror reported risks.

Sixth, I explore the concept of bicycling support and how it is influenced by various factors, particularly perceptions of cycling risk.

Finally, I examine reported crash statistics to understand how accurately reported risk represents current and potential cyclists' experienced and perceived risks.

Chapter 3 – Theory and Methods

My research aims to fill a gap in the existing literature regarding what is known about varying types of perceived risk among bicyclists, drivers' views of bicycling risk, and roadway designs to address risk for both drivers and cyclists. This study focused on bicycling risk, including the general knowledge, attitudes, behaviors, and experiences of bicyclists and drivers that contribute to such risk, and the reported crash statistics that represent actual risk. In particular, I seek to provide insight for the following questions:

1. How do sociodemographics, beliefs about bicycling, experiences driving and bicycling, and knowledge of roadway laws affect attitudes toward bicyclists and bicycling among survey respondents?
2. How do perceptions of risk compare with non-risk-related impediments to bicycling with regard to influencing the decision to bicycle?
3. How do preferences for roadway design differ between bicyclists of varying experience levels, and between cyclists and drivers?
4. How do various specific traffic risks affect respondents' perceptions of bicycling risk? How do perceptions of risk vary according to bicycling experience?
5. How do perceptions of risk match with risks experienced by the respondents and their family or friends?
6. How do perceived and experienced risks reported by the respondents match with official crash statistics?

Overview of Methods

I chose to investigate these questions using focus groups, an online survey tool, and analysis of reported crashes. For my focus groups, I recruited 31 graduate students and residents from several of the cities in my study, including Berkeley, Oakland, San Francisco, Albany, El Cerrito, and Richmond. In particular, I targeted older residents because of the unlikelihood that they would be well represented in my internet survey. I used the focus groups to explore attitudes toward and beliefs about bicycling and bicyclists, experiences driving near cyclists and cycling near drivers, knowledge of roadway rules, and roadway design preferences. The findings from the focus groups then informed the survey. Details about the focus group administration are included in Chapter Four, and a copy of the focus group scripts is located in Appendix A.

I used an online survey to explore how qualitative findings from the focus groups translated to quantitative findings among the larger population. I conducted the survey via an online survey website, a link to which was emailed to a convenience sample of nearly 1200 people in the summer of 2011. Over 460 people responded to the survey, resulting in a 39% response rate. Through the survey, I explored the questions listed above in more detail. Additional details about the survey administration can be found in Chapter Five, and a copy of the survey is located in Appendix B.

For the third phase of my dissertation, I analyzed five years of reported crashes for several cities in the Bay Area. I used the crash analysis to examine how official crash statistics match with respondents' self-reported experienced and perceived risks, and to explore how the data contributes or detracts from a greater understanding of bicycling risk. Additional information about the crash analysis methodology is located in Chapter Nine.

Theoretical Grounding

I frame my research using social cognitive theory from the field of public health, risk assessment theory, and theory from the social sciences. Below, I describe how theory from each field guides certain analyses in the dissertation.

Public Health

Many public health researchers frame their studies using Social Cognitive Theory (SCT), an ecological theory that analyzes behavioral change by focusing on the relationship between individuals and their immediate environment (Bandura, 2004; Edberg, 2007). SCT examines: 1) knowledge of health risks and benefits, 2) perceived self-efficacy that one has some control over one's health choices, 3) expectations about the costs and benefits for various habits, 4) goals and strategies to reach them, 5) perceived facilitators to doing so, and 6) social and structural impediments to making desired changes. Though SCT clearly looks at a variety of factors that could affect a person's decision to bicycle, this proposal focuses on the social and structural impediments to creating behavior change - in this case, how a) the presence and type of bicycle facilities and b) driver behavior and attitudes towards cyclists affect perceptions of risk and social legitimacy for current and potential cyclists. This focus aligns with research on the importance of the physical environment to fostering self-efficacy with regard to physical activity (Satariano and McAuley, 2003). These themes are explored in Chapters Three through Five and Seven.

Risk Assessment

Literature from the area of risk assessment helps frame how past experiences and the experiences of family and friends affect one's perception of risk. Alhakami and Slovic (1994) examined the influence of general perceptions of an activity on the perceived risks and benefits of the activity. They found that if people feel favorably toward an activity, they tend to judge the benefits as high and the risks as low. Conversely, unfavorable impressions yield perceptions of low benefit and high risk. This is known as the "affect heuristic" – identification of something as "good" or "bad" based on one's feelings about it (subconscious or conscious) (Slovic et al., 2007). Related research has found that the pathway can be reversed – i.e., that information can be provided which influences perceptions of risks or benefits and then influences overall perceptions (Finucane et al., 2000). Risk assessment provides a frame for examining the influence of bicycle facilities, personal experiences, the experiences of others, and social norms on perceptions of safety at the individual (for oneself) and community (for others) levels. These themes are further explored in Chapters Three, Four, Six, and Seven.

Sociology/Anthropology/Urban Planning

Theories of discourse are central to many of the social sciences, including sociology, anthropology, and urban planning, and frame another of the hypotheses in this proposal. Discourse refers to a system of ideas, concepts, and classification that ascribes meaning to social and physical occurrences, and that is perpetuated through social practices (Fischer, 2003; Hajer, 1993). As discourse is context-specific, many have analyzed it for insight into social hierarchy and power dynamics. Foucault held that discourse reflected a history, as well as current circumstances, and that what was missing was as important as what was present (Foucault, 1991). With these characteristics, discourse serves to construct and reinforce power dynamics, as much as to reflect them (Fischer, 2003). While discourse analysis has often focused on the meaning and context of words, the study of social semiotics also includes signs as an important part of discourse, through their role in communicating cues regarding status (Fairclough, 1992; Hodge and Kress, 1988). This research examines the role of discourse in constructing and reinforcing attitudes toward bicyclists through 1) the presence or absence of bicycle symbols on the roadway and 2) the language used to describe bicyclists within drivers' personal social norms. These themes are further explored through Chapters Three through Five and Seven.

Psychology

Literature on attitudes and behavior has found that there is a wide range in the amount of correlation between the two, and that the correlation depends on a number of factors, including normative constraints, how strongly a belief is held, whether or not a person has a vested interest in the behavioral issue, and how the attitude was originally formed (Ajzen and Fishbein, 1973; Fazio, 1986; Fazio and Zanna, 1978; Regan and Fazio, 1977; Sivacek and Crano, 1982). Endogenous factors, like attitudes, have been found to be more predictive of behavior than exogenous factors such as related behaviors (Johansson et al., 2006). Research has also shown that certain attitudes are predictive of other attitudes (Ajzen, 2001). This study examines how various factors, including behavior, experiences, and beliefs about cycling risk influence attitudes toward cyclists in one's community. These themes are explored in Chapters Three, Four, and Seven.

Depicting Theoretical Pathways

Figure 4 displays pathways for how knowledge, bike facilities, social norms, and experiences may influence attitudes and behaviors to affect perceived bicycling risk and the decision to bicycle. This dissertation examines the theoretical pathways indicated by the solid black lines.

Figure 4. Hypothesized Relationships between Influences on Driver Behavior and Attitudes towards Cyclists and Cyclists' Perceptions of Safety

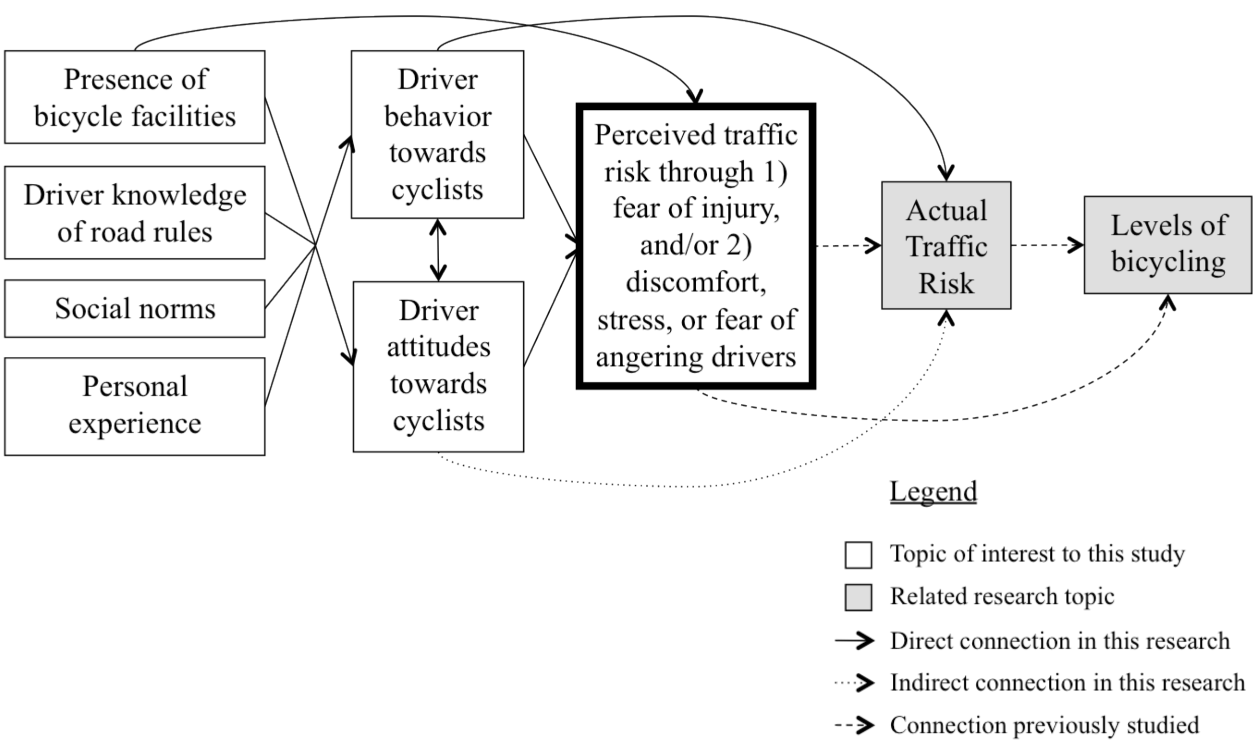
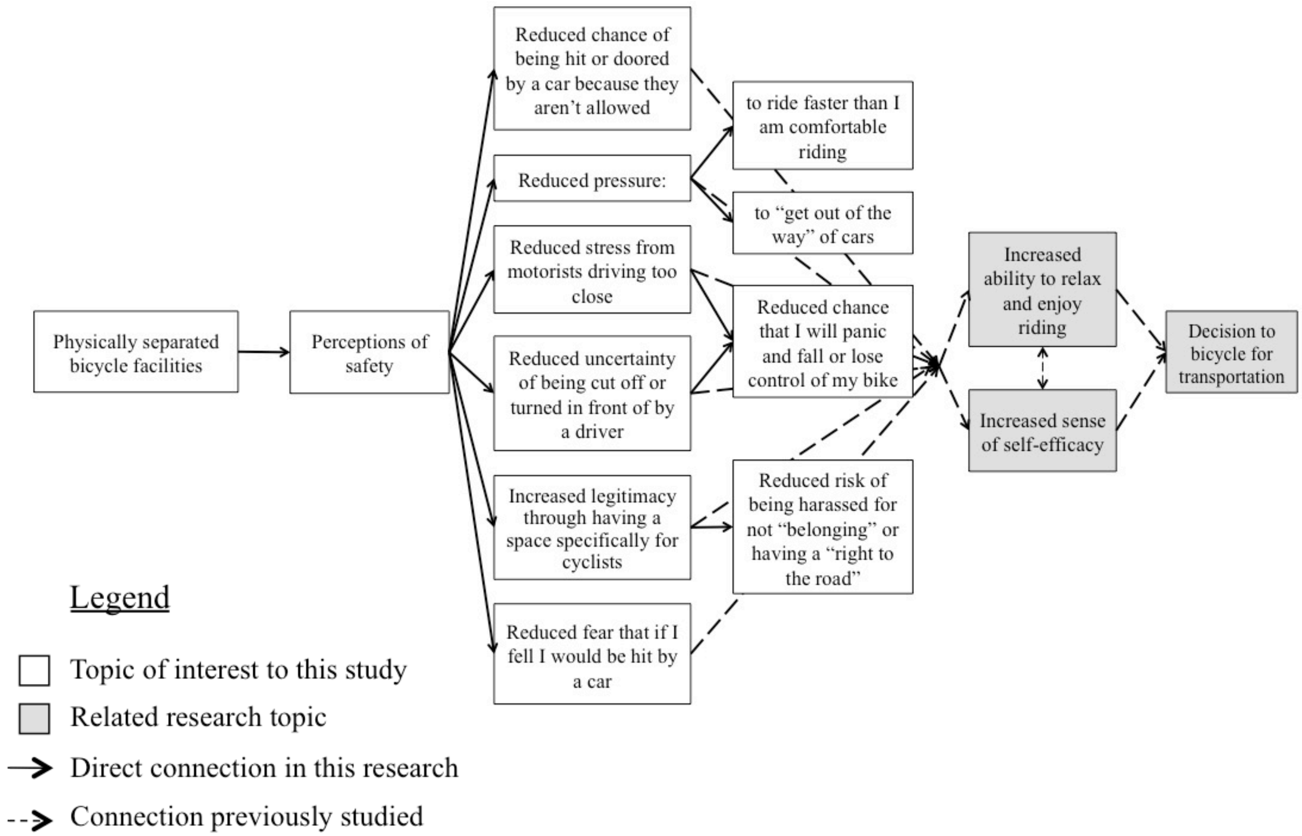


Figure 5 display pathways for how the presence of bicycle infrastructure could affect various concerns about bicycling near drivers and the decision to bicycle. As above, the solid black lines indicate theoretical pathways studied in this dissertation.

Figure 5. Possible Pathways for How Driver Behavior and Attitudes towards Cyclists/Cycling May Affect Perceptions of Traffic Risk



*Self-efficacy is the term used in public health to describe a person's confidence that they can overcome barriers to accomplish goals or achieve desired change (Edberg, 2007).

Limitations of the Study

There are several limitations to the data presented in this dissertation. First, the data analyzed herein is based on the responses of a survey that is likely subject to some response bias—particularly from people who care about bicycling or driving near bicyclists and were therefore more likely to participate in the survey. In addition, due to funding and time constraints, I conducted the online survey with email addresses from a convenience sample that, while intended to be representative of the Bay Area population, cannot be said to have ultimately been so. My decision to conduct the survey via the internet, while it facilitated data collection and reduced the possibility of data entry error, also meant that people without regular internet access, in particular the elderly and the very poor, were less likely to have a chance to participate. Although elderly participants were well-represented in my focus groups, results from the online survey should not be assumed to apply to the elderly without further study.

The survey construction was also imperfect. After analyzing my results, I saw that my cyclist categorization was imprecise, and I believe I should have included one more category to better represent the cycling frequencies of the respondents. I also did not ask specifically about seasonal bicycling, as other studies have done, although I did use the term "weather permitting". In addition, the survey used different response scales for regular cyclists than the scale used for potential and occasional cyclists when asking about perceived traffic risks. I used different scales in recognition of the difference between the two populations and to make the questions more relatable to each group, but the difference makes exact, direct comparisons of the two groups impossible. A similar limitation exists between comparing the non-traffic-risk and risk-related barriers. I also did not ask questions about where the survey respondents work, so I do not know how their workplace affected their answers, nor the length long their commutes, nor whether there are any bicycle facilities near their workplace.

Another limitation of the research is that respondents' reports of collision and near miss experiences were based on memory, and therefore subject to recall bias. In order to mitigate the potential for recall bias, I only asked whether my respondents had experienced something, rather than the timeframe for the experience or number of times they experienced it. While this data is helpful for establishing overall trends among bicyclists and drivers, it cannot speak to the prevalence, risk per person, or risk per trip.

Finally, the roadway design ratings were not based on a stated preference framework, and thus cannot be said to represent ratings that have fully considered trade-offs between features (for example, the loss of parking in some cases). In addition, these roadway designs were based on one commercial roadway in the Bay Area with certain base features. Although these findings corroborated those of similar research studies, it is possible that the priority of features could change under different circumstances. It also cannot be guaranteed that all respondents held the same definition of "comfort" when answering the questions.

These limitations are overcome in part by some of the study's strengths. First, the online survey received over 460 responses—a large enough sample size to mitigate some of the concerns about population and response bias. In addition, although the elderly were not well-represented within my online survey, they were very well-represented in my focus groups, and their perspective is captured in this dissertation. Finally, the findings presented in this dissertation either corroborate findings from earlier studies, or are unique contributions that fit with theory. This consistency with past research and theory suggests that the limitations of the study are not extraordinary.

Chapter 4 – Exploring Bicycling Risk through Focus Groups

In this chapter, I present the findings from focus groups used to qualitatively explore themes related to bicycling risk that were identified in the literature. The focus groups also provided an opportunity to investigate gaps in the literature and understand if they should be further explored through the survey. The goal was not to conduct a thorough qualitative study of bicycling safety but to develop robust hypotheses about bicycling safety that could be tested in a survey instrument across a broad representative sample of the Bay Area's population. The focus group topics included general knowledge about bicycling and bicycling risk, attitudes and behaviors toward bicyclists and bicycling, experiences of bicyclists and drivers that contribute to such risk or perceptions of risk, and perceptions of comfort and safety associated with driving and bicycling on various roadway designs. The findings of the focus groups guided the design of the subsequent survey, the results of which are presented in Chapters Four through Seven.

Focus Group Administration

In February and March of 2011, I conducted five focus groups, consisting of graduate students and residents of Berkeley, El Cerrito, Oakland, Albany, and San Francisco, five of the primary cities investigated throughout this project. Participants were solicited via email through a local bicycle advocacy group, graduate student listserves, and church member lists. The graduate student and bicycle advocacy listserves provided access to a population that bicycles more than average, allowing testing of bicycle themes that might not have arisen from a more general sample. The church membership in particular targeted an older demographic that was not expected to be reached through the survey. While including the elderly in the focus groups even though it was likely that they would be underrepresented through the survey is an unconventional manner of conducting focus groups, I hoped it would provide greater breadth to the research, and at least give some context for any patterns among elderly respondents to the survey.

The groups were split between drivers who bicycle and drivers who do not. Requirements for participation included being at least 18 years old, residing in the Bay Area, and being licensed to drive a motor vehicle. Participants in the bicycling driver groups also needed to have bicycled within the last year. Focus group participants all signed a written consent form allowing me to digitally record and take notes from our discussions. Each focus group lasted 1.5 hours and participants were compensated with a meal during the session.

The groups averaged 6 participants each, for a total of 31 participants. Demographics for the groups follow.

- Over half (55%) of participants were male.
- Forty-two percent of participants were aged 25-45, 19% were aged 45-65, and 39% were aged 65 or older.
- Nearly 75% of participants were white, while 10% each were Asian or Hispanic; only one participant (3% of the focus group population) was black.
- Two-thirds of the participants were married or coupled.
- Forty-five percent of the participants had children.
- Three of the focus groups were driver-only; 61% of participants were in these three groups.

I developed broad questions for the focus groups based on my review of the literature and the gaps identified in Chapter Two. Research on pedestrians and motorcyclists also informed some of the questions. The complete instrument I used can be found in Appendix A. The questions asked of the focus group participants were related to the following subject areas:

1. Experiences bicycling as a child and as an adult
2. Experiences driving near bicyclists
3. How bicycling figures into their social network, e.g., whether they had friends or family who bicycled
4. If friends and family bicycle, what types of trips they make (e.g., recreational, shop trips, commute trips, etc.) and where they ride
5. Perceptions of comfort bicycling and driving near bicyclists on a variety of roadways (accompanied by visual aids, as shown in Figure 6 through Figure 15)
6. Benefits of bicyclists in urban areas
7. Feelings of anxiety/frustration from other drivers when bicyclists are on the roadway
8. Influence of roadway design on comfort level driving near bicyclists and bicycling near drivers
9. Driving and bicycling behaviors
10. Crash and near miss experiences involving a bicyclist
11. The influence of past experiences driving and bicycling on current attitudes toward bicycling
12. The influence of the participant's friends' and family's experiences driving and bicycling on the participant's current attitudes toward bicycling
13. Ideas about how to make driving near bicyclists safer in urban areas
14. Reactions to proposed changes in traffic law to facilitate bicycling

In addition to the list of questions, I used visual aids to facilitate the parts of the discussion focused on roadway design. To create the images, I took photos of two local streets: one a two-lane residential street with parking, the other a four-lane arterial lined with commercial, business, and residential in various parts. I then used Adobe Photoshop® to alter the images to represent different roadway designs. These alterations resulted in the visual aids shown in Figure 6 through Figure 15. I enlarged the photos and pasted them on 11x17 boards to display while discussing perceptions of fear and comfort associated with the roadway. A second copy of each image was passed around for reference during the discussion. Respondents were able to access any design for comparison.

I hired an assistant to help me observe and take notes on tone and body language to supplement the digital recordings of each session. In each case, the group sat around a table to facilitate a sense of community and also enable the digital recording.

Data Analysis

After each focus group, I reviewed the notes and listened to the digital recordings to make additional notes. I used notes from the first two focus groups to revise the focus group script before facilitating the remainder of the groups. In particular, one of the streets I had selected for exploring roadway design preferences had a unique aspect that confused several of the participants and distracted the discussion. After discovering this distraction during the first two focus groups, I selected a new photo based on their feedback and experienced no further problems with that section of the discussion.

I also used the recordings to note salient themes and tone of voice. I compared these notes with the notes from my assistant, which described body language. When reporting and interpreting findings in this chapter, I relied on these verbal and non-verbal language cues. For example, I interpreted a vigorous head nod to indicate agreement with a statement.

The themes presented in this chapter aim to give an overview of the types of discussion that took place during the focus groups. When statements are quoted here, I have included an approximation of their representativeness.

Focus Group Findings

The focus group participants provided a wealth of information about perceptions of bicycling risk, experiences driving and bicycling, influences on attitudes and behavior toward cyclists, and roadway design preferences. In this way, the groups acted as a testing ground for concepts in the survey and the adequacy of the visual aids. This section describes the main findings from the focus groups.

Opinions about the Benefits and Drawbacks of Bicycling

To gauge an overall opinion about bicycling among the non-cycling drivers[6], I asked them about the benefits they saw to having bicyclists in their cities. The focus group participants were generally neutral or enthusiastic about bicycling, with over 30% citing benefits to the environment such as reduced pollution and fossil fuel use from bicycling. Another 15% cited the corollary benefits of fewer cars on the road, including less competition for parking spaces. One non-cycling driver said, “I appreciate the ones who are willing to do that (ride a bike), because I’m not. But that takes another car off the road.” About 23% named cycling’s physical health benefits; as one said, “I admire the physical part of it—I admire people who ride bikes.”

Concerns about cyclists’ safety arose in all of the non-cycling drivers’ focus groups. About 30% of the non-cycling respondents noted worries about hitting cyclists or cycling danger in general. According to one, “In Berkeley, we have the danger of people being run over.” Another noted, “my son did bike…and after he…stopped, I was so glad, so grateful, because I worried about it constantly.” Three of the participants had good friends who had experienced severe injuries from bicycling, and those crashes had significantly influenced the participants’ opinions about bicycling safety. In addition, nearly half of the non-cycling drivers suggested that they were annoyed with or worried by bicyclists who break traffic laws. As one said, “they don’t believe in stop signs...”

Only one focus group participant was consistently negative toward bicyclists, repeatedly calling them “scofflaws” and saying that she did not want bicyclists in her city or want to spend public money on bicycle facilities that could encourage bicycling. However, this participant also made one of the most thoughtful observations about cycling: “Basically, the laws were set up and everything is built to accommodate mainly pedestrians and automobiles, and there really isn’t any good accommodation for bicycles. They don’t really fit into the given structure too well, and that is exacerbated by the fact that bicyclists are scofflaws. Maybe part of the reason that

[6] The question about benefits of bicycling was added to the focus group script for non-cycling drivers after the first focus group had taken place, so percentages represent a base of 14 people instead of 19.

they are scofflaws is because things aren't really set up for them to begin with, but that's no excuse."

Influences on Bicycling Habits

To get an idea of the focus group participants' exposure to bicycling, I asked them about their past and current bicycling experience, as well as whether friends or family currently bicycle. All but one of the 19 non-cycling drivers bicycled as children, and approximately 60% of them had bicycled as adults at some point. How much one cycled as a child did not strongly correlate with whether one bicycled as an adult. Three of the respondents volunteered that they did not currently bicycle because of the hills near their residence; another four stated that they were dissuaded from bicycling due to concerns about safety.

Most of the non-cycling participants knew "a few" people who bicycled currently, and almost 50% had close friends and family who bicycle. Of those friends and family, over half bicycle for utilitarian purposes, while about one-third bicycle for recreation. The only person in the focus groups who did not have any friends or family who currently bicycle was also the person who repeatedly stated that cyclists were "scofflaws." [7]

There was a range of riding frequency within the focus groups for bicycling drivers. About 64% of cycling drivers bicycled several times a week ("frequent" cyclists), while the remainder rode 1-2 times/week at most. About 36% of cyclists rode only for utilitarian purposes (all of whom were frequent cyclists), while only 18% rode just for recreation. Those who rode more often and for more trips were much more likely to use all street types for riding; those who rode only for recreation tended to limit their use to off-street paths. One recreational cyclist also used sidewalks when on busy streets. The cycling drivers had generally been cycling for years and most reported having bicyclists among their family and friends.

Drivers' Perceptions of Their Own Behavior

I also asked questions about the participants' behavior around cyclists to understand how their behavior may contribute to or detract from bicycling safety on the roadway, and to gauge the extent to which the drivers were aware of how their behavior could affect cyclists.

The drivers in the focus groups generally considered themselves to be good drivers. One summarized his impressions as, "sounds like all of us are extremely careful about bicyclists because we don't want them to get hurt." When asked questions about specific actions such as passing or turning, they all reported looking around for potential hazards and to trying to give cyclists extra room when passing—although one participant admitted to having "almost (hit people with her car door) on multiple occasions."

Part of this care was attributed to the experiences of family and friends. One woman's sister regularly bicycles, so this participant reported thinking of her sister when she sees bicyclists while driving. Another woman knew people who had been seriously injured while bicycling, which she said "raised (her) awareness and probably changed (her) behavior." Two of the other non-cycling drivers reported having never crashed or come close to crashing (i.e., a near miss) with a cyclist because "there (were) lots of bikes in (my) neighborhood", necessitating paying attention.

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[7] A "scofflaw" is someone who flouts the law—particularly laws that are difficult to enforce (such as, perhaps, stopping at stop signs when police aren't around).

The cycling drivers unanimously believed they were better, more conscientious drivers due to their experiences bicycling, with a couple of participants even stating that they drive slowly behind bicyclists for the purpose of "protect(ing)" them from other drivers.

Drivers' Perceptions of Other Drivers' Behavior
In the same vein as the previous topic, I wondered how the focus group participants reacted to other drivers' actions on the roadway. The participants seemed to be split when asked opinions about other drivers' behavior. On the one hand, a couple of people expressed annoyance with what they perceived to be overly considerate behavior toward cyclists (for example, a reluctance to pass—perhaps referring to the protective behavior cited above). As if to prove their point, two non-cycling drivers in another focus group stated concerns that other drivers would behave aggressively toward them if they did not quickly pass cyclists. Others reported seeing drivers "taunt cyclists by getting too close" or honking their horn – "that's pretty frightening," stated one participant. Overall, nearly 40% of non-cycling drivers reported feeling concerned by other drivers' behavior toward cyclists. In addition, 16% of non-cycling drivers mentioned concerns about drivers opening car doors in the paths of oncoming bicyclists, while another couple of participants spoke of worries about the prevalence of distracted driving and driving under the influence. The cycling drivers expressed particular concerns about drivers endangering cyclists on major streets, particularly given experiences they've had with aggressive drivers.

Drivers' Perceptions of Bicyclists' Behavior
I also asked questions about perceptions of bicyclists' behavior to understand what might irk or scare the focus group participants while driving near cyclists. Some topics arose consistently within the groups (for example, the need for predictability), while others arose in only one group. I examined these topics further in the survey to see how these themes pertained to the general population.

The biggest issue for drivers was the lack of predictability when encountering cyclists. Over half of the non-cycling drivers mentioned that they were unsure how bicyclists would behave, particularly at intersections. Several mentioned the frustration of watching cyclists run stop signs or red lights, at times endangering themselves and others. One stated, "you don't feel like (some bicyclists) are going to stop. I try to follow the rules. I wish more of them at times would follow the rules." About 16% of non-cycling drivers stated annoyance with bicyclists who change their behavior from that of a driver to a pedestrian for the sake of convenience. For example, "Obviously if I see someone on a bike who's crossing in front of me, I'm not going to try to hit them, but my mental reaction depends on my mood. Sometimes I'm perfectly willing to slow down and let them ride right across, and sometimes I think, 'damnit, if you want to be a pedestrian, get off the bike!'" Over 40% expressed a desire for bicyclists to consistently use lights at night, while 16% talked about wanting the predictability of hand signals.

Related concerns about behavior during Critical Mass and bicycling club rides also surfaced in one of the non-cycling focus groups. As one described, "Bicyclists are bad enough in 1s, 2s, and 3s. Have you ever seen a bicycling club 200 strong…and they all ride right through the stop signs? You're sitting there waiting three minutes to get through the intersection!" Another related, "That's every week (where I live)."

Perceived danger also emerged as a concern resulting from bicyclists' behavior. Over 30% of non-cycling drivers linked cyclists' actions to increasing the danger for drivers, particularly in the case of bicyclists passing drivers on the right. One participant told of the annoyance of having to pass bicyclists on the roadway, particularly when the bicyclist has passed her on the right (her "blind side") at a light or stop sign, only to have her catch up and pass the cyclist again, necessitating a repetition of the cycle. Similarly, one driver expressed feeling "startled by bikes that catch up with (him) at traffic lights", worrying that he could hit the cyclists if they swerved. Another said, "I don't know if it's arrogance or they just lose consciousness or…stop paying attention...It's just terrible…they will just drift out into your lane…going 5 mph… it's like they're oblivious." In a particularly dramatic example, another participant stated, "I've seen fatal accidents caused by bicyclists who weren't scathed at all...two cars ended hitting each other because they were trying to swerve and avoid a bicycle rider."

Two of the non-cycling participants reported having been hit or almost hit by cyclists while walking. For example, "as a pedestrian, I've almost been hit by these cyclists (on multi-use paths) several times." Concerns about bicyclists riding with children also arose in one of the non-cycling driver focus groups, with three out of six people expressing worry. One said, "(it) bothers me to see bicyclists who tow kids in trailers behind them; the kids are in danger because the trailer is low to the ground and not visible….(I would feel better if) the child (were) in front." Another agreed, "(the flag that comes with many trailers) does not help."

Three of the non-cycling drivers also discussed "bicycle rage." One told the group, "I (once) passed a bike rider in (the regional park) Tilden…and she came up behind me and she had this gun that shot this projectile right through my left rear tire." To which another responded, "I believe that. That's what I call bicycle rage…I was going to go into the canyon from (local town) Orinda and a guy had come down the road and boy he gave me the finger and he was yelling at me. I had done nothing! I thought at the time, 'I'm so glad he doesn't have a gun."

These discussions painted a picture of drivers operating with much less predictability than they desire, and helped form several of the survey questions about bicyclists' behavior and various types of bicycling risk in the survey.

Cyclists' Perceptions of Drivers' Behavior

I discussed experiences with crashes and near misses with one of the cycling driver focus groups. Two of the participants reported having been hit while bicycling by drivers who pulled out of parking spots or driveways without looking or tried to beat them to a turn and cut them off. Nearly all reported near misses with drivers distracted by looking for parking, buses pulling toward or away from bus stops, or aggressive drivers. In addition, over half of the participants felt that road rage was common in some Bay Area neighborhoods, recalling that drivers had yelled at them for being on the road. One participant stated that her family members believe that cyclists don't belong on the road because they are more vulnerable, less powerful, and would "lose in a competition, so why even have the competition? Just don't cycle." One of the women who had been hit said, "it's unfortunate we cyclists cannot have conversations after confrontation…people are often sorry, don't mean or want to hit cyclists, but they're afraid and they don't grasp that it's their responsibility to pay more attention and that they don't own the road." The frequency of crash and near miss experiences among the focus group participants suggested that I should further explore the topic in the survey.

Cyclists' Perceptions of Other Cyclists' Behavior

The cycling drivers were also critical of other cyclists' behaviors. One stated that he is "amazed" at cyclists "who ride without lights or blatantly blow through red lights or stop signs." Nearly all reported regretting that so many cyclists don't predictably obey the law. As one participant said, "I can see that drivers are nervous about what I will do" when approaching a stop sign. As with the non-cycling drivers, the bicycling drivers would feel more comfortable if cyclists would more consistently use lights at night and obey the law with regard to stop signs and red lights. These findings reinforced that I should study cyclist behavior in my survey.

Support for Modified Traffic Laws

While participants repeatedly related their annoyance with cyclists who break the law, most of the participants suggested that the frustration arose from the lack of predictability from the cyclist, and therefore a sense of increased danger. One participant suggested that he was frustrated both with the lack of predictability and the sense that it was "unfair" that cyclists got to break laws when he had to follow them. After consistently hearing the frustration, I added a question to the focus group scripts to gauge opinions about modifying traffic laws to make some commonly cited infractions legal. For example, in Idaho, cyclists are legally allowed to treat stop signs like yield signs and proceed without stopping completely if no one else has the right-of-way (colloquially known as "stop-as-yield"). They are also allowed to treat red traffic lights as stop signs—once they have stopped completely, they can proceed with caution if no one else has the right-of-way ("red light-as-stop"). These laws have been proposed in California, and would change the legality of two of the actions that focus group participants found frustrating, so I took the opportunity to explore their popularity.

Nearly uniformly, cycling drivers suggested support for the a law that would allow "stop-as-yield", but were uncomfortable with a law that would allow "red light-as-stop." As one said, "I wouldn't like to see 'light equals stop sign'; however, 'stop sign equals yield' is just codifying what's de facto anyway." The lack of certainty associated with cyclists' actions seemed to have the biggest influence on the support: "this is one of the most important issues in terms of the anxiety that happens between cars and cyclists—when I come to an intersection in a car, I don't know what the cyclist is going to do…obviously any car that breaks a rule is expected to get a ticket, but cyclists are 'beyond the law.'"

The non-cycling drivers were generally more skeptical, but open to the stop-as-yield aspect of the law. For example, "That would be okay with me only if…(in the event that the cyclist went through the sign without yielding and something happened), then it would be (the cyclist's) fault automatically." Another suggested, "It'd be worth trying, because that's what's happening anyway." No one supported the part of the law that would allow a cyclist to legally go through a red light after stopping. As one said, "where would be the cut-off? (I like) the security of the red light and being assured that no one would be coming." This divergence of opinion about the two parts of the law suggested that it would be interesting to further explore through the survey.

The Influence of Training

Cycling education emerged in a couple of the non-cycling focus groups, with the drivers generally bemoaning the lack of required education for bicyclists. In particular, one participant believed that educating cyclists about riding with (rather than against) traffic and obeying laws would increase predictability. Others wanted cyclists to be aware of the potential outcomes of their actions (such as not using lights or not wearing helmets). Still others noted the benefit they would receive as drivers if education were more substantial. One suggested that he doesn't look and doesn't expect cyclists, even in the Bay Area, as he grew up in Los Angeles "without the habit", and is "not used to checking for bike lanes."

Roadway Design Preferences

I showed the focus group participants photos of several roadway designs to test their reactions as cyclists and drivers, and to gauge whether the subject were worth further exploring in the survey. The photos are pictured in Figure 6 through Figure 15. The participants provided feedback on the selection of roadway designs, the quality of the photos, and their impressions of comfort as drivers and cyclists for the treatments chosen. This feedback helped me to substantially improve the photos and modify the selections presented to the survey respondents. This section describes how the participants reacted to the various designs.

I began the section by examining perceptions of residential streets, in order to establish a baseline for perceptions of cycling and driving safety among the focus group participants. However, the majority of roadway design photos were based on commercial streets, which tend to carry traffic at higher speeds than residential streets, and, due to multiple land uses, present complications such as parallel parking that create a busier street with increased opportunities for conflicts.

Non-cycling and Cycling Drivers' Opinions about Roadway Design for Residential Streets

There was consensus among non-cycling and cycling drivers that bicyclists would generally be expected on any residential street as pictured in Figure 6. The participants uniformly felt comfortable driving and bicycling (for cycling drivers) in this situation, due to its low-speed and residential nature. In addition, almost everyone suggested that adding the bicycle symbol as in Figure 7 further conveyed that bicyclists were to be expected, although a couple of the non-cycling drivers were confused by it. One cycling driver said, "I would feel safer (with the bicycle symbol) because people wouldn't be surprised by me on a bicycle." Another suggested that "the marking makes the (car drivers) less belligerent; bikes have the 'right to be there.'" A non-cycling driver remarked, "I would still expect mostly cars, but in this case, I'd at least have been thinking of checking for bicyclists." These statements suggested that roadway markings can convey legitimacy for bicyclists and predictability for bicyclists and drivers, two themes that I explored further through the survey.

Figure 6. Residential Street

Figure 7. Residential Bicycle Boulevard

Non-cycling and Cycling Drivers' Opinions about Roadway Design for Commercial Streets
After briefly debating the residential streets, the discussion turned to the comfort and expectations of various roadway designs for commercial streets. The perceived predictability of the design played a large role in the comfort associated with the facility. Both non-cycling and cycling drivers preferred designs that conveyed how they and others using the roadway should behave, with consensus among all participants that bicycle treatments (e.g., stencils, marked bicycle lanes) indicated that they should expect to see bicyclists on the commercial streets. I explored this concept of legibility further through the survey. In addition, the non-cycling participants uniformly preferred roadway designs where bicyclists had their own designated space—and the more visible the space, the better. As one participant stated, "If bikes are going to be on (the road), I'd prefer it to be marked." Cycling drivers were less clear about their preferences, preferring separated space in some ways, but citing complications such as making left turns and being hit by car doors. This section elaborates on participants' reactions to the various treatments.

Roadway designs with shared space
Roadway designs that keep bicyclists and car drivers in the same space were not enthusiastically received by the non-cycling drivers. For example, when shown a photo of the green shared lane in Figure 8 (a fairly new treatment in which cyclists are to ride in the middle of the lane, but that car drivers can also use), the non-cycling drivers[8] immediately disliked it, with one saying he didn't "understand how it works", while another said "this makes me very uncomfortable." A third participant called the design "stupid, crazy, and dangerous." About half of the non-cycling drivers expressed the concern that the treatment "doesn't make sense if the cyclist can't go the speed of traffic." There was general agreement that the green shared lane was less preferable even than no treatment (Figure 9) because of the assumed danger to cyclists and the lack of trust

[8] The photo of the green shared lane was added after the first two focus groups, and was therefore only shown to 14 non-cycling drivers and 4 cycling drivers.

that it could actually work well. Only two non-cycling participants expressed an opinion that the treatment might be beneficial once people were instructed about how to properly use it.

The cycling drivers reacted differently depending on whether they were picturing themselves as car drivers or as cyclists, although in both cases at least half of the members expressed uncertainty about the treatment. When picturing themselves as drivers, half of the group indicated that the symbol would increase awareness: "(the) symbol makes me wonder (about) bicyclists; I'd precede with caution." However, there was also concern about a lack of familiarity for half of the group. For example, "I'd find this very disconcerting; I've never seen this, so I wonder, "what the heck is this?"

When picturing themselves as cyclists on the roadway, the more frequent cyclists felt less comfortable with the treatment, saying they would "just ride on the right anyway." In contrast, those who bicycle less frequently received it more enthusiastically. One said, "I'd take the lane; it's telling me to take the lane." This concern about lack of familiarity and legibility among the focus group participants suggested that these themes should be further tested in the survey.

Figure 8. Commercial Street – Green Shared Lane

We also discussed the "shared space" design that is the generic roadway without any bicycle facilities, as pictured in Figure 9. Non-cycling drivers routinely preferred separated space over the no-treatment option, in large part because of safety concerns. In addition, the majority of participants (cycling and non-cycling drivers) stated that they would be less likely to expect bicyclists on this type of roadway because there was no bicycle marking. Nearly 20% of participants were specifically concerned about having to slow down and move around the cyclist or switch lanes. One non-cycling driver noted, "(I'm) particularly worried about bikes between me and the parked cars…I'm not like a fighter pilot in my car…you know, I just want to make sure there's room, so I'll tend to slow down and hope that I can swerve (around the cyclist) or move into the next lane." Another stated, "there are so many blindspots with vehicles that it's an invitation to problems…and if you hit a cyclist, you do a lot of damage–not so with a car." A third agreed, "bikes are so much smaller and harder to see." The cycling drivers did not speak this way about cyclists, but a couple did report driving slowly behind a cyclist in this circumstance in order to "protect" him from other drivers. In addition, the general consensus was that a "no treatment" option (as in Figure 9) was preferable to an option that seemed unclear (as in Figure 8). These statements from the non-cycling drivers underscored that drivers may perceive multiple benefits from separation (e.g., through bicycle lanes) that are not commonly discussed, such as predictability, increased perceptions of safety, etc. These ideas were tested through the survey.

The majority of cycling drivers indicated that they would bicycle on this type of facility, but for most it would be less preferable than riding on roadways designated for bicyclists, ceteris paribus. This preference seemed to correlate with experience, an association I tested in the survey.

Figure 9. Commercial Street – No Bike Treatment

Shared lane markings ("sharrows"), pictured in Figure 10, drew a more mixed response. Among the non-cycling drivers, the sharrow was weakly received, with about 11% saying they didn't see it as different than a roadway without markings, while another 11% suggested that people may not "know what (it) means." Still another 11% thought that the sharrow did make a difference and told drivers to expect bicyclists. Some of the cycling drivers were more enthusiastic. According to one, "(the sharrow) makes a *huge* difference to me; I'm just telling you how I drive: this actually says, 'expect to see a cyclist coming down here… be aware.'" About half of the cycling drivers (as well as one non-cycling driver) expressed concerns that the sharrow was painted too close to the "door zone."[9] As one said, it "would feel uncomfortable"—although it was still preferable to no treatment.

When considering how they would feel as cyclists, the cycling drivers uniformly preferred roadways with bicycle markings, although several expressed concerns that a marking within the door zone actually compromised their safety. These participants liked the sharrow

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[9] The "door zone" is the common name for the space into which a car door opens, which can be three to four feet wide. Unfortunately, this is often the space available for a striped bicycle lane on a street, so many bicycle lanes are considered to be within "door zones."

much more than the no treatment scenario, with one saying, "(I feel) much safer on this one—I wouldn't even consider (riding a bike on a street without a bike facility)." While the cycling drivers thought this sharrow should have been located further into the traffic lane, nearly 40% preferred it to the striped bicycle lane in Figure 11, as they viewed the placement of the bike lane to be too close to the door zone. Several also thought that the sharrow conveyed more flexibility, particularly with regard to needing to exit the bike lane to make a left turn, expressing worries that drivers would not know the laws and might get angry with them for leaving the lane. This variation in responses to the sharrow, as well as the potentially negative aspects of a bicycle lane, suggested that these concepts should be further explored through the survey.

Figure 10. Commercial Street – Shared Lane Marking

Roadway designs with separated space

Roadway designs showing separated spaces for drivers and cyclists also received mixed reviews from the focus group participants. The striped bike lanes (pictured in Figure 11) elicited a positive reaction from most of the non-cycling drivers, but less so from the cycling drivers. For example, one non-cycling driver said, "(a) striped bike lane delineates the space better and creates more responsibility and predictability for the driver and cyclist." Another stated, "(b)ased on the bike lanes, I would expect bikers." Yet another saw bicycle lanes as particularly beneficial when considering the fact that bicyclists are not required to have any formal roadway education, so drivers cannot be sure that the bicyclist will behave in a predictable way: "…by having the line or the designated space, the driver then has a greater sense that the cyclist will be predictable." However, another non-cycling driver brought up the conflict between opening a car door and an oncoming cyclist. "I've been in situations when the cyclist swerves into my lane because of a parked car opening the door, and that makes me swerve and puts me in danger." I used this variety of impressions of the bicycle lane to formulate questions about the benefits and detractions of bicycle lanes on the survey.

Cycling drivers also preferred the striped bicycle lane for driving near cyclists: "For me, the line delineates the space; that marker makes me more conscious when parking and opening the door into traffic; (I) would expect to see more bicyclists there." As cyclists, however, the cycling drivers were more mixed in their opinion, as noted in the discussion about sharrows, above. About one-third expressed concerns about being confined to the bike lane and potentially irking drivers if they need to leave.

Figure 11. Commercial Street – Striped Bicycle Lane next to Parking Lane

In contrast to the striped bicycle lane, the green painted bicycle lane pictured in Figure 12 was consistently positively viewed. Nearly 80% of the non-cycling drivers liked it, saying that it would increase awareness for drivers. One said, "If you miss (the symbol in the striped bike lane in Figure 11), you don't necessarily know it's a bike lane… whereas (the green painted lane) tells you every foot." Similarly, the cycling drivers liked the green lane while driving. One exclaimed, "(This is) clearer! I like it a lot more because there is no guessing…if I was in a car and opening the door into traffic, I'd be more aware of the lane because of the green paint." Another linked the paint to a message that bicyclists belong: "This immediately tells me that this is a city that welcomes bicycles everywhere; they are respected and welcome here; it's like a welcome mat for bicycles."

As cyclists, the reaction was mixed. Half of the participants clearly liked it, with one saying, "I like (the green painted bike lane) because…I'd be more comfortable in my space…it's really clear…because it's painted on both sides, I feel safer that the cars know (not to) cross that white line and the people in the parked cars know (not to) intrude on the green." The other half of the participants liked the treatment, but was still hesitant about being trapped in a bicycle lane. For example, "I guess that's so visible that I feel like they'll give us the benefit of the doubt, (but) I still like the sharrows because you have more leeway…(the bike lane is) like a barrier that we're not supposed to get out of." Two of the cycling drivers also expressed concern about how slippery the paint would be as a riding surface.

Figure 12. Commercial Street – Green Painted Bicycle Lane next to Parking Lane

Two of the least liked designs included those with a bicycle lane between a parking lane and the sidewalk, as pictured in Figure 13 and Figure 14. While the "inside bike lane" has been used for years in cities with high bicycling rates like Copenhagen, it was unanimously rejected among the non-cycling focus group participants who reviewed it—with or without the barriers.[10] These participants called the design "terrible" and expressed serious concerns about the need to load and unload passengers, particularly the elderly and very young. They also expressed concern that a growing elderly population needed access to the curb to help with disembarkation. Cycling drivers were also generally concerned about passengers, whom they believed would not be accustomed to needing to check for cyclists before opening their doors. In addition, one participant raised a concern about drivers making left turns and not being able to see oncoming cyclists due to the parked cars.

As cyclists, the perceptions of the treatment differed. Three of the four cycling drivers who reviewed the barrier-separated lane mentioned being more cautious in the situation due to the need to watch out for opening doors and pedestrians leaving the curb. However, the majority also believed that this treatment would welcome many different users. One participant observed, "…oblivious passengers (would be) problematic…(but) it's definitely better for people with kids." Another agreed that it was "very friendly to different kinds of people with different speeds and abilities on the cycle."

[10] The photos of the barrier-separated and inside bike lanes were added after the first three focus groups, and were therefore only shown to 6 non-cycling drivers and 4 cycling drivers.

Figure 13. Commercial Street – Striped Bicycle Lane between Parking Lane and Curb

Figure 14. Commercial Street – Barrier-separated Bicycle Lane with Car Parking

In contrast, the barrier-separated lane without parallel parking pictured in Figure 15 was considered much more acceptable for driving and cycling—despite impressions among several of the cycling drivers that the treatment conveyed a higher road speed (generally not a desirable characteristic for cycling) than a treatment that is not separated from traffic by barriers. The biggest concern raised by cycling and non-cycling drivers in this scenario was the unlikelihood of neighborhood support for removing parking (a concept tested in the survey). However, both drivers and cyclists liked the treatment. One cycling driver noted, "this says that this lane is safe for adults and kids and all different kinds of cyclists; you'd be relaxed in doing it."

Figure 15. Commercial Street – Barrier-separated Bicycle Lane, No Parking

Summary of Key Findings

As can be seen from the findings discussed above, the focus groups provided rich material about the beliefs, experiences, and preferences of both cycling and non-cycling drivers. The following themes emerged as important enough to further test through the survey.

Influences on bicycling habits and barriers to bicycling
The bicycling habits of friends and family seemed to influence the participants' attitudes toward bicycling, mirroring what has been found in research about motorcyclists. However, the social network effects were not strong enough among focus group participants to overcome other barriers to bicycling, such as physical ability, topography, and fear.

Opinions about bicycling in one's city (benefits, drawbacks, and support)
Many of the non-cycling drivers noted benefits to having bicyclists in their cities, including reduced fossil fuel usage and pollution, and increased physical health. However, these drivers also expressed concerns about safety, and not just safety for the cyclist himself. Several of these participants suggested that they worry that cyclists will endanger others on the roadway, including drivers and pedestrians, and that they may put their children at risk by cycling with them. In addition, although it was clear that participants linked roadway design to increased cycling and cycling safety, they were not uniformly willing to sacrifice parking or support public funding for the construction of the facilities.

Drivers' perceptions of their own and other drivers' and cyclists' behavior
The drivers in the focus groups (cycling and non-cycling) tended to believe that they were conscientious, even though a few admitted to passing close or forgetting to check before opening a car door or making a turn. Several expressed concern about other drivers' behavior. With regard to cyclists, the recurrent theme for drivers was predictability. This concept seemed to

influence preferences for roadway design, complaints about bicyclists' behavior (e.g., running stop signs or not using lights at night), and worries about safety.

The prevalence of collisions and near misses
A majority of the cycling drivers in one group reported having either been hit or almost hit (a near miss) while bicycling, suggesting that these events might be more prevalent than crash statistics (which aggregate only reported crashes) would suggest. This finding was particularly noteworthy given that near misses are rarely if ever reported, and little research has investigated them to date.

Support for modified traffic laws and knowledge of current traffic law
The cycling and non-cycling drivers both stated frustration with bicyclists breaking traffic laws. Both were also open to the "stop-as-yield" law, but less so to the "red-light-as-stop" law, as a way to legalize the common yielding behavior of cyclists that seems only to generate confusion and reduce predictability in current practice. One group of cycling drivers also expressed concerns that drivers did not know traffic laws pertaining to bicycle lanes, which in turn affected these participants' preferences for roadway design.

Roadway design preferences as a driver and a cyclist
Bicycle symbols and markings were seen by all to significantly influence expectations about who will use the roadway. With regard to preferences for treatments, cycling drivers and non-cycling drivers were generally aligned (although not always) about the types of bicycle treatments they would like to see on the roadways as drivers. Cycling drivers often held different opinions about roadway designs when picturing themselves as cyclists in contrast to drivers.

Informing the Survey
The focus groups contributed to the survey in several ways. First, and perhaps most importantly, I drew on the findings from the focus groups, in addition to the gaps identified in the literature review, to inform the survey. In addition, after each of the focus groups, I solicited feedback about the various parts of the discussion, including what the participants would have like to have discussed had we had more time. If the literature review suggested that more knowledge about these areas would be helpful, I added them to the survey, as well. The participants also offered constructive criticism about the roadway design photos. For example, participants expressed confusion about the brake lights of cars, as well as the extent of the parking lane in the photos. Based on this feedback, I altered and substantially improved the photos for the survey.

A copy of the survey and the revised roadway design photos can be found in Appendix B. In the following chapters, I introduce the survey and describe the analysis and resultant findings.

Chapter 5 –Survey of Drivers and Cyclists: Introduction & Initial Analysis

To examine attitudes toward cycling, the perceived risks of cycling, and roadway design preferences in an urban context, I conducted an internet survey of Bay Area drivers and bicyclists in the summer of 2011. In this chapter, I present summary statistics for the survey population. In the following chapter, I elaborate on the findings from the survey about roadway design preferences for drivers and cyclists. In Chapter Seven, I present the findings about survey respondents' perceptions of risk and support for bicycling.

Key findings from this chapter include that non-traffic-risk barriers strongly influence infrequent and potential cyclists, and that women are more affected by all barriers to bicycling. I also found significant differences according to cycling frequency regarding a desire to support bicycling in one's city and beliefs about safe bicycling in urban areas. Findings about knowledge of roadway laws indicated that no one group is particularly better educated than the others, regardless of cycling frequency.

Internet Survey Methodology

In July 2011, I emailed a link to an online survey to a convenience sample of 1,177 people living in the nine-county San Francisco Bay Area who had previously participated in UC Berkeley research on the Bay Area FasTRAK toll tag and "casual carpooling" across the Bay Bridge, and who had agreed to participate in future research. While the original research had been designed to represent the general population, I cannot guarantee that the final sample does so due to self-selection among the respondents for participating in future research and my research study in particular. The survey was hosted by the online survey business SurveyGizmo, and all data was anonymously collected and securely stored online. To participate in my survey, respondents were asked if they either drive a car or ride a bicycle on at least an occasional basis. People who solely walked or used public transit were thanked for their interest and dropped from the survey. Upon completion, I offered an incentive in the form of a $5 gift card to a store of the respondent's choosing. Because the gift card form required a unique email address that was stored independently of the survey responses, I was able to track the response rate even though the survey itself was anonymous. I calculated the response rate using email addresses because, while the link only worked one time per computer, some of the original email recipients forwarded the email to others who were not on the email list.[11] I received 463 valid, completed surveys from email list respondents, for a response rate of 39%.

Figure 16 shows the number of survey respondents from each county in the Bay Area. It is clear that the majority of survey respondents are concentrated in the counties of San Francisco, Alameda, and Contra Costa. While I would have welcomed more respondents from the other areas, this geographic representation reflects the counties with the most bicycling in the Bay Area, as bicycling tends to be more common in the more populated more densely developed areas. This representation therefore matches well with the aims of this study. Future research could investigate the low rate of bicycling in rural and exurban areas.

[11] I became aware of this when multiple people from the same local bicycling advocacy organization filled out the gift card form—something they could only access upon completion of the survey. I did not want their responses to bias the results, so I only used the responses from people for whom I had email addresses.

Figure 16. Number of Respondents from Each County in Study Area

Internet Survey Instrument

I developed the survey questions based on gaps identified thorough the literature review presented in Chapter Two, as well as the results of focus groups described in Chapter Four. The survey investigated the following themes:

1. Perceived risks of bicycling
2. Non-safety barriers to bicycling
3. Beliefs about the benefits and drawbacks of cycling, and support for bicycling
4. Influence of family, friends, and personal experiences on attitudes toward and beliefs about bicycling
5. Influence of the built environment on beliefs about and attitudes toward cycling
6. Near miss and collision experiences as a bicyclist and driver
7. Behaviors as a cyclist and driver
8. Knowledge of roadway laws as a cyclist and driver
9. Opinions about proposed roadway laws
10. Preferences for roadway design as a cyclist and driver
11. Demographic influences on the aforementioned themes

I pilot-tested the survey with two groups of graduate students and a 99-person, randomly-selected sample of the email list before sending it to the remainder of the email list. To minimize response bias within the survey, I randomized the answer choices and the question order where possible. Due to the focus on driver-bicyclist interactions, this survey did not ask questions about pedestrian-bicyclist interactions. A copy of the survey can be found in Appendix B.

Categorizing Respondents

Table 1 shows a breakdown of the respondent population, categorized by bicycling frequency. Based loosely on a survey by Dill and Voros (2007), these categories were determined by asking people how often, weather permitting, they bicycled for "work/school or errands" and how often they bicycled for recreation. The categories equated to the following:

- **Non-cyclist**: a respondent who reported never bicycling, or bicycling less than once per year for either utilitarian or recreational purposes, and who would not consider bicycling for any reason in the future
    - **Potential cyclist**: non-cyclist who indicated a willingness to consider bicycling for any reason in the future
- **Occasional cyclist**: a respondent who reported bicycling at least once per year but less than several times per week for either utilitarian or recreational purposes
    - **Yearly cyclist**: occasional cyclist who reported bicycling at least a few times per year for any purpose, but less than several times per month
    - **Monthly cyclist**: occasional cyclist who reported bicycling at least several times per month for any purpose, but less than several times a week
- **Regular cyclist**: a respondent who reported bicycling at least several times per week for either utilitarian or recreational purposes
    - **Weekly cyclist**: regular cyclist who reported bicycling at least several times per week for any purpose, but not daily
    - **Daily cyclist**: regular cyclist who reported bicycling every day for any purpose

When I make distinctions between weekly and daily cyclists and all others (non-, potential, yearly, and monthly cyclists), I refer to the former as "regular" cyclists, and the latter as "non-regular" cyclists.

Statistical Methods

I analyzed the survey data using Microsoft Excel and STATA IC, Version 12 (StataCorp, College Station, TX) to conduct a combination of Chi Square, correlation, and analysis of variance tests, in addition to multivariable modeling. The final dataset included over 900 variables, so I used STATA to conduct principal components analysis ("PCA") and factor analysis ("FA") to reduce the number of variables where possible. Because principal components are easier to interpret, I used the PCA results when approximately equal to the FA results. Due to endogeneity in my dataset, I used a structural equation model ("SEM") to simultaneously model several regression equations to predict bicycling support. Structural equation modeling also allowed me to conduct latent factor analysis to explore how various latent constructs related to my dependent variables might influence my results.

I attempted a SEM to model the design preference scores in Chapter Six, but, due to having been predicted from a sub-sample of the data, I lacked the sample size to test the full relationships in a simultaneous equation model. See Appendix C for tables presenting summary statistics of all of the variables and bi-variate relationships between the variables.

Survey Demographics

The data in Table 1 describe the survey population. Not surprisingly, weekly and daily cyclists are significantly younger than non-cyclists, and there are significantly fewer female yearly, monthly, and daily cyclists. There were more female weekly cyclists than male, a split almost certainly affected by response bias given Census data from the Bay Area that indicate that men bicycle for work from 1.75 to 5 times more than women (American Community Survey, 2006-2010). The overall trend of more women respondents than men could reflect the tendency of women to participate more than men in surveys (Curtin et al., 2000).

Table 1. Survey Population Characteristics

	Non-cyclists (n=45) %	Potential cyclists (n=145) %	Yearly cyclists (n=100) %	Monthly cyclists (n=71) %	Weekly cyclists (n=76) %	Daily cyclists (n=26) %
Age						
18-24	4	4	5	6	9	12
25-34	27	36	25	48	38	50
35-44	11	21	23	10	18	12
45-54	13	18	35	21	18	8
55-64	27	19	10	13	14	19
65-74	13	1	2	3	-	-
75+	4	1	-	-	-	-
	Spearman's rho significant ($p \leq 0.01$)					
Sex						
Male	29	35	54	59	43	62
Female	71	63	46	39	55	38
	Chi-square significant ($p \leq 0.001$)					
Race/Ethnicity						
Caucasian or White	49	54	60	62	70	65
*Hispanic	7	3	5	4	7	-
African American or Black	9	6	3	4	4	-
Asian	13	21	14	13	5	23
Native American or Alaska Native	2	1	-	-	-	-
Nat. Hawaiian or Pacific Islander	-	1	2	1	1	-
Other	9	7	5	11	7	4
Two or more races	4	5	7	1	4	4
Decline to say	7	2	4	3	3	4
	Fisher's exact not significant					
Driving Frequency						
Never	-	-	3	3	7	-
Less than once per week	7	2	4	8	13	38
One to three days per week	22	26	15	18	38	54
Four or more days per week	71	71	78	70	42	8
	Spearman's rho significant ($p \leq 0.000$)					
Annual Household Income						
Less than $35,000	20	14	9	17	16	19
$35,000 - $49,999	11	12	8	10	9	4
$50,000 - $74,999	22	18	22	15	22	12
$75,000 - $99,999	13	14	12	15	13	12
$100,000 - $149,999	13	14	28	14	13	38
$150,000 or more	7	13	13	14	13	8
Decline to say	13	14	8	14	13	8
	Spearman's rho not significant					
Children ≤ Age 16 in Household						
Yes	11	23	32	20	14	15
	Chi-square significant ($p \leq 0.05$)					

The cycling groups also varied according to the distribution of races and ethnicities, with weekly cyclists having the highest percentage of Caucasian respondents. While this seems to fit with most research on bicycling, which has a high percentage of Caucasian respondents, it is not clear if this proportion reflects more who is bicycling or who responds to surveys about bicycling. Regardless, the large percentage of Caucasian bicyclists in this study suggests that the survey responses cannot be assumed to apply to other races without further research.

In terms of driving frequency, the distribution between cycling groups follows the expected direction, with the driving frequency significantly ($p \leq 0.000$) negatively associated with the bicycling frequency. However, the large majority of the sample drives at least once a week, irrespective of bicycling frequency. There was no significant difference between groups regarding income. Finally, a significantly ($p \leq 0.01$) smaller percentage of weekly cyclists had children than any other group. Of the respondents who had children, significantly more ($p < 0.10$) yearly and monthly cyclists than others had children who rode bicycles on the sidewalk or on the street.

Table 2 shows how the survey population compares with the larger Bay Area population. The survey population is disproportionately weighted toward 25-34 year-olds, females, and Caucasian respondents, and includes fewer respondents from both the very low and very high ends of the income spectrum. In addition, fewer of the survey respondents have children under age 18 than would be expected from the general population. Despite the differences between the survey population and the Bay Area population, I did not weight the data for this analysis. I consulted multiple statisticians on the matter, and the collective opinion was that the respondents, having been solicited through a convenience sample, may systematically differ from the general population in unknown ways. Weighting the data would therefore not reliably address any potential bias. Because of this, I present the data and analyses unweighted.

Table 2. Survey Population Compared to Bay Area Characteristics

	Survey Respondents (N=463) %	Bay Area Population (N=6,666,861) %
Age[1]		
18-24	6	9
25-34	36	15
35-44	18	15
45-54	21	15
55-64	16	12
65+	4	12
Sex[1]		
Male	45	50
Female	54	50
Race/Ethnicity[2]		
Caucasian or White	59	51
*Hispanic	5	23
African American or Black	5	7
Asian	15	25
Native American or Alaska Native	-	1
Native Hawaiian or Pacific Islander	1	1
Other	7	11
Two or more races	5	5
Decline to say	3	-
Annual Household Income[3]		
Less than $35,000	15	22
$35,000 - $49,999	10	10
$50,000 - $74,999	19	15
$75,000 - $99,999	13	12
$100,000 - $149,999	18	18
$150,000 or more	12	22
Decline to say	12	-
Children < Age 18 in Household[4]		
Yes	22	30

[1] United States Census, 2011 Summary File 1, QT-P1 Age Groups and Sex
[2] United States Census, 2011 Summary File 1, QT-P3 Race and Hispanic or Latino Origin
[3] American Community Survey 2007-2011 5-year Estimates, B19001 Household Income in Past 12 Months
[4] United States Census, 2011 Summary File 1, DP-1 Profile of General Population and Housing Characteristics
* Hispanic counted separately from other races in Census, so total adds up to more than 100%.
[#] The survey asked about children under age 16, while the Census asked about children under age 18, so these results are close, but not exactly comparable.

Attitudes, Beliefs, Knowledge, and Influences of the Survey Population

In order to understand the general attitudes of the survey population toward bicycling, and what might influence those attitudes, I asked multiple questions about supporting bicyclists, familiarity with bicycling or bicyclists, and perceptions of bicycling traffic risk. The information in this chapter forms many of the independent variables tested in the model presented in Chapter Eight.

Geographic Influences on Bicycling

To get an idea of how familiar the survey participants were with bicycle facilities, I asked them about the presence of bicycle lanes in their cities, near their homes, and in cities where they had lived in the past. Only 6% of the sample reported that they had never lived in a city with more bicycling than their current city.

There was a significant ($p \leq 0.05$) difference between the percentage of respondents in each cycling group who reported that there are bicycle lanes or routes in their city:

- 92% of daily cyclists,
- 95% of weekly cyclists,
- 86% of monthly and yearly cyclists,
- 81% of potential cyclists, and
- 76% of non-cyclists.

Of those who know that there are bike lanes or routes in their cities, there was a significant ($p \leq 0.05$) difference between the percentage of respondents in each cycling group according to how close they live to a bicycle lane or route. The following percentages of respondents reported living within a few blocks of a bike lane or route:

- 88% of daily cyclists
- 72% of weekly and monthly cyclists,
- 68% of yearly and potential cyclists, and
- 58% of non-cyclists.

Nearly 90% of respondents provided the closest intersection to their home, allowing me to check for the presence of bicycle lanes and routes using GIS data. The objective data for who lives within 0.25 miles of a bicycle lane is shown below. When compared with the self-reported data about living near a bicycle lane, the GIS data suggests that respondents from all groups may overestimate how close they are to a bike lane, although non-cyclists are the least likely to do so:

- 58% of daily and weekly cyclists,
- 32% of monthly cyclists,
- 43% of yearly cyclists,
- 37% of potential cyclists, but
- 49% of non-cyclists.

Regardless of the match between the subjective and objective presence of bicycle lanes, there is a clear order to these numbers, with awareness of and proximity to bicycle lanes and routes increasing with cycling frequency. This may reflect the influence of the built environment on one's mode choice, housing location self-selection on the part of the respondents, or the influence of these respondents themselves on their nearby built environment. Future research could further investigate the role of self-selection, as well as examine a sample of the street network to determine if the density or quality of bike lanes and routes explains more than a simple indicator of living close to one.

General Beliefs About and Attitudes toward Bicycling

This study focuses on traffic risk, but, as seen in the literature review in Chapter Two, research has clearly demonstrated that there is a wide range of barriers to bicycling. These include, among other things, distance, time, topography, enjoyment, and weather. In this section, I explore the responses to survey questions about barriers to bicycling, general attitudes toward and support for bicycling in the respondents' cities and among their family and friends, and general beliefs about bicycling. Non-traffic-risk barriers are discussed in this chapter, followed by a detailed examination of perceived and actual traffic risk in Chapters Six and Eight. The information presented here will contribute to a greater understanding of how attitudes, behavior, and non-risk-related barriers effect bicycling comfort and frequency, as well as perceived cycling risk.

Barriers to Bicycling

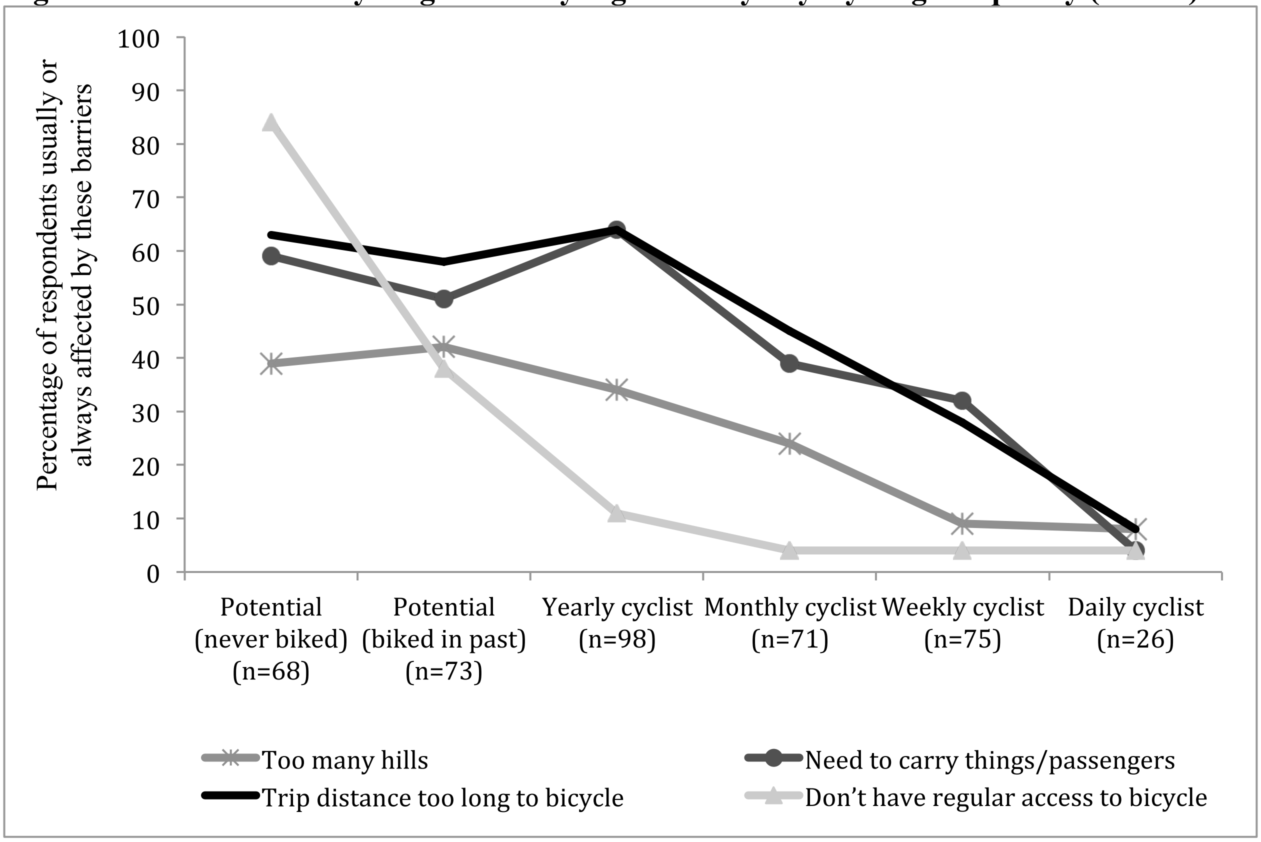
While this research focuses on perceived and actual risk, it is also important to understand how non-traffic-risk impediments identified in past cycling research influence my survey respondents' decisions to bicycle. To learn more about this influence within my survey sample, I asked my respondents how frequently (on a 5-point Likert scale) the following non-traffic-risk barriers affected their decision to bicycle for work, school, or errands:

- Trip distance
- Need to carry things/passengers
- Lack regular access to bike
- Presence of hills
- Concerns about personal safety from crime
- No bike lanes or routes where need to travel
- Feelings of embarrassment if cycling other than for recreation
- Weather
- No secure bike parking at destination
- Cycling discomfort due to local roadway quality

These questions were only asked of current and potential bicyclists, resulting in a smaller sample size (n=411).

Several patterns among the survey responses are worth noting. First, as shown in Figure 17, cycling frequency was significantly ($p \leq 0.001$) negatively associated with four of the barriers: trip distance, need to carry things/passengers, lack regular access to bike, and presence of hills. This figure divides potential cyclists into two groups—those who have never biked and those who have biked in the past—in order to demonstrate the difference between those groups with regard to having regular access to a bicycle. Those who have never biked are much less likely to have regular access to a bike than potential cyclists who have biked in the past.

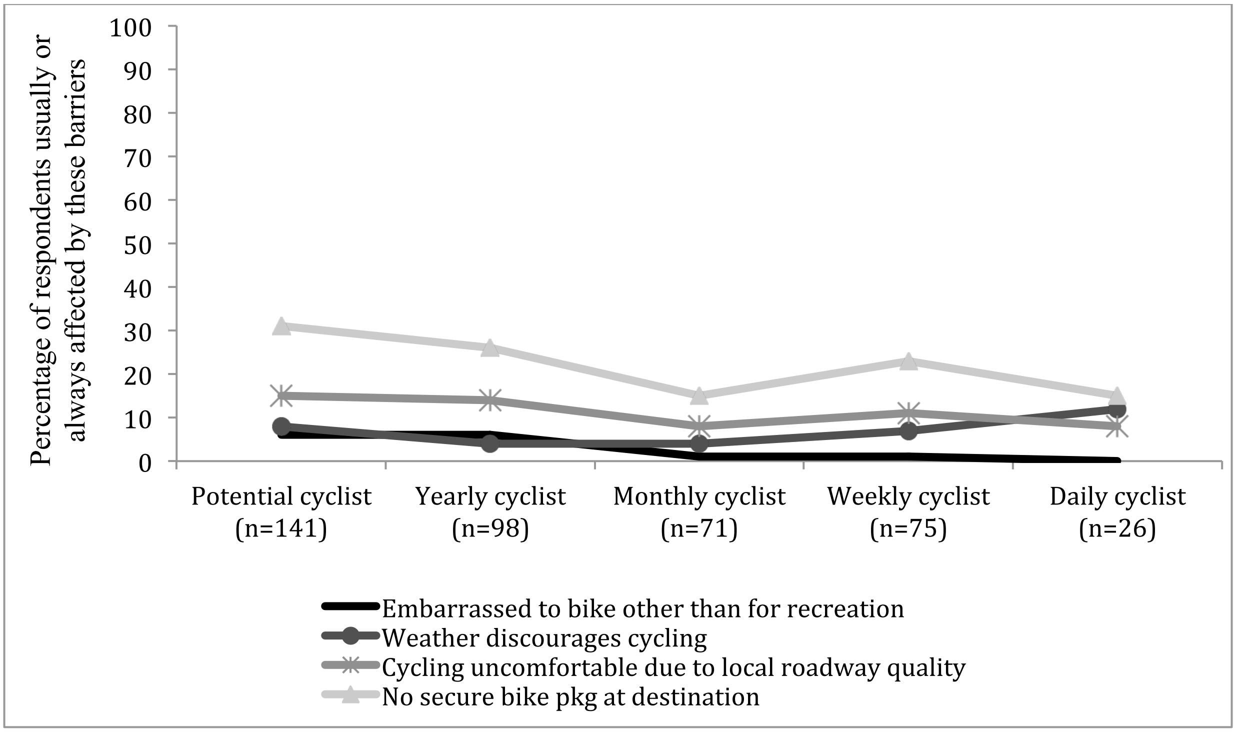
Figure 17. Barriers to Bicycling that Vary Significantly* by Cycling Frequency (N=411)



* Significant difference between cycling groups at 99.999% level.

Figure 18 shows that for some of the barriers, there was no significant difference between respondents according to cycling frequency. These barriers included feeling embarrassed while cycling other than for recreation (applicable to only 4% of respondents); weather (6%); feeling uncomfortable bicycling due to local roadway quality (13%); and lack of secure parking at destination (25%). The uptick for weekly cyclists who lack secure parking seems out of place, but may reflect both a lack of parking and those respondents' desire to bicycle more if they felt their bikes would be secure. In contrast, monthly cyclists may be less concerned about the lack of secure bicycle parking if they never intend to ride their bikes for certain trips.

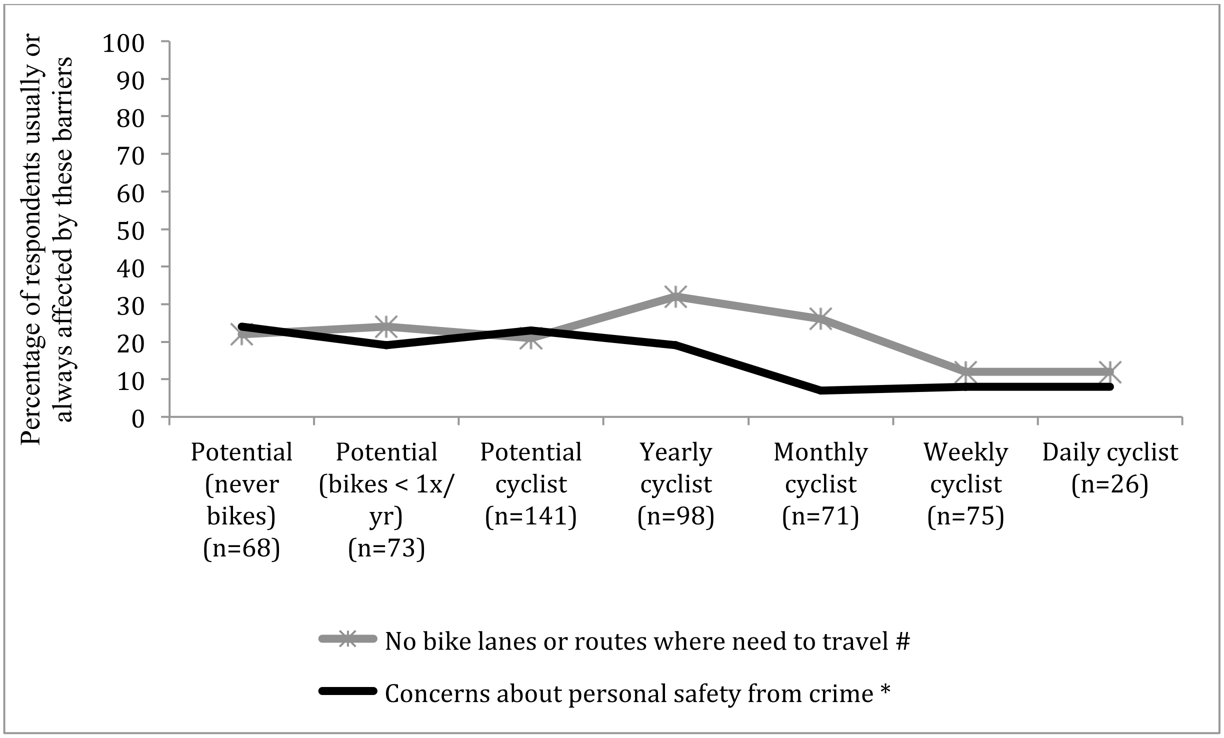
Figure 18. Barriers to Bicycling that Vary Little by Cycling Frequency (N=411)



It may seem surprising that yearly and monthly cyclists are less likely to list weather as a barrier than regular cyclists, but this may be explained again by one's intention to bicycle. The reason for the difference between occasional and potential cyclists is less clear, but is statistically negligible and may just reflect preferences. The fact that there is no significant difference between groups for these barriers does not render them unimportant. For example, one-quarter of the sample—and over 30% of potential cyclists—would benefit from increased access to secure bicycle parking.

Concerns about personal safety from crime and not having bike lanes or routes where one needs to travel were marginally significantly different according to cycling frequency, as shown in Figure 19. Concerns about personal safety from crime are significantly ($p \leq 0.05$) negatively associated with cycling frequency, as might be expected. However, the barrier of not having bike lanes or routes where one needs to travel, while the least applicable for regular cyclists, is stronger for occasional cyclists than potential cyclists. This suggests that the provision of bicycle infrastructure might be more effective in enabling current bicyclists to bicycle more than in convincing potential cyclists to begin bicycling. This is not to say that it could not also be a powerful tool in attracting new cyclists, but that it may not be enough in isolation. Likely, the barriers examined in Figure 17 will also need to be addressed where possible, such as decreasing trip distance (for example, through urban infill), and innovations in carrying passengers and loads while bicycling. In addition, the findings in Chapter Seven demonstrate that concerns about bicycling risk also play a role in one's decision to bicycle.

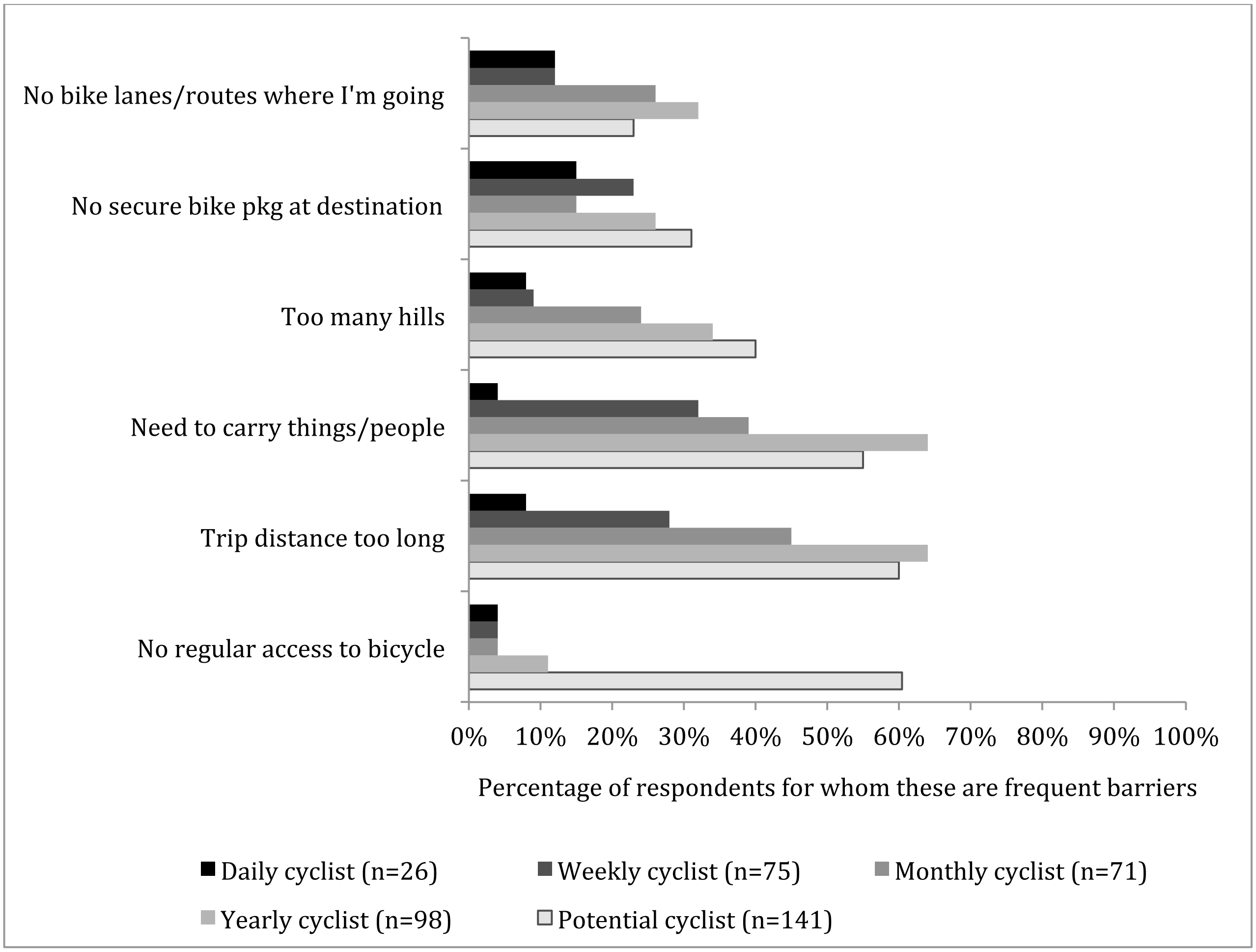
Figure 19. Barriers to Bicycling that Vary Moderately by Cycling Frequency (N=411)



Significant differences between cycling groups at the following levels: # $p \leq 0.10$; * $p \leq 0.05$

Figure 20 compares the barriers that were either significantly different between cycling groups or listed by at least 25% of the survey sample as usually or always affecting the decision to bicycle. It shows that the barriers that are cited by the most people overall are also those with the most difference between groups (in particular, trip distance and the need to carry things or people, cited by 49% and 47% of respondents, respectively). The barrier of too many hills, while significantly different between groups, was listed by only a few more people than the lack of secure parking in the survey—28% versus 25%, respectively. Slightly fewer people listed not having bike lanes or routes where one wants to travel (23%), while only 15% cited concerns about safety from crime.

Figure 20. Comparison of Non-traffic-risk Barriers to Bicycling (N=411)



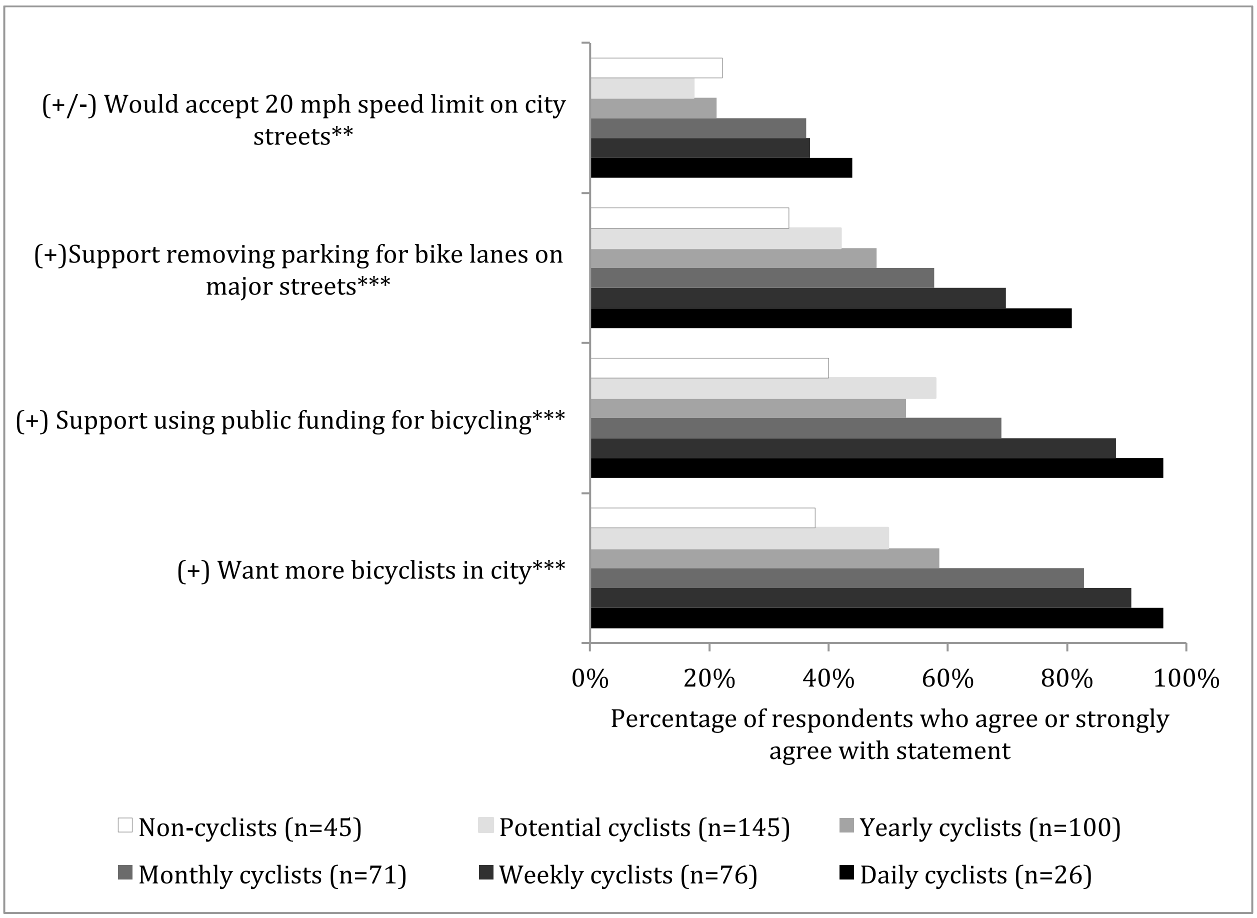
I also examined these barriers with regard to age and sex. There was a marginal significant difference ($p \leq 0.05$) between respondents according to age for the likelihood of feeling embarrassed bicycling and not having regular access to a bicycle, and a stronger significant difference ($p \leq 0.01$) according to age for those who feel concerned about personal safety. I was surprised to find that it was actually the younger respondents, particularly those age 25-44, who were significantly more likely to always be influenced by these barriers than older respondents.

With regard to sex, females were more likely than males to always be influenced by these barriers than males, in some cases significantly so. For example, females were significantly ($p \leq 0.05$) more likely to always be influenced by the impracticality of bicycling due to a need to carry a load, the discomfort of bicycling due to roadway quality, and not having regular access to a bicycle. They were also significantly more likely ($p \leq 0.01$) to always be concerned about personal safety while bicycling. These findings corroborate earlier research by Emond, Handy et al. (2009), and provide insight into the areas that may be most important to address in order to encourage more women to bicycle.

Attitudes toward Bicycling

I also wanted to understand respondents' attitudes toward bicycling in general. In terms of official support for bicycling, 33% of daily cyclists and 20% of weekly cyclists belong to a Bay Area organization that advocates for bicyclists, compared to 10% of monthly cyclists and 2% or less of potential and yearly cyclists. No non-cyclists in my survey population belong to such an organization. In terms of unofficial or stated support for bicycling, Figure 21 displays the percentage of respondents who agreed with questions about various ways to support bicycling in one's city. Research has found that drivers who also bicycle tend to be more sympathetic toward other bicyclists than non-bicycling drivers (Basford et al., 2003). This tendency was confirmed among my survey respondents: there was a significant difference in the amount of general support for bicycling according to the respondents' bicycling frequency. Despite the influence of bicycling frequency, a majority of respondents agree with the supportive ideas with the exception of lowering the speed limit.

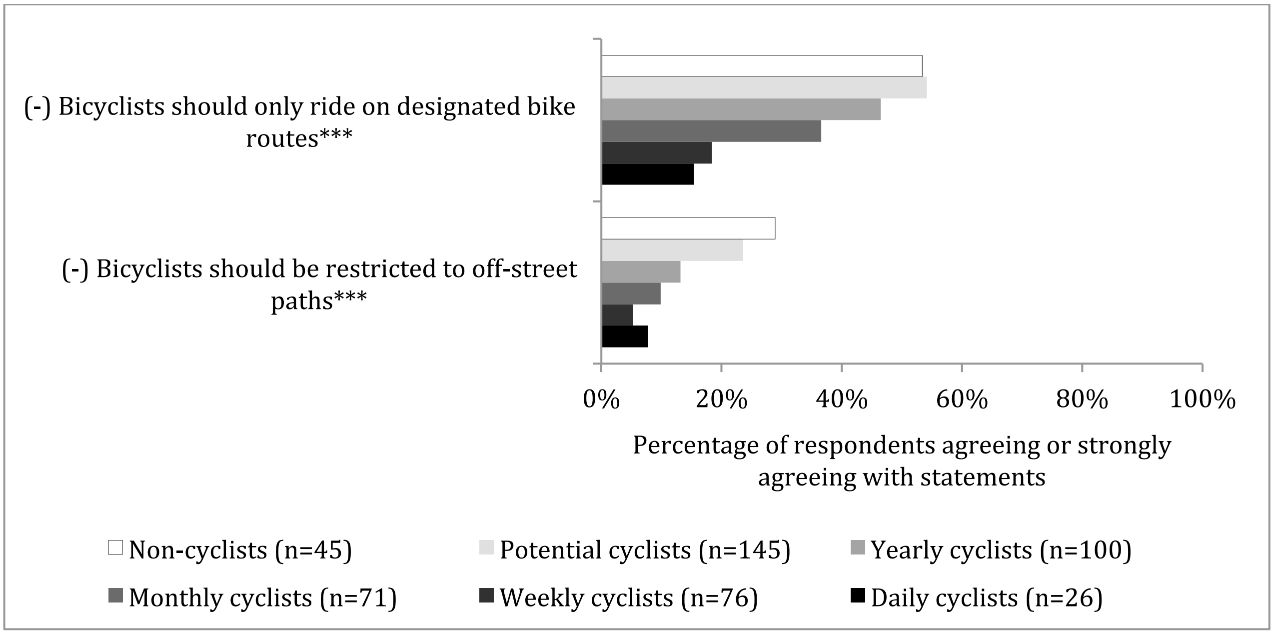
Figure 21. Bicycling Frequency Significantly Affects Support for Bicycling (N=411)



Significant differences indicated by the following: ** = $p \leq 0.01$, *** = $p \leq 0.001$

Figure 22 shows that bicycling frequency also significantly affects respondents' desires to restrict bicycling, either to off-street paths or to roadways marked as bicycle routes. While a majority of respondents disagree with or are neutral about restricting bicyclists to off-street paths, a high percentage of respondents agree that bicyclists should be restricted to designated bike routes. In the latter case, over 50% of non- and potential cyclists agree that cyclists should be restricted, compared to only 18% of regular cyclists.

Figure 22. Bicycling Frequency Significantly Desires to Restrict Bicycling (N=411)



There is also a significant difference between cycling groups with regard to having family and friends who bicycle, as shown in Table 3. Cycling frequency was significantly ($p \leq 0.001$) positively associated with having close friends or family who ride a bicycle for work or errands, as well as with regularly seeing people one knows while bicycling. Cycling frequency was also significantly negatively associated with discouraging friends or family from bicycling for utilitarian purposes.

Table 3. Percentage of Respondents who Agree with Statements about Bicycling among One's Friends or Family, by Bicycling Frequency

	Non-cyclists (n=45) %	**Potential cyclists** (n=145) %	**Yearly cyclists** (n=100) %	**Monthly cyclists** (n=71) %	**Weekly cyclists** (n=76) %	**Daily cyclists** (n=26) %
(+) Regularly see people I know riding bicycles***	**38**	30	52	59	76	**77**
(+) Have close friends/family who ride a bike for work/errands***	**53**	54	65	82	89	**88**
(-) I would discourage friends or family from considering biking to work/errands***	**38**	16	11	10	8	**4**

***Chi square significant difference at level of $p \leq 0.001$

Note that only a small minority of each group would discourage their friends and family from considering bicycling to work or errands. Comments from the 7% of frequent cyclists who would discourage friends and family from cycling suggest that traffic risk plays a role in their reasoning.

Table 4 displays the percentage of respondents who agree with various statements about bicycling safety in one's city. Note that there is a highly statistically significant difference between the groups for statements about bicycling risk, indicated by bold font in the table. In contrast, there was no significant difference between the groups for the influence of bicycle markings or the safety respondents' felt when driving near bicyclists following traffic laws. In both cases, the vast majority of respondents agreed with these statements.

Table 4. Percentage of Respondents who Agree or Strongly Agree with Statements about Bicycling Safety, by Bicycling Frequency

	Non-cyclists (n=45) %	**Potential cyclists** (n=145) %	**Yearly cyclists** (n=100) %	**Monthly cyclists** (n=71) %	**Weekly cyclists** (n=76) %	**Daily cyclists** (n=26) %
(+/-) Bicycle markings remind me that bicyclists may be present	89	85	87	80	89	88
(+/-) Feel safer driving near bicyclists who obey traffic laws	91	96	94	90	88	77
(-) **Feel anxious when I see bicyclists pulling kids in a trailer*** **	**69**	63	49	46	41	**38**
(-) **Cyclists are safer riding on the sidewalk than in the street in busy areas** **	**44**	43	31	38	30	**15**
(-) **The biggest threat to a cyclist's safety is his/her actions*** **	**62**	50	62	41	39	**15**

Significant differences indicated by the following: ** = $p \le 0.01$, *** = $p \le 0.001$

Knowledge of Roadway Laws

I also wanted to test the effect of roadway knowledge on one's attitudes toward and beliefs about bicycling. An Australian study found that drivers who were more familiar with roadway laws pertaining to bicyclists were also more likely to hold positive attitudes toward bicyclists (Rissel et al., 2002). In order to test this connection within my sample, as well as to examine the potential connection between knowledge and perceptions of safety, I asked the survey respondents a series of questions about driver's education and bicycle safety classes, traffic laws in general, requirements for riding in a bicycle lane, and driving near bicycle lanes. The exact wording of the questions can be found in the survey copy in Appendix B.

Only 13% of respondents (no significant difference between groups) stated that their driver's education class covered bicycling; another 44% could not remember. Of those who remembered the bicycling coverage, 72% took driver's education in California. Beyond driver's education, 20% of weekly and daily cyclists have taken a class specifically on bicycle safety, compared to 12% of yearly and monthly cyclists, 9% of potential cyclists, and 5% of non-cyclists.

The first row in Table 5 is shaded to highlight the fact that a majority of each cycling group knew laws pertaining to bicycling with traffic (i.e., that you must ride in the direction of traffic, use hand signals when turning or merging, and use lights after dark). However, aside from the daily cyclists, cycling frequency did not correlate with this knowledge. In addition, the occasional and potential cyclists in this sample did not know the laws as well as either the non-cyclists or the regular cyclists. The last row of the table is shaded to highlight the fact that nearly 30% of yearly cyclists, and over one-fifth of potential and monthly cyclists, did not know that cyclists are legally required to ride with traffic. This lack of knowledge may contribute to preventable conflicts on the roadway, a subject that should be explored in future research.

Table 5. Percentage of Respondents who Knew Roadway Laws about Bicycling, by Cycling Frequency (N=462)

	Non-cyclists (n=45) %	**Potential cyclists** (n=145) %	**Yearly cyclists** (n=100) %	**Monthly cyclists** (n=71) %	**Weekly cyclists** (n=76) %	**Daily cyclists** (n=26) %
Ride with traffic, use lights and hand signals*	78	64	59	55	64	85
Ride with traffic, use hand signals	9	8	6	11	11	8
Ride with traffic, use lights	2	4	3	8	7	8
Use hand signals and lights	4	8	11	10	4	-
Ride with traffic	-	2	4	4	3	-
Use hand signals	-	1	1	1	4	-
Use lights	4	1	2	4	1	-
No rules or did not know	2	12	14	6	7	-
Did not know to ride with traffic**	10	**22**	**28**	**21**	16	-
	Chi-square not significant					

* Chi square significant difference at level of $p \leq 0.05$; **Fisher's exact ≤ 0.01

I also asked respondents when, if ever, they were required to ride in a bicycle lane. In California, although cyclists are not expressly mandated to ride in the lane if present, they are required by law to ride "as close to the right as is practicable", which effectively means that they must ride in a bicycle lane when there is one and it is safe to do so. There are several exceptions to this rule, including 1) leaving the bicycle lane if one is able to ride at the normal speed of traffic; 2) if one needs to overtake another vehicle (e.g., a slow moving bicyclist); 3) if one needs to avoid debris or a dangerous situation (e.g., a driver opening a car door); and 4) if one needs to make a left turn. Table 6 displays the percentage of each group that knows about the various exceptions. The shaded rows highlight problematic trends. The first row is shaded to highlight the fact that very few respondents of any group knew all four exceptions. The bottom three rows are shaded to draw attention to the pattern between responses and cycling frequency: more regular cyclists than non-regular cyclists believed that riding in the bicycle lane is never required, while more non-cyclists than potential and current cyclists believed that it is always required. Finally, as seen with the laws about riding behavior, the yearly cyclists were once again the most likely to report not knowing when one is required to ride in a bicycle lane.

Table 6. Percentage of Respondents who Knew Laws about Riding in a Bicycle Lane, by Cycling Frequency (N=463)

	Non-cyclists (n=45) %	**Potential cyclists** (n=145) %	**Yearly cyclists** (n=100) %	**Monthly cyclists** (n=71) %	**Weekly cyclists** (n=76) %	**Daily cyclists** (n=26) %
All four exceptions	-	2	3	4	11	4
Three exceptions	22	12	22	28	21	27
Two exceptions	33	41	20	20	22	27
One exception	7	14	13	14	9	8
Never required	**9**	6	12	11	18	**23**
Always required	**11**	7	4	3	4	**4**
Don't know	18	19	**26**	20	14	8
	Chi-square significant $p \leq 0.01$					

I tested whether knowledge of either of these laws pertaining to bicyclists was related to perceived traffic risks for my sample. For non-regular cyclists, there was a marginally significant and positive correlation ($p \leq 0.10$) between knowing the law about riding in a bicycle lane and worrying about a driver driving too close or making a mistake as a cyclist. There was also a significant and positive ($p \leq 0.05$) correlation between worrying about motorists driving too fast while passing and knowledge of the rules about proper bicycling for non-regular cyclists. For regular cyclists, there was no significant relationship between worries and knowledge of either law. Two important issues that this data set did not address are 1) how knowledge of bicyclists' rights affect their actions upon encountering a dangerous situation in the bicycle lane (e.g., a car door opening into the bicycle lane, debris that makes the lane impassable, etc.), and 2) how drivers' knowledge of bicyclists' rights affect their reactions to bicyclists trying to leave the bicycle lane (e.g., aggressive behavior toward the cyclist, etc.). Future research should investigate the prevalence of these potentially dangerous situations.

I also asked the survey respondents if drivers were required to pull into a bicycle lane before making a right turn from a street with a bicycle lane (the answer: yes). This question is important because it measures knowledge about one of the most common crash types: the "right hook." A right hook is a broadside crash that occurs when a bicyclist is proceeding straight and a driver turns right in front of—or into—her. The prevalence of right hook collisions has been used to fight the installation of bicycle lanes (Forester, 2001) even though right hook collisions can occur any place where bicyclists are required to ride "as close to the right as is practicable", as in California. More occasional and potential cyclists (approximately 43%) answered the question correctly than non-cyclists (38%) or weekly cyclists (33%), although these differences were not significantly different. One-third of the sample answered the question incorrectly, and the rest did not know. This finding is troubling not just because many drivers may not know and therefore may cut off bicyclists—it also suggests that many bicyclists do not know the law and may therefore be dangerously positioning themselves at intersections.

Opinions about Potential Laws in California

I also asked survey participants their opinions about potential laws in California. For the past several years, bicycling advocacy groups have debated pushing to amend traffic laws such that bicyclists could treat stop signs as yield signs and red lights as stop signs. Such a law has existed since 1982 in Idaho, without an accompanying increase in traffic crashes. However, a bill to introduce the law in California has never made it out of the State legislative committee. Little public opinion has been published about the subject, so I wanted to gauge it within my sample. I also asked about requiring bicyclists to wear helmets in California. The law currently requires children, but not adults, to wear them. Several of my focus group participants expressed the opinion that all cyclists should wear them; thus, I wanted to test this idea among the larger survey group as well.

Table 7 displays the percentage of respondents agreeing with the potential laws. The data revealed that well over 50% of the sample think that adult bicyclists should be required to wear helmets while bicycling, although this thinking tended to decline with bicycling frequency. This finding may reflect a general perception of bicycling as dangerous, or a societal tendency toward risk aversion.

Table 7. Percentage of Respondents who Would Support Potential Changes to Bicycling Laws in California, by Cycling Frequency (N=462)

	Non-cyclists (n=45) %	**Potential cyclists** (n=145) %	**Yearly cyclists** (n=100) %	**Monthly cyclists** (n=71) %	**Weekly cyclists** (n=76) %	**Daily cyclists** (n=26) %
Helmet required for all cyclists**	**82**	70	64	51	47	**62**
Stop sign as yield***	**43**	58	68	76	87	**92**
Red light as stop sign***	**31**	42	51	48	63	**81**

Significant differences by cycling frequency at the following levels: ** = $p \leq 0.01$; *** = $p \leq 0.001$

As might be expected, cycling frequency was significantly positively associated with supporting traffic laws that would allow cyclists to treat stop signs as yield signs, and red lights as stop signs. While a majority of respondents supported both proposed laws, there was a clear divergence between cycling groups in their support. Occasional and regular cyclists overwhelmingly support being able to treat a stop sign as a yield sign, with regular cyclists being especially in favor of it. Fewer respondents supported being able to treat a red light as a stop sign, although still a much higher percentage of regular cyclists than non-regular cyclists supported it. This may reflect reduced certainty about the ability to avoid risk with allowing someone to go through a red light versus a stop sign. As one focus group respondent said, "I don't want to allow any rule that would make something my fault (as a driver) if someone else makes a bad decision."

Summary of Key Findings

In this chapter, I described my survey population and discussed their attitudes toward and beliefs about bicycling. Key takeaways from this chapter include the following findings.

Bicycling Frequency and Proximity to On-street Bike Infrastructure

1. Bicycling frequency is significantly positively related to knowing whether there are bicycle lanes or routes in one's city, and living within a few blocks of one, corroborating findings that the built environment affects one's mode choice.

Barriers to Bicycling

2. As expected, potential and occasional cyclists experience fundamental barriers to bicycling to a larger degree than regular cyclists. These include trip distances being too long to bicycle, bicycling being impractical because of a need to carry things or people, not having regular access to a bicycle, and, for some, the presence of hills near their home.
3. A significantly higher percentage of respondents aged 25-44 were likely to always be influenced by not having regular access to a bike, feelings of embarrassment while cycling other than for recreation, and concerns about personal safety.
4. Women's decisions about whether to bicycle are more frequently affected by all of the barriers examined in this chapter, significantly so by concerns about personal safety, not having regular access to a bicycle, the impracticality of bicycling, and feeling uncomfortable bicycling due to roadway quality.

Support for Bicycling

5. Survey respondents who do not currently bicycle were significantly less likely to desire (and want to support) more cycling in their cities than respondents who do bicycle, particularly those who bicycle regularly.
6. In concert, survey respondents who do not currently bicycle were significantly more likely to want to restrict cycling in their cities than respondents who do bicycle, particularly those who bicycle regularly.

Bicycling in One's Social Network

7. Significantly fewer non- and potential cyclists than current cyclists regularly see people they know bicycling and/or have close friends or family who bicycle for work or errands.
8. Non-cyclists were significantly more likely than other respondents to discourage friends and family from considering bicycling for work or errands.

Perceived Bicycling Safety

9. A large majority of all groups believe that bicycle markings on the street remind them that bicyclists may be present.
10. However, there were significant differences between non-cyclists, occasional cyclists, and regular cyclists regarding what it means to bicycle safely in urban areas. In particular, a much higher percentage of non-cyclists and potential cyclists believed it was safer to bicycle on the sidewalk than on the street in urban areas (a behavior that is not only illegal in many places, but that can also be dangerous due to possible conflicts with pedestrians and drivers not expecting fast-moving cyclists to be on the sidewalk).
11. In addition, a majority of non-cyclists and yearly cyclists, and half of potential cyclists, believed that the biggest danger to a bicyclist was his own actions.
12. Non-cyclists and potential cyclists were also significantly more likely than regular cyclists to feel anxious when seeing a child pulled in a bicycle trailer.

Knowledge of Roadway Laws & Support for Bicycle-friendly Laws

13. Despite differences in perceptions of risk, a majority of the sample thinks that adult bicyclists should be required to wear a helmet.
14. Knowledge of roadway laws regarding bicycling was mixed among all groups, but yearly were the most likely to report not knowing how a bicyclist should behave, while at the same time the most likely to know how a driver should behave. A majority of the sample knew the correct answer for only one law. In particular, there was discrepancy according to bicycling frequency for when a bicyclist is required to ride in a bicycle lane. The lack of roadway knowledge may have consequences for bicycle crash risk, and should be further investigated.
15. A majority of the sample supported a law allowing bicyclists to treat stop signs as yield signs when cross traffic is not present, with support increasing significantly as bicycling frequency increased.
16. A similar trend was found with regard to supporting allowing cyclists to treat red lights as stop signs, although the overall support for this law was lower than the support for stop-as-yield, even among regular bicyclists.

The following chapter further examines the survey data, elaborating on findings about roadway design preferences and beliefs about bicycle lanes among the respondents.

Chapter 6 - Roadway Design Preferences and Associated Beliefs

This chapter continues the analysis of the survey, focusing on findings about comfort ratings for various roadway designs (shown in Appendix B) and beliefs about bicycle lanes. Key findings from this chapter include that a much higher percentage of drivers and bicyclists are comfortable on roadways with separated bicycling facilities than on roadways with shared space. In particular, roadway designs with barrier-separated bicycle lanes were statistically equally popular among all groups, regardless of bicycling frequency. In addition, the majority of the sample believe that bicycle lanes confer benefits to cyclists and drivers in terms of predictability and legitimacy on the roadway.

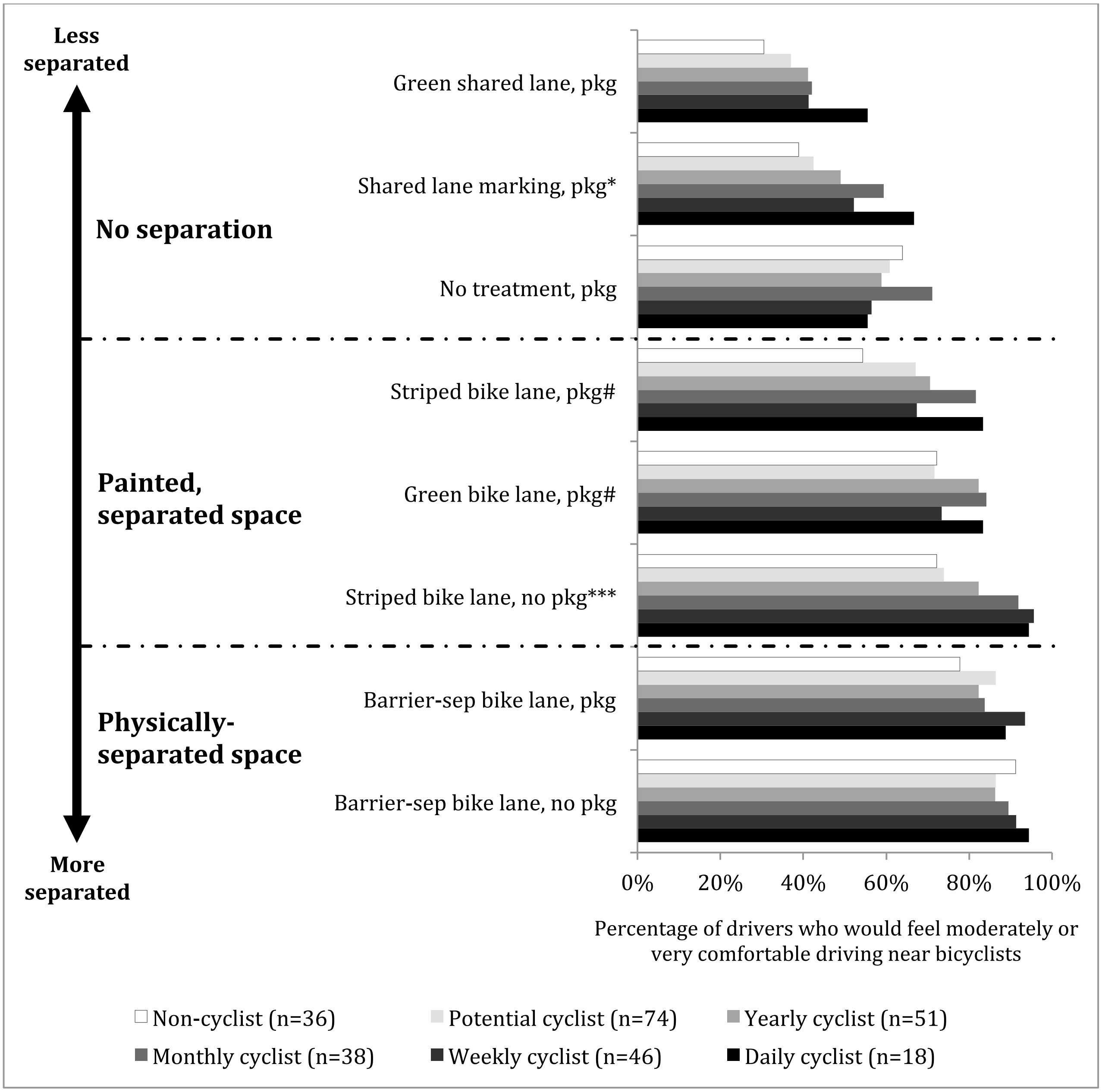
Roadway Design Preferences: We All Want the Same Thing

Research on stated preferences has found that bicyclists prioritize separation from moving traffic and parked cars, although revealed preference studies have found a limit to the extent most bicyclists will detour to find such facilities (Broach et al., 2012; Parkin et al., 2007; Tilahun et al., 2007; Winters et al., 2011). A recent study from Vancouver examined these preferences according to cycling experience, and found that a majority of cyclists of all experience levels prefer to be as separated from traffic as possible, with potential cyclists desiring the most separation of all groups (Winters and Teschke, 2010). Knowing cyclists' preferences is critical to encouraging more cycling, but, given the needs of practitioners to balance safety and throughput, we also need to know how drivers view various design options. Up to this point, little research has investigated the roadway design preferences of the drivers who share the road with bicyclists.

In this vein, I asked my survey respondents to rate a series of multi-lane, commercial roadway designs in terms of their comfort 1) driving near bicyclists, and 2) bicycling near motorized traffic. Comfort was rated on a seven-part Likert scale, with a neutral option and the modifiers "somewhat", "moderately", and "very" comfortable or uncomfortable. Because the survey was long, I gave the 418 survey respondents who were either potential or current cyclists the option of whether to rate the roadway designs. The 45 non-cyclists were automatically given these driver preferences questions as a result of having a shorter overall survey, although data from only 36 are presented here, due to blank responses. Fifty-four percent of cycling respondents chose to continue the survey, for a resulting subsample of 225 responses for cyclists' roadway design preferences, and 263 responses for drivers' roadway design preferences. These preferences may contain some self-section bias.

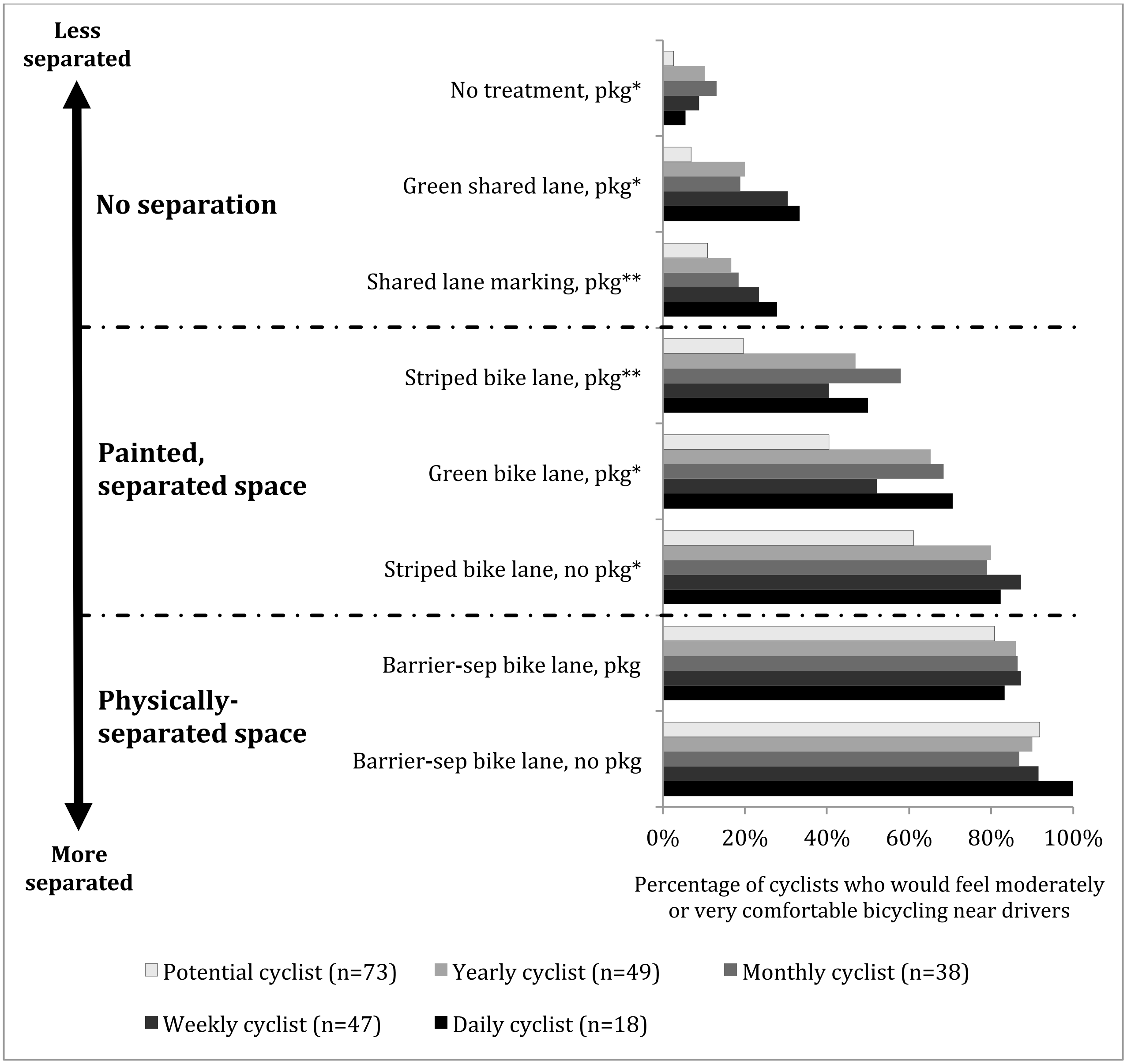
The designs were refined versions of the photos presented in the focus groups, which were all based on the same commercial street and manipulated through Adobe Photoshop to include various design treatments. The photos were randomized within each survey to control for ordering effects. The eight photos can be seen in the survey copy located in Appendix B. Figure 23 displays the percentage of drivers feeling "moderately" or "very" comfortable driving near cyclists in each scenario, while Figure 24 displays the results the percentage of cyclists feeling "moderately" or "very" comfortable bicycling in each scenario. I combined "moderately" and "very" comfortable for these graphs in recognition of the fact that some people, particularly those with little to no cycling experience, may not feel "very" comfortable on any treatment.

Figure 23. Survey Respondents who Drive Feel More Comfortable with Greater Separation from Bicyclists (N=263)



Significant differences between groups indicated by the following: # = $p \leq 0.10$; * = $p \leq 0.05$, *** = $p \leq 0.001$

Figure 24. Survey Respondents who Bicycle Feel Overwhelmingly More Comfortable with Greater Separation from Drivers (N=225)



Significant differences between groups indicated by the following: * = $p \leq 0.05$, ** = $p \leq 0.01$

There are several points to note from these figures. First, there are only two roadway designs that evenly appeal to all groups, regardless of cycling frequency. Figure 25 and Figure 26 display these two designs, which both involve barrier-separated bicycle lanes and are also the two designs with the most overall appeal as both a bicyclist and a driver. I was surprised to find that the barrier-separated lane next to on-street parking (Figure 26) was ranked at least moderately comfortable by so many respondents, given the concerns raised by most focus group participants about the need to access the curb for loading and unloading passengers, particularly the elderly. The difference in reactions may reflect that nearly 40% of the focus group participants were age 65 or older, while only 4% of the survey respondents were in that age category. There was no significant difference in design preferences according to age, but that may have resulted from the small sample size, particularly for older respondents.

Figure 25. Barrier-separated bike lane without on-street parking

Figure 26. Barrier-separated bike lane next to on-street parking

Second, more current cyclists than potential cyclists felt at least moderately comfortable bicycling on all roadway designs, with the exception of the barrier-separated bicycle lane without parking shown in Figure 25; this treatment, ranked at least moderately comfortable by a high percentage of all groups, appealed to even more potential cyclists than occasional cyclists. This corroborates the findings from research in Vancouver and Portland, OR, about the negative association between cycling experience and preference for separation from traffic and parking (Dill and McNeil, 2012; Winters and Teschke, 2010). Third, a higher percentage of respondents ranked each treatment at least moderately comfortable as a driver than as a cyclist, again with the exception of the barrier-separated lanes, which were rated at least moderately comfortable by approximately the same percentage of respondents for both scenarios.

The comfort ratings seem to indicate the following order of preference regarding roadway design for bicyclists:

1) Barrier-separation between moving non-motorized and motorized traffic
2) Separation from parked cars
3) Visual demarcation of space using paint (e.g., the green painted bicycle lane)
4) Visual demarcation of legitimacy using paint (e.g., the shared green lane or sharrow)

This order seems particularly pronounced for potential cyclists. While regular and occasional cyclists' comfort levels remain close for the barrier-separated treatments and the bicycle lane without on-street parking, potential cyclists' comfort levels clearly drop once barriers are no longer part of the design. They drop once again when parking is introduced without a barrier—even in the case of the green painted bicycle lane shown in Figure 27 (a design for which only 41% of potential cyclists feel at least moderately comfortable). Beyond the green bicycle lane, the percentage of potential cyclists who feel at least moderately comfortable is very low. In contrast, a majority of occasional and regular cyclists still feel at least moderately comfortable using the green painted bicycle lane. However, comfort for these groups clearly drops in the case of a striped bicycle lane next to parking, as shown in Figure 28, and declines dramatically for all options that lack a separated, marked space for cyclists.

Figure 27. Green painted bicycle lane next to on-street parking

Figure 28. Striped bicycle lane next to on-street parking

The first three priorities for roadway designs also seem to reflect drivers' preferences. A large majority of all groups rated the separated (by barrier or paint) designs as at least moderately comfortable for driving near bicyclists. However, only 41% of non-cycling drivers (including drivers who are potential cyclists) rated the shared lane markings (shown in Figure 29) as at least moderately comfortable, and, with the exception of those who bicycle daily, less than 43% of all groups rated the green painted shared lane (shown in Figure 30) as such. Comments from the focus group participants suggest that these low ratings reflect uncertainty about how to behave—and how bicyclists will behave—in situations with shared space, particularly regarding the green shared lane. A higher percentage of regular bicyclists rated these last two treatments as at least moderately comfortable while driving, perhaps because they were able to picture themselves cycling and imagine how to behave—and how they would want the car driver to behave—in such a circumstance.

Figure 29. Shared lane marking (sharrow) next to on-street parking

Figure 30. Green painted shared lane marking next to on-street parking

These preferences for comfort result in a hierarchy of roadway designs: some are clearly low in the list for drivers and cyclists (sharrows and painted shared lanes), and some are clearly preferable for drivers and cyclists (barrier-separated bike lanes, lanes on streets without parallel parking, painted bike lanes). The complication seems to be what to do when there is not enough room for a bike lane. In that case, bicyclists prefer more treatment, rather than less, while drivers prefer the opposite.

There is some irony reflected in these rankings. While no comprehensive roadway database exists to determine exactly how prevalent each of these treatments is in the United States, only a few cities have built barrier-separated bicycle lanes (e.g., Portland, Oregon; New York City; San Francisco; Washington, D.C.; Chicago). In addition, these cities had to seek approval from the Federal Highway Administration (FHWA) to install the barrier-separated lanes as experiments because these treatments, although seemingly universally appealing, are still not in the American Association of State Highway and Transportation Officials (AASHTO) Bike Guide—the "official" roadway design guide dealing with bicycles.[12] Green (or other colors of) painted lanes have only been in the design guide since 2009, although a few cities have had painted lanes for over a decade years (Birk et al., 1999; Hunter, 1998)—again often as part of an FHWA exemption or study.

The bicycle treatments that have been sanctioned long enough to be prevalent are among the least popular options in Figure 23 and Figure 24: the striped bicycle lane next to parking (given that on-street parking has been a staple of street design for decades), the shared lane marking, and the no-treatment option (occasionally coupled with bicycle route/share the road signage). So, while the U.S. Department of Transportation (USDOT), Centers for Disease Control and Prevention (CDC), American Academy of Pediatrics (AAP) and other prominent organizations have urged people to bicycle more to improve health, reduce emissions, and

[12] These treatments are present in the National Association of City Transportation Officials (NACTO) Design Guide, developed as an alternative to the AASHTO Bike Guide and published for the first time in 2011.

increase livability, most cities have installed few, if any, bicycle treatments—and the ones they have installed are among those deemed least comfortable. That cities have seen an increase in bicycling despite this mismatch between preferences and the built environment could be taken as a sign that there is serious latent bicycling demand.

Modeling Driver and Bicyclist Preferences

I examined these comfort ratings through a series of bi-variate and regression analyses to understand the influence of the demographic, attitudinal, behavioral, and experiential variables. The rankings as motorists and bicyclists were significantly correlated with many other variables when using bi-variate correlation, including worries about traffic risk while bicycling and sex; Appendix C shows the variables tested and their correlations. I then combined the design scores into composite variables to test via multi-variable regression (one for scores as a driver, the other for scores as a cyclist). The sample sizes for these analyses are lower than elsewhere in the dissertation, as the roadway design section of the survey was optional.

The results are not presented here, as they brought up more questions than they answered. This likely resulted in part from the small sample size, as well as misspecification of the model. For example, initial results revealed that the driver design scores and the bicyclist design scores were significantly associated with one another. This seems somewhat intuitive—that one would associate the comfort felt in one role with the comfort felt in another role. However, I was not able to gain compelling insights into the feedback loop through these regression models, as the variables that were significant in the bicycle comfort model were not significant in the driver comfort model, and vice versa. I tried several structural equation models to further flesh out the connection, but my sample size was too small for them to work well. Future research with a larger sample would likely shed additional light on the connection through a SEM.

Bike lane beliefs

I also asked my respondents to rate their level of agreement or disagreement with several statements about bicycle lanes in particular. The percentage of respondents who agreed or strongly agreed with each of the statements is shown in Table 8. For most of these statements, there was no significant difference between groups according to bicycling frequency. Note that the trend seems to be general agreement with the more positive aspects of bicycle lanes, and disagreement with the more negative aspects. For example, nearly 100% of respondents agree or strongly agree that bicycle lanes tell drivers to expect bicyclists on the roadway. A supermajority of respondents also believes that bicycle lanes give bicyclists their own space. These two statements likely underlie some of the comfort ratings for bicycle facilities seen in Figure 23 and Figure 24.

Table 8. Respondents Believe Bicycle Lanes are Beneficial, with Few Drawbacks (N=262)

	Non-cyclists (n=36) %	**Potential cyclists** (n=73) %	**Yearly cyclists** (n=52) %	**Monthly cyclists** (n=37) %	**Weekly cyclists** (n=48) %	**Daily cyclists** (n=18) %
(+) Bicycle lanes…						
…tell drivers to expect bicyclists	89	96	90	97	96	89
…give cyclists their own space	86	89	92	95	96	89
…make cyclists more predictable on the roadway	83	86	75	81	85	88
…allow cyclists to ride at their own pace	75	68	73	75	75	67
(-) Bicycle lanes…						
…tell drivers that cyclists don't belong on non-bicycle routes*	36	40	24	19	31	22
…make it more difficult for cyclists to turn left	36	32	31	30	21	28
…increase the chance of being doored**	22	15	6	8	17	22
…encourage drivers to drive closer to cyclists	8	10	4	11	6	22
…unnecessarily restrict fast cyclists	9	3	4	0	4	6

Significant differences between non-cyclists, occasional cyclists, and regular cyclists at the following levels:
* = $p \leq 0.05$; ** = $p \leq 0.01$

A supermajority also agree that bicycle lanes make bicyclists more predictable on the roadway—a potential benefit for drivers (indeed, 85% of non- and potential cyclists agreed with this statement) that runs counter to the idea that bicycle lanes benefit only bicyclists. This agreement may help explain recent findings that drivers in the San Francisco East Bay and Los Angeles metro area named bicycle lanes as a top requested traffic safety improvement along two major arterial roadways (Sanders and Cooper, 2013; Sanders et al., 2012).

Bicycling advocates may find it troubling that nearly 40% of non- and potential cyclists agree that bicycle lanes tell drivers that cyclists don't belong on non-bicycle routes, as this belief may mitigate some of the perceived benefits of bicycle lanes by creating a confusing circumstance for drivers and cyclists and contributing to an unwelcoming atmosphere for cyclists—particularly in areas with few bicycle facilities. Future research should further investigate this finding. Despite this finding, there is no significant correlation between driving frequency and the belief that cyclists don't belong on non-cycling routes, as in Table 9. The belief about cyclists not belonging on non-bicycle routes may therefore reflect a lack of understanding about roadway rules in California (i.e., that bicyclists are allowed on all roadways except where expressly prohibited), but it may also reflect the contrasting legitimacy that pavement markings give to bicyclists on roadways that were originally designed for automobiles rather than bicyclists.

The potential of bicycle lanes to communicate that bicyclists only belong on certain streets has long been used as an argument against bicycle lanes by vehicular cyclists, who fear that their roadway rights and freedom will be taken away if bicycle lanes proliferate (Forester, 2001). However, as seen in Figure 24, the vast majority of cyclists of all types feel more comfortable with bicycle-specific facilities than without them, suggesting that avoiding the use of on-road bicycle treatments contradicts efforts to attract more people to bicycle. Instead, driver education and training might be a more appropriate way to address the misconceptions arriving from non-uniform bicycle facilities. Another option would be to place bicycle markings on each roadway. In European cities with a high bicycling mode share (e.g., Copenhagen, Denmark; Amsterdam, Netherlands; Paris, France), major roadways typically have some type of separated bicycle facility, while minor, residential roadways often have signage. These findings provide a foundation for future research in this is area.

Table 9. Drivers See Bike Lanes as Beneficial, Regardless of Driving Frequency (N=262)

	4+ days/wk (n=158) %	1-3 days/wk (n=75) %	< 1 day/wk (n=23) %	Never (n=6) %
(+) Bicycle lanes…				
…tell drivers to expect bicyclists	93	95	100	67
…give cyclists their own space	92	89	95	67
…make cyclists more predictable on the roadway	83	85	83	50
…allow cyclists to ride at their own pace	73	69	78	50
(-) Bicycle lanes…				
…make it more difficult for cyclists to turn left	32	26	30	33
…tell drivers that cyclists don't belong on non-bicycle routes	28	35	30	33
…increase the chance of being doored	12	15	26	17
…encourage drivers to drive closer to cyclists	8	8	13	17
…unnecessarily restrict fast cyclists	3	3	9	17

Summary of Key Findings

In this chapter, I examined the roadway design preferences of my survey population, both as drivers and as cyclists, and their beliefs about the benefits and drawbacks of bicycle lanes. Key takeaways from this chapter include the following findings.

Preferences for Roadway Design

1. At least 80% of every group felt at least moderately comfortable bicycling and driving on roadways with barrier-separated bicycle lanes than any other roadways—more than any other treatment, irrespective of bicycling frequency.
2. More current cyclists than potential cyclists reported feeling at least moderately comfortable on all roadway designs except the roadway with barrier-separated bicycle lanes and no parking, for which slightly more potential cyclists than occasional cyclists reported feeling at least moderately comfortable.
3. In contrast, striped bicycle lanes and sharrows were considered at least moderately comfortable by only a small minority of the sample—and very few potential cyclists.
4. A higher percentage of respondents reported being at least moderately comfortable as drivers than as cyclists on all treatments.
5. Drivers and bicyclists both seem to prefer the roadway designs in the same order when there is room for separated space. Preferences seem to be based first on a desire for physical separation by a barrier, then separation from parked cars, then visual demarcation through paint.
6. Preferences for roadway design among cyclists and drivers diverge when shared space is considered, with bicyclists desiring more paint—likely to convey greater legitimacy, and drivers desiring less paint, which qualitative evidence suggests is due to a need for clarity. This is a particularly "wicked problem" for the U.S., in which urban areas have typically given priority to cars through travel and parking lanes. When city officials choose not to reduce the parking or travel lanes for cars, there is often not space available for a separated cycling facility.

Benefits and drawbacks of bicycle lanes

7. A large majority of respondents agree that there are several beneficial aspects of bicycle lanes, including that they tell drivers to expect bicyclists, they give bicyclists their own space, and they make bicyclists more predictable to drivers. There was no strong statistical correlation between groups according to bicycling or driving frequency regarding these perceived benefits.
8. Some respondents, particularly non- and potential cyclists, also believed that bicycle lanes told drivers that bicyclists did not belong on non-bicycle routes. While far fewer respondents viewed bicycle lanes as negative in comparison to those who view them as beneficial, these negative effects may mitigate some of the increased legitimacy bicyclists seem to gain from bicycle lanes and markings.

The findings for roadway design preferences suggest a disconnect between what people desire and what is allowed to be built. For example, despite their apparent appeal, barrier-separated bicycle lanes are not in the official AASHTO Bikeway Design Guide, and have therefore been installed only with special permission from FHWA. In contrast, striped bicycle lanes and sharrows, despite a lack of enthusiasm—particularly for the latter—are officially approved and therefore proliferate where bicycle facilities are built. The implications of these findings will be further discussed in Chapter Ten.

In the following chapter, I examine perceived traffic risk among my survey respondents.

Chapter 7 – Perceived Traffic Risk for Adult Bicyclists

This chapter builds on the findings presented in previous chapters by examining survey participants' perceptions of and worries about bicycling risk for themselves and others. Key findings include that cycling experience seems to mitigate the influence of worries about traffic risk on the decision to bicycle, but that experience also exposes cyclists to risk more frequently and seems to make them more aware of it. Near misses and collisions experienced while cycling significantly affect perceived risks, particularly for weekly cyclists. Perceived risks are also significantly related to the collision experiences of friends and family. Finally, perceived risks seem to exercise important influence on the decision to bicycle, even when compared to non-risk barriers such as weather and topography.

The following chapter explores how perceived bicycling risk affects bicycling support in one's city, while Chapter Nine examines how perceived risks compare with reported crash risk.

Perceptions of Safety for Various Travel Modes

My survey asked questions about many aspects of bicycle risk for both drivers and bicyclists, including how perceptions of cycling risk relate to roadway design preferences, knowledge, attitudes, behavior, and experience among the respondents, and how reported crash statistics reflect findings about perceived risks.

I began the survey by asking about perceived safety while bicycling, walking, and driving. The literature presented in Chapter Two established that bicycling risk is repeatedly cited as a barrier to increased bicycling, but rarely have studies looked at their respondents' risk tolerance for other modes—perhaps the people surveyed were equally worried about walking or driving, but were not asked. To understand whether cycling was viewed as particularly risky among my survey participants, I asked them how safe or unsafe (5-part Likert scale) they felt while driving, walking, and bicycling along residential and commercial streets in their city. As seen in Table 10, more people feel "safe" or "very safe" while walking than while driving or bicycling in both neighborhood and commercial settings. The large majority of respondents also reported feeling safe or very safe driving in residential and commercial areas, and even bicycling in residential areas. However, *less than 30%* of the respondents reported feeling safe when bicycling in commercial areas.

Table 10. Respondents Overwhelmingly Feel Safe Traveling—Except for Bicycling on Commercial Streets

	Percentage of respondents who feel safe bicycling, walking, and driving on residential and commercial streets						
	Non-cyclists (n=45) %	Potential cyclists (n=144) %	Yearly cyclists (n=100) %	Monthly cyclists (n=71) %	Weekly cyclists (n=76) %	Daily cyclists (n=26) %	Total (N=462) %
Residential Streets							
Bicycle**	69	71	80	76	80	92	76
Drive	93	88	89	93	87	96	90
Walk*	84	90	98	92	96	96	93
Commercial Streets							
Bicycle	32	27	19	30	29	42	**27**
Drive	80	72	71	77	62	81	72
Walk**	71	78	80	81	87	81	80

Spearman's rho indicates significant differences between groups at the following levels: * $p \leq 0.05$; ** $p \leq 0.01$

In addition, when these responses are categorized according to bicycling frequency, we see that non-cyclists are the least likely to feel safe bicycling in residential areas, and are statistically significantly less likely to feel safe walking in either residential or commercial areas. The findings about bicycling safety corroborate past research about barriers to bicycling and bicycling risk. Fewer potential cyclists than non-cyclists feel safe bicycling in commercial areas, indicating that safety may be slightly less of a barrier to those who never intend to bicycle again than for those who would consider bicycling again, but don't currently do so. In a similar vein, yearly cyclists were the least likely to feel safe bicycling in commercial areas, suggesting that safety may be a more significant barrier to increasing bicycling frequency in this group than among others.

These findings are important, as research has found that if one segment of a trip is considered to be "unbikable", the entire trip may therefore considered unbikable (Mekuria et al., 2012). Given that many destinations (e.g., shops, offices, etc.) are located along major streets, the perceived danger from riding along such streets may be enough to convince someone not to make the trip by bicycle.

In addition, research on reported crash statistics supports these responses. For example, Guler, Grembek, et al. (2012) found that bicycling in California is an average of 6.1 and 6.25 times more dangerous on a per-minute basis than walking or driving, respectively. Similarly, Joshi, Senior et al. (2001) found that bicycling in the U.K. is 7.5 times more dangerous than driving on a per-kilometer basis. However, while these statistics paint an overall picture of bicycling risk, they do not provide insight as to what makes cycling dangerous— knowledge that is critical if the risk is to be addressed. To better understand bicycling risk, we not only need to know what behaviors precipitate crashes and their prevalence, which will be covered in Chapter Nine, we also need to know how these and other behaviors may contribute to *perceptions* of risk.

For example, are there actions by drivers that, while not strongly related to reported crashes, significantly affect how safe a bicyclist feels on the roadway? The next section explores perceptions of bicycling risk.

Perceived Risks of Bicycling

In order to understand how the survey respondents conceptualized bicycle risk, I asked their opinions about a list of dangerous interactions with drivers. These dangers were identified through the focus groups described in Chapter Four, the literature review, and results of the pilot testing. Because increasing bicycling is a policy goal that necessarily depends on new people bicycling, I queried the potential, yearly, and monthly cyclists about the strength of influence (a 4-part Likert scale) of these possible dangers on the decision to bicycle for any purpose. I asked weekly bicyclists how often (a 5-part Likert scale) these same possibilities worried them while bicycling. The answer choices differed between the groups in recognition of the likelihood that their perceptions and experiences of risk would differ. Regular cyclists also preferred a frequency scale in the pilot testing, while for many of the potential, yearly, and monthly cyclists, the frequency scale was essentially meaningless.

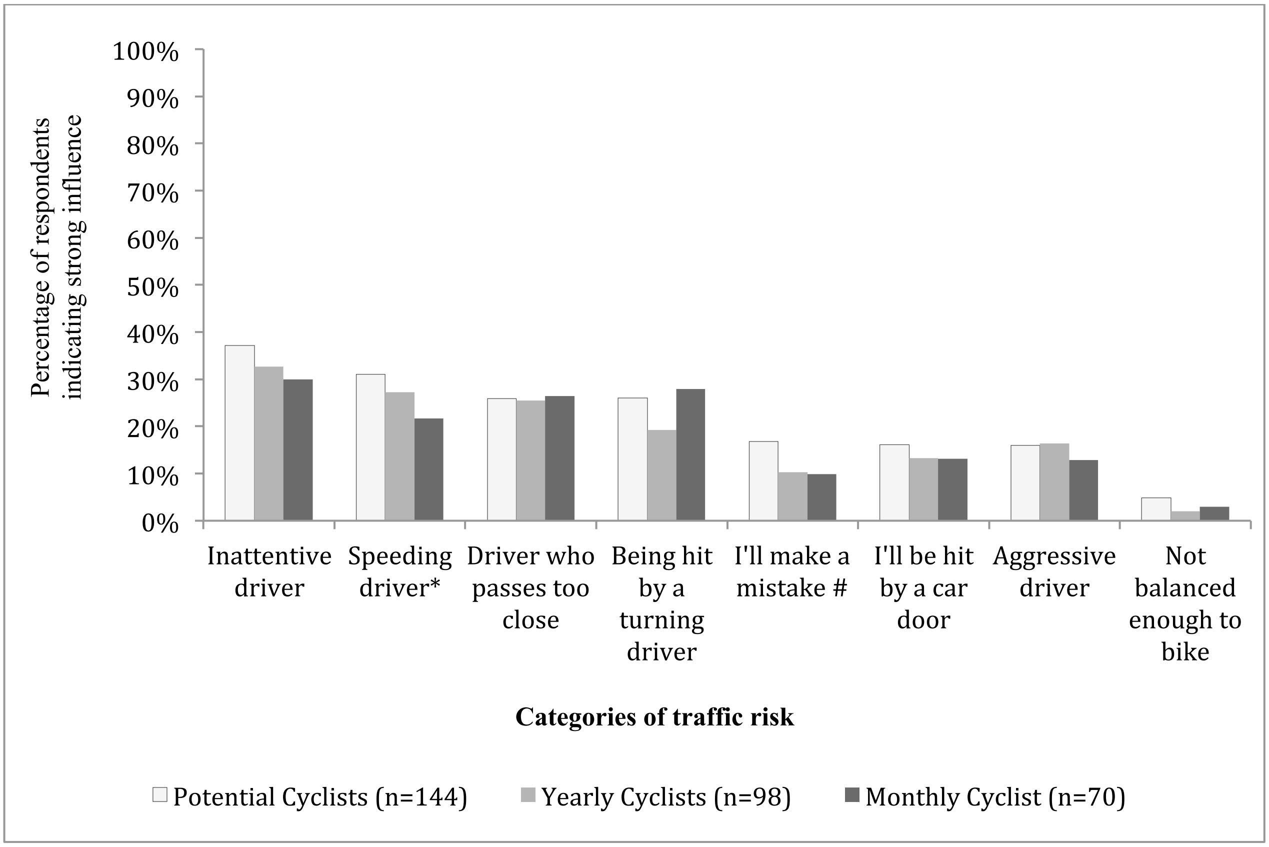
To compare the results between the two groups, I equated the scales in the following way:

- Strong influence = Usually/Always worry
- Somewhat influence = About half the time worry
- Slight influence = Occasional worry
- No influence = Never worry

Risk-related Barriers for Potential and Occasional Bicyclists

I asked the potential, yearly, and monthly bicyclists to rate the level of influence various dangers had on their decision to ride a bicycle for any purpose. I found that the potential worries generally exert a stronger influence on potential cyclists than on yearly and monthly cyclists, suggesting that the experience and skills gained from bicycling may mitigate perceptions of risk. It is also possible that those who are willing to bicycle even once a year have a higher risk tolerance than those who never bicycle and/or do not own a bicycle. In some cases, there is a significant difference between the percentage of each group strongly influenced by a certain fear, while in others, the difference is negligible. I also found that certain worries seem to have much greater overall influence than others. For example, very few people are strongly influenced by a perceived lack of balance, and less than one in five respondents who never bike are strongly influenced by worries of being hit by a car door or being harassed. In contrast, nearly half of these respondents are strongly influenced by worries of being hit by a distracted driver, and nearly one-third are strongly influenced by fears that drivers will drive too fast or too close to them. Figure 31 shows the percentage of respondents for whom various risk-related worries strongly influenced the decision to bicycle for any purpose.

Figure 31. Perceived Traffic Risks More Strongly Influence Decision to Bicycle for Potential Cyclists than Occasional Cyclists (n=312)



Significant difference between groups at the following levels: # $p < 0.10$; * $p < 0.05$

Those who lack access to a bicycle ranked these safety issues in a nearly identical order. However, in every case those who never have access (i.e., those who don't own a bicycle) list the worry as having stronger influence than those who do have bicycles. This finding seems to corroborate the findings from earlier studies showing that not owning a bicycle has been linked to fear of bicycling (Beck and Immers, 1994; Xing et al., 2008).

Traffic Risk-related Barriers for Regular Bicyclists

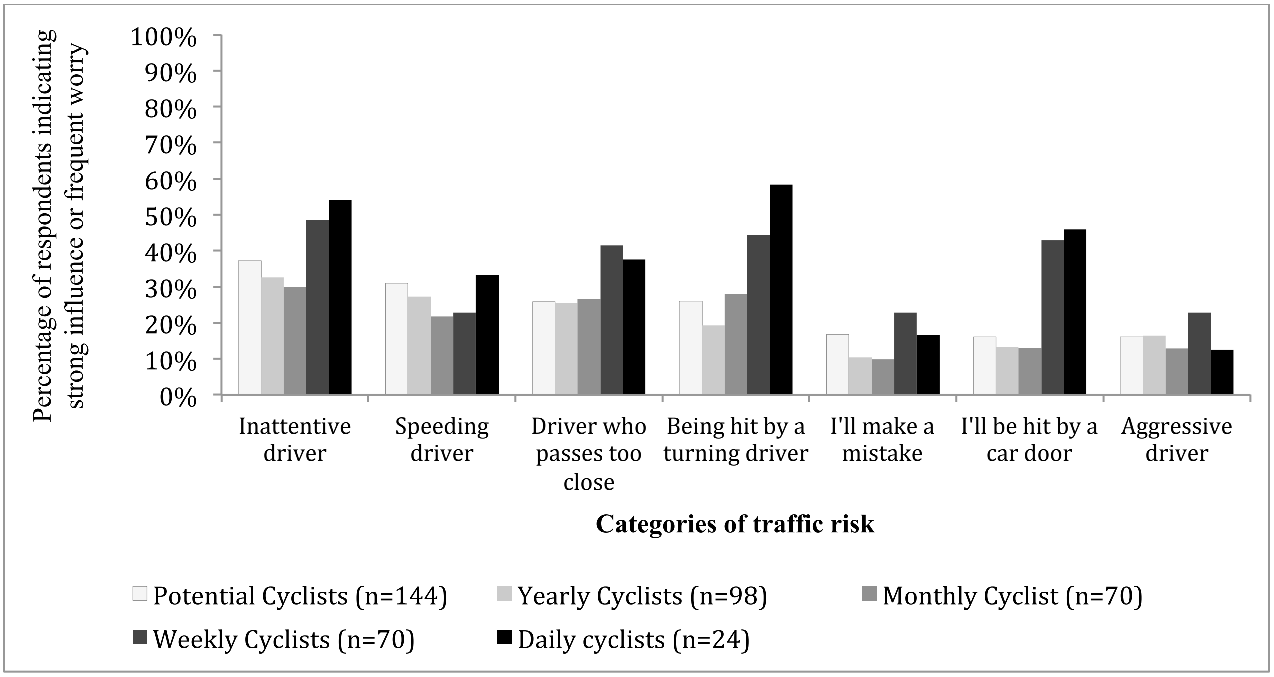
I also asked regular bicyclists about barriers related to bicycling traffic risk. Daily and weekly cyclists are combined in this table, as there was no significant difference between the groups. There is a clear hierarchy among the possible worries that "usually" or "always" worry regular bicyclists versus those that "rarely" or "never" worry them. In addition, some worries, such as experiencing a driver drive too fast while passing or encountering an aggressive driver, have a large discrepancy between those who usually or always experience it and those who rarely or never do. Other worries, such as drivers passing too close by, seem to evenly divide the survey population. Table 11 displays the frequencies with which these cyclists reported worrying about possible safety concerns when they ride.

Table 11. How Often Various Traffic Risks Worry Regular Bicyclists (n=94)

	Usually/ Always %	**Half the time** %	**Occasionally/ Never** %
Worried that I'll be hit by a driver not paying attention	50	21	30
Worried that drivers will cut me off while turning	48	13	37
Worried that I'll be hit by a car door	44	21	35
Worried that drivers will drive too close to me	40	16	44
Worried that drivers will drive too fast near me	26	17	57
Worried that I will make a mistake that will endanger myself or others	21	11	68
Worried that drivers will be intentionally aggressive toward me	20	16	64

Figure 32 adds data about regular cyclists to the information shown in Figure 31 to demonstrate that, while bicycling experience seems to mitigate the influence of various worries on the decision to bicycle, regular cyclists still worry frequently about many dangerous incidents. In fact, a high percentage of regular cyclists are usually or always worried about almost all of the incidents listed. Regular cyclists already bicycle multiple times a week or every day, so it is unlikely that these risks strongly influence their decision to bike. However, my data suggest that the worries are significantly negatively related to perceptions of comfort for bicycling facilities, and perceptions of risk have been found to influence route choice when cycling (Winters et al., 2012).

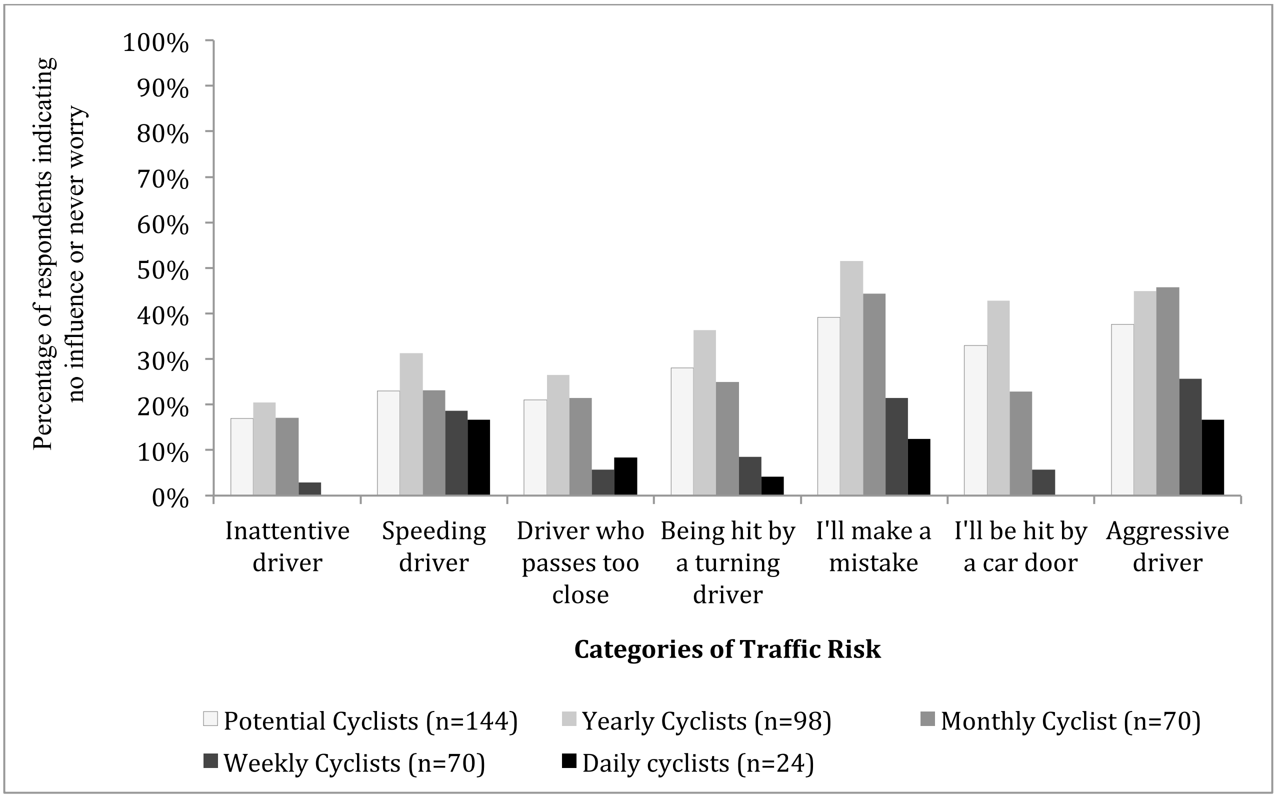
Figure 32. Cycling Experience Mitigates the Influence of Perceived Traffic Risks on the Decision to Bicycle, but Tends to Increase the Frequency of Worry (N=406)



In addition, the risks that usually or always worry the most regular cyclists are not necessarily the risks that strongly influence the most potential and occasional cyclists. There is some alignment, as in the case of inattentive or aggressive drivers; however, a much higher percentage of regular cyclists usually or always worry about being hit by a turning driver or by a car door than the percentage of non-regular cyclists who are strongly influenced by these risks. These findings suggest that the role of cycling frequency in mitigating perceived risk is less clear than Figure 31 indicated. Experience may mitigate how influential a risk is on the decision to bicycle, but the findings in Figure 32 suggest that experience may also make one more aware of—and therefore more worried about—certain risks.

Figure 33 shows the percentage of respondents for whom these same traffic risks are not worrisome or influential. Note that in every case, a smaller percentage of regular cyclists reported that these risks never worried them than the percentage of non-regular cyclists for whom these risks had no influence. For example, while 26% of non-regular cyclists reported being strongly influenced by the worry that drivers will pass too close to them while cycling, less than 10% of regular cyclists reported never worrying about this risk. In fact, no daily cyclists indicated that they "never worry" about inattentive drivers or being hit by a car door, while nearly 20% and 34% of non-regular cyclists, respectively, report that those worries have no influence on them. Similar trends exist for the other risks, underscoring the idea that any effect of bicycling frequency on mitigating perceived bicycling risk is limited somewhat by being more frequently exposed to risk. This relationship between risk and exposure is further explored in the following section and in Chapter Nine.

Figure 33. The Extent to which Traffic Risks Have "No Influence" on Non-Regular Bicyclists and "Never Worry" Regular Bicyclists (N=406)



The Influences of Actual Risk on Perceived Traffic Risk

This section explores the influences of collision and near miss experiences for one's self and among one's family, friends, and neighborhood on various worries about traffic risk.

Influences of Collisions and Near Misses

As described in Chapter Three, theory from the fields of public health and risk assessment suggest that if a person has experienced a traffic risk (such as being hit or almost hit by a car door while cycling), they will be more aware of—and perhaps more actively worried about—it in the future. In addition, studies have shown that people are affected by the experiences of their family and friends (Brooks and Guppy, 1996), suggesting that any crashes or near misses among family or friends could influence one's perceived risks. The analyses presented in this section examined these pathways and found both to be statistically significantly related to perceived risk. Table 12 shows the correlations between worries about various perceived traffic risks and whether someone had experienced a related near miss or collision (e.g., the worry about being hit by a car door and having been hit by one). Several near miss categories are significantly related to perceived risks for all cyclist types, but particularly for weekly and yearly cyclists. Near misses for weekly cyclists, in particular, were highly significantly ($p \leq 0.001$) related to worries about the risk of being hit by a car door, encountering an aggressive driver, being cut off by a turning driver and a driver passing too close or driving too fast. Worries about inattentive drivers are also significantly ($p \leq 0.01$) related to near miss experiences for weekly cyclists. Weekly cyclists' perceived risks were also significantly ($p \leq 0.05$) related to having been hit by an aggressive driver or a driver passing too close, and marginally significantly ($p \leq 0.10$) related to having been hit by a turning driver. These findings corroborate research by Joshi et al. (2001) about the potential influence of near misses in forming and maintaining perceptions of safety.

Table 12. Near Misses Significantly Associated with Worries about Traffic Risk (N=262)

	Related Collision				Related Near Miss			
	Yearly cyclist (n=98)	**Monthly Cyclist (n=69)**	**Weekly Cyclist (n=70)**	**Daily Cyclist (n=24)**	**Yearly cyclist (n=98)**	**Monthly Cyclist (n=69)**	**Weekly Cyclist (n=70)**	**Daily Cyclist (n=24)**
Worry about being cut off by a turning driver	*	-	#	-	*	-	***	*
Worry about aggressive drivers (including honking)	-	-	*	-	**	-	***	-
Worry about being doored	-	-	-	-	**	-	***	
Worry about drivers passing too close	-	-	*	#	-	*	***	*
Worry about drivers driving too fast	#	-	-	-	-	-	***	#
Worry about inattentive drivers	-	-	-	-	-	-	**	-

Significance indicated at the following levels: # $p \leq 0.10$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

The relationship appears to be much stronger for weekly cyclists than for daily cyclists, which may indicate a systematic difference between the two populations, but also may also result from the small sample size for daily cyclists. For daily cyclists, near misses were significantly ($p \leq 0.05$) related to worries about being cut off by a turning driver or having had a driver pass too close. There was also a marginally significant ($p \leq 0.10$) relationship between having experienced a near miss and worries about a driver passing with too high a speed, and having been hit and worries about a driver passing too close.

Experiences had less clear effects on yearly and monthly cyclists' worries, which may reflect the significant ($p \leq 0.0001$) correlation between cycling frequency and the experience of a near miss or collision—that is, these cyclists have likely been exposed to fewer incidents than regular cyclists. Perceived risks for yearly cyclists were significantly ($p \leq 0.01$) related to having nearly been hit by an aggressive driver or a car door. They were also significantly ($p \leq 0.05$) related to having been hit or nearly hit by a turning driver. There was a marginally significant ($p \leq 0.10$) association between worries about drivers passing too fast and having been hit by a motorist passing with too little space. Monthly cyclists' perceived risks were not significantly related to any of the associated collisions, and were only significantly ($p \leq 0.05$) related to having had a near miss with a driver passing too closely.

It seems counterintuitive that perceived risks for both yearly cyclists and weekly cyclists are higher than the perceived risks for monthly cyclists. This may be due to the mitigating effect of exposure, as seen in Figure 32 and Figure 33. The analysis suggests that exposure decreases the strength or frequency of perceived risks among occasional cyclists such that fewer monthly cyclists than yearly cyclists are strongly influenced by most risks. However, bicycling frequency also significantly increases exposure to the risks, such that fewer weekly and daily cyclists never worried about the risks than any of the other cycling respondents.

While these significant associations likely reflect the trauma of being hit by a car, they may also be explained by other aspects of cycling risk. First, they may reflect the severity of these particular incidents, as severe incidents likely have greater influence on worries than mild incidents. These findings also provide evidence that near misses, a typically unmeasured aspect of traffic risk, may factor heavily into what makes bicycling seem unsafe for various user groups. Finally, whether these specific incidents are significantly associated with perceived risks is only part of the story, and one that needs to be further investigated by future research. There may also be other variables that affect one's perception of risk.

Influence of friends and family

Table 13 shows the percentage of respondents in each group who know someone—themselves, friends, or family—who has crashed with a driver while cycling, or crashed with a bicyclist while driving. Note that at least one-third of the respondents know someone who has crashed with a driver while bicycling. In contrast, only 10% of respondents know someone who has crashed with a cyclist while driving.

Table 13. Percentage of Respondents Who Have Experienced or Whose Friends or Family Have Experienced a Bicycle-Driver Collision (N=463)

	Non-cyclist (n=45) %	**Potential cyclist** (n=145) %	**Yearly Cyclist** (n=100) %	**Monthly Cyclist** (n=71) %	**Weekly Cyclist** (n=76) %	**Daily Cyclist** (n=26) %
You, friends or family have crashed with a driver while bicycling**	24	31	35	45	54	46
- Bicyclist was hurt	11	15	17	20	30	15
- Driver was hurt	-	-	-	1	1	-
You, friends or family have crashed with a cyclist while driving	16	8	6	13	11	15
- Bicyclist was hurt	9	3	-	4	-	4
- Driver was hurt	-	-	-	1	-	-

Significance indicated at the following levels: ** $p \leq 0.01$

Table 14 displays the results of analysis of the correlation between various worries about traffic risk and knowing a driver (including oneself) who had crashed with a cyclist. Worries about perceived risks for monthly cyclists were much more likely to be significantly ($p \leq 0.05$) correlated to knowing someone who had hit a cyclist—particularly, worries about being cut off by a turning driver, being hit by a distracted driver, and being hit by a car door. Worries about traffic risks for daily cyclists were marginally significantly related ($p \leq 0.10$) to knowing a driver who had crashed with a cyclist, particularly worries about distracted drivers and drivers passing too fast near a cyclist. There does not seem to be a pattern in this data, so it is difficult to know if there is something deeper, or if the small sample size influenced the results.

Table 14. Influence of One's Own, Friends', and Family's Crash Experiences as a Driver on Worries about Traffic Risk (N=400)

	You, friends or family have crashed with a cyclist while driving				
	Potential cyclist (n=141)	**Yearly Cyclist (n=97)**	**Monthly Cyclist (n=69)**	**Weekly Cyclist (n=69)**	**Daily Cyclist (n=24)**
Worry about being cut off by a turning driver	-	-	*	-	-
Worry about a distracted driver	-	-	*	-	#
Worry about being doored	-	-	*	-	-
Worry about drivers driving too fast while passing	-	-	-	-	#

Significance indicated at the following levels: # $p \leq 0.10$; * $p \leq 0.05$

Table 15 shows the influence of family and friends who have crashed with a car while cycling. As in Table 14, there was no significant correlation between any worries and this knowledge for yearly cyclists. For potential cyclists, only the worry about being hit by a car door was significantly related to knowing a cyclist who had been hit by a motorist. Again, the significant correlations were strongest for monthly cyclists, particularly for worries about drivers coming too close. Weekly cyclists' worries were significantly related to their own or others' crash experiences in the case of being cut off by a driver and being hit by a car door. For daily cyclists, the significant worry was being cut off by a turning driver. Because of the question's wording, it is impossible to completely tease out the effects of one's own experiences versus the experiences of family and friends. However, there is a stark difference between the results in Table 12, which solely covered one's own experiences, to those in Table 15, which includes the experiences of friends and family. This is particularly the case for monthly cyclists, suggesting that the experiences of family and friends significantly affect their perceptions of risk.

Table 15. Influence of One's Own, Friends', and Family's Crash Experiences as a Cyclist on Worries about Traffic Risk (n=404)

	Friends or family have crashed with a driver while bicycling				
	Potential Cyclist (n=144)	**Yearly Cyclist (n=98)**	**Monthly Cyclist (n=69)**	**Weekly Cyclist (n=69)**	**Daily Cyclist (n=24)**
Worry about being cut off by a driver making a turn	-	-	*	#	*
Worry about being doored	*	-	*	*	-
Worry about drivers driving too close	-	-	**	-	-
Worry about drivers driving too fast	-	-	*	-	-
Worry about aggressive driver	-	-	#	-	-
Worry about distracted driver	-	-	*	-	-

Significance indicated at the following levels: # $p \leq 0.10$; * $p \leq 0.05$; ** $p \leq 0.01$

Perceived Risk: Just Another Barrier?

In Chapter Five, I discussed findings about non-traffic-risk barriers to bicycling, while this chapter has focused on findings about perceived traffic risk. While I did not ask the survey respondents to rank these barriers against one another, it is instructive to examine the percentage of respondents who reported being always or usually influenced by each of these barriers and risks to begin to understand their relative influence.

Table D3 in Appendix D shows the percentage of respondents reporting that each of the barriers, including perceived risks, usually or always affected their decision to bike. To simplify the discussion for this chapter, I classified the barriers as fundamental, probable, or possible, and will discuss them within each of those categories. The categorization is based on the percentage of respondents reporting them as either "strongly influential" or "usually" or "always" affecting the decision to bike.[13] Of course, each cycling group differs according to relative perceptions of what is more or less of a barrier, but this categorization is an efficient way to digest a fairly large amount of nuanced information.

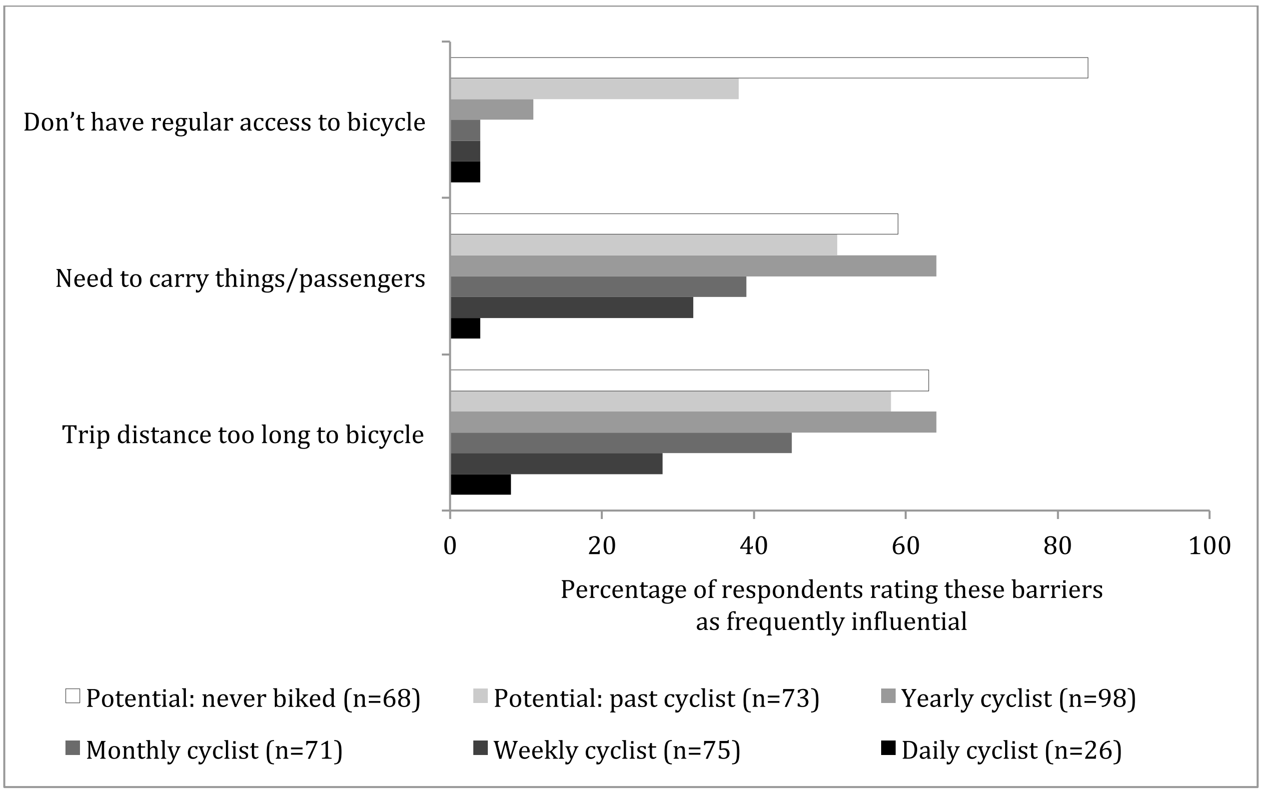
Fundamental Barriers

The first category, fundamental barriers, were those that were listed by at least 50% of any group of cyclists *other than regular cyclists* as usually or always affecting the decision to bike for any purpose. Regular cyclists were excepted from this criteria because they rated many of the perceived risks as usually or always worrying them, but they clearly bicycle despite these impediments. For all other cyclists, however, these barriers influence the decision to bicycle. Fundamental barriers included trip distance being too long to bike, thinking that bicycling was impractical due to a need to carry loads or passengers, and not having regular bike access.

[13] Recall that regular cyclists, due to their cycling frequency, reported how often they worried about perceived risks, rather than how strongly they were influenced by them.

As Figure 34 shows, trip distance was listed as usually or always affecting the decision to bike for over 60% of potential and yearly cyclists. Thinking bicycling was impractical was listed for about 55% of potential cyclists and 64% of yearly cyclists, suggesting that both barriers need to be addressed if policy goals to encourage more people to bicycle are to be met. Although slightly less affected by these barriers, still approximately 40-45% of monthly cyclists were usually or always affected by them. Only about 30% of weekly cyclists were usually or always affected by these barriers, and less than 10% of daily cyclists were. Not having regular access to a bicycle was considered a serious impediment by potential cyclists, particularly those who had never biked (of whom 84% listed it as usually or always affecting their decision). About 10% of yearly cyclists were usually or always affected by not having regular access, compared to less than 5% of monthly or regular cyclists. Note that there are no perceived risks in this figure, as none were deemed to be strongly influential for more than 50% of the non-cycling respondents.

Figure 34. Comparison of Fundamental Bicycling Barriers for Potential and Current Cyclists



Probable Barriers

The next category, probable barriers, includes those listed by at least 25% of any group other than regular cyclists. These barriers show a more nuanced difference between groups, and include the following (parentheses indicate the percentage of total respondents usually or always affected):

- Worry about distracted drivers (38%)
- Worry about drivers passing too close (30%)
- Worry about being cut off by a turning driver (30%)

- Hills (28%)
- Worry about drivers driving too fast while passing (27%)
- Lack of secure bike parking (25%)
- Lack of bike lanes or routes where need to travel (23%)

I compared the percentage of respondents in each group who listed these barriers as usually or always influencing their decision to bicycle. Potential cyclists who never bike were more likely than other cyclists to be affected by almost every non-risk-related barrier listed. While this reflects what we saw earlier in the chapter in Figure 31, we now see that, for these potential cyclists, their worries are approximately commensurate with the non-risk-related barriers. In addition, potential cyclists who never bike seem to be more worried about the perceived risks than other non-regular cyclists, even potential cyclists who have biked in the past. This may indicate that worries about cycling risk are keeping some people from ever trying to bicycle, even if they are interested in doing so. It may also be evidence of the mitigating effect of some cycling experience on perceived risks.

I also found that worries about distracted driving top almost every other probable barrier for every group, the only exception being hills for yearly cyclists and potential cyclists who have biked in the past, and daily cyclists worried about being cut off. For yearly cyclists, the difference between the two categories was negligible. As Chapter Nine shows, crash records for the Bay Area indicate that this high amount of worry about distracted drivers does not reflect reported crash statistics. However, this may result from issues with crash recording, rather than the absence of risk from distracted drivers. It may also result from the sensationalizing of distracted driving in the media and through policy efforts to discourage it. These possibilities and the perceived risk of distracted drivers should be further explored in future research.

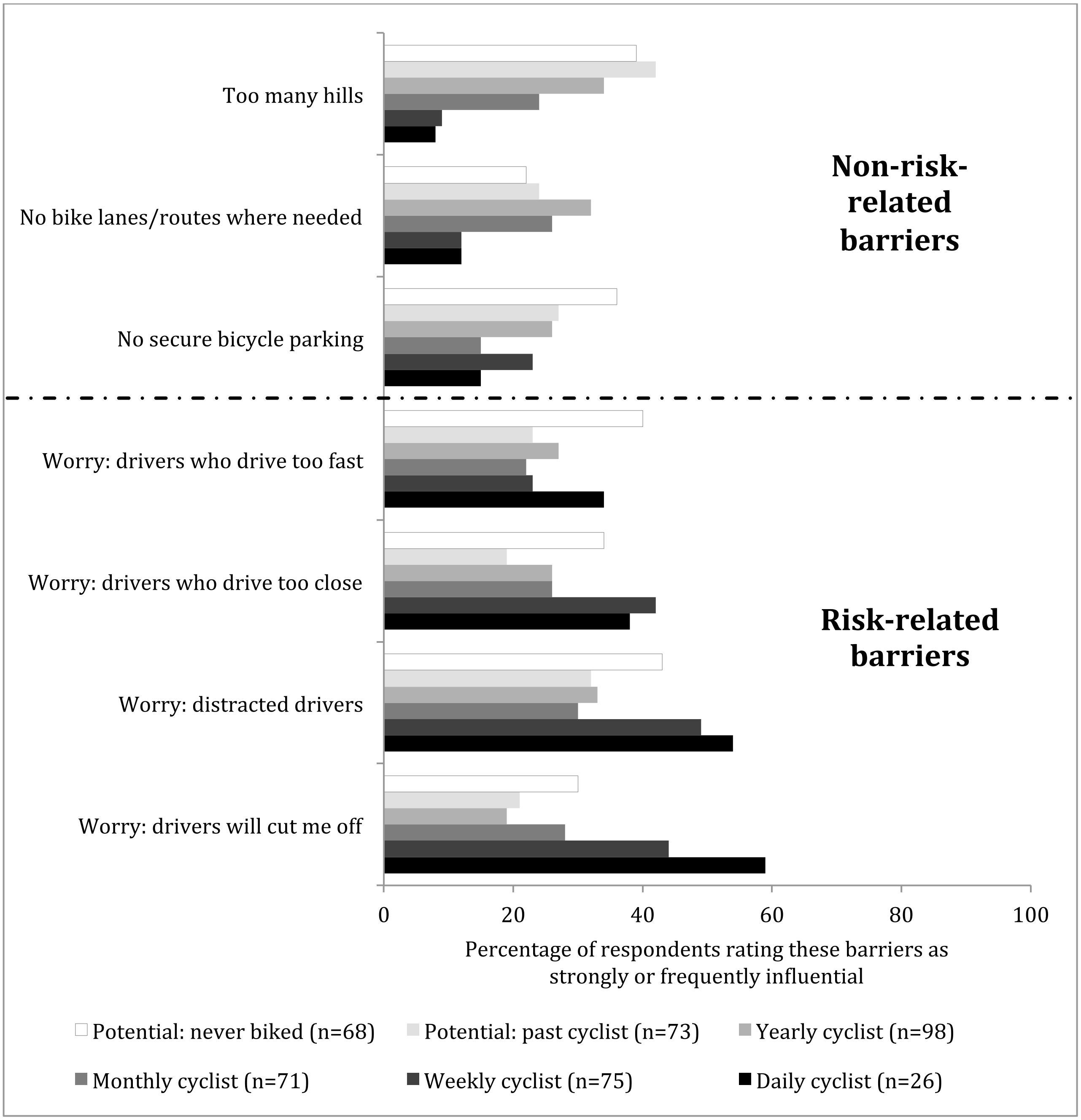
In addition, a higher percentage of yearly cyclists are affected by not having bike lanes or routes where they want to travel than any of the other groups (32% versus 22-26% for monthly and potential cyclists, and 12% for regular cyclists). As discussed in Chapter Five, this suggests that constructing more bike lane and route miles without addressing the other fundamental and probable barriers may do more to increase trips among yearly cyclists than convince potential cyclists, particularly those who have never biked, to begin cycling.

As might be expected, among the potential and occasional cyclists, those who bicycle at least several times a month are generally less affected by all of the non-risk-related barriers. Those who bicycle regularly are even less affected. This is intuitive given that those who bicycle more frequently have likely found strategies to work around such barriers.

Additionally, the range in percentage of people rating each barrier as affecting them is much larger for regular cyclists than other groups. This again reflects the relatively low percentage of respondents rating the non-risk-related barriers as affecting them, but it also reflect the relatively high percentage of regular cyclists usually or always worried about traffic risks. For example, between 50-60% of daily cyclists are usually or always worried about being cut off by a driver or hit by a distracted driver, while 40-50% of weekly cyclists are worried about the same risks. In contrast, less than 10% of regular cyclists are usually or always affected by hills, and less than 20% are usually or always affected by a lack of bike lanes or routes where they need to travel.

Finally, the four largest barriers for regular cyclists are worries, in contrast to the clear mix for non-regular cyclists. What is unclear from this research is how cyclists transition from worries being true barriers that keep them from cycling, as may be the case for some of the potential and other non-regular cyclists, to worries being an accepted hazard of the activity, but not a reason to avoid it. This spectrum should be further explored in future research. These findings are reflected in Figure 35. Recall that regular cyclists were queried about frequency of worry, rather than influence. The risk-related barriers are more unpleasant accompaniments than true barriers.

Figure 35. Comparison of Probable Bicycling Barriers for Potential and Current Cyclists



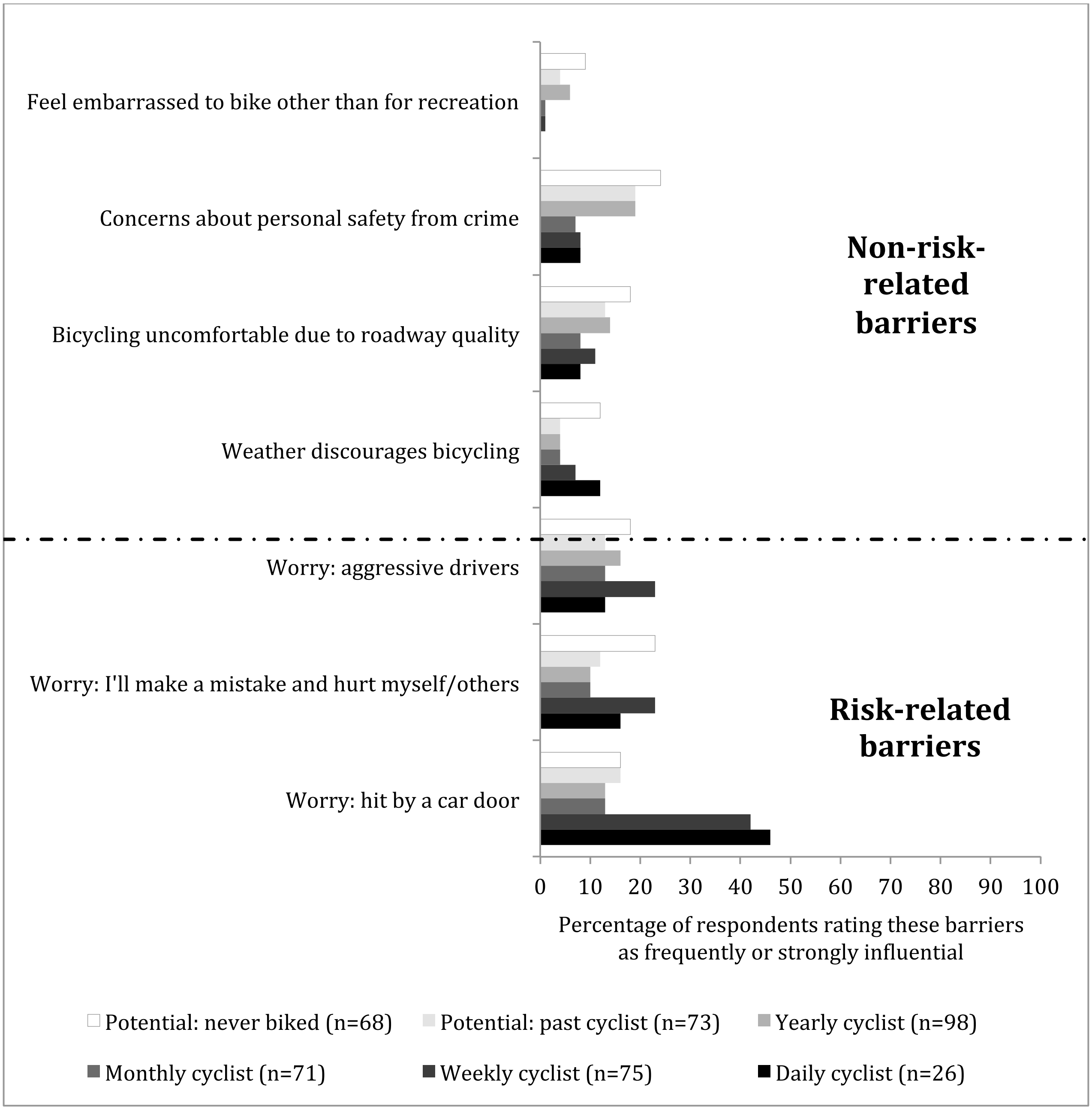
Possible Barriers

The last category, possible barriers, is composed of barriers that were requested by less than 25% of each group except regular cyclists. Possible barriers include the following (percentage of total respondents usually or always affected):

- Worries about being hit by a car door (21%)
- Worries about aggressive drivers (16%)
- Concerns about personal safety from crime (15%)
- Worries about making a mistake and hurting myself or others (15%)
- Physical discomfort due to roadway quality (13%)
- Weather (6%)
- Feeling embarrassed by bicycling other than for recreation (4%)
- Worries about not having enough balance to bike without falling (3%)

Figure 36 compares the possible barriers among cycling groups. The main takeaway from this chart is the relatively low influence these barriers, including worries about certain traffic risks, seem to have on the decision to bicycle for potential and occasional cyclists. The physical barriers are almost completely unimportant to regular cyclists, and two of the perceived risks—worries about aggressive drivers or making a mistake—usually or always worry less than 25% of them. However, the risk of being hit by a car door, of small influence for non-regular cyclists, consistently worries regular cyclists.

Figure 36. Comparison of Possible Bicycling Barriers for Potential and Current Cyclists



Discussion of Barriers

The categories suggest a hierarchy for addressing various barriers to bicycling. First, it is clear that if people do not have access to a bicycle, cannot meet their load-carrying needs, or if trip distances are too long (the fundamental barriers), bicycling will not be an option for those trips. The barrier of not having a bicycle was significant only for potential cyclists, and thus will likely best be addressed indirectly, through directly addressing the other barriers that keep them from wanting to bicycle enough to own a bike. Bike-sharing systems can provide bike access to those who don't already have it, but these are limited in geographic distribution and still may not appeal to potential cyclists if other barriers have not been addressed. More research focusing on potential cyclists is needed.

Addressing the barrier of trip distance will be a long-term process that may include changing the urban form over time to bring destinations closer together. It is also possible that when respondents reported that trip distances were too long, they were thinking not only of the actual distance to the destination, but also the time it would take to get there—especially comfortably and safely. Thus, another long-term goal would be to make current trips more bikable by shortening the travel time for trips using bicycle infrastructure, and providing more of the infrastructure to increase the possibility of such trips. For example, Berkeley, California uses a system of bicycle boulevards that give cyclists the right-of-way at most intersections. Thus, a trip made via bicycle boulevard has many fewer stops than a trip made on a neighboring street, allowing the cyclist to arrive to his destination more quickly. The more attractive options there are to bicycle, the more likely it will be that the trip will be accessible by bike. Another option to shorten travel time would be to legally allow bicyclists to treat stop signs as yield signs, mirroring an Idaho law that the majority of my survey respondents supported.

Addressing the issue of load-carrying will also likely include a mix of near- and long-term strategies. There will always be trips that require a motor vehicle for the size of load or number and type of passengers they carry. However, there are likely also trips that could be made by bicycle if the person had the right equipment to do so. While there are options currently available for carrying small loads or children under a certain size on a bicycle, the options for carrying both children and loads (known as "cargo bikes") are often prohibitively expensive, contravening the economical benefit of bicycling. Thus, a long-term strategy may be for bicycle manufacturers to create more affordable cargo bicycles that would allow trip substitution without a major financial investment. Another aspect of addressing this barrier is, again, to provide bicycle infrastructure people would feel comfortable using when carrying loads—especially children. If people don't feel safe carrying their children on a bike, they won't likely consider it an option regardless of the equipment.

It is also clear from the data that the "probable" barriers need to be addressed. In this category, the more pressing barriers are the worries about perceived risks—particularly the worry about distracted drivers and drivers passing too close, cutting one off while turning, and driving too fast. We saw earlier in the chapter that perceived risks tend to be associated with actual risk in the form collision and near miss experiences. Therefore, behavioral change on the part of drivers and cyclists will likely play a major role in addressing these perceived risks. This could be accomplished in part through participation in driver and bicyclist education programs that focus on teaching participants how to behave appropriately and safely while driving near bicyclists and bicycling near drivers, as well as roadway rights and responsibilities. To ensure the success of this strategy, driver education programs may need to be revamped to include consistent and thorough information about bicycling, and incentives for participation may be necessary—particularly for bicycling education programs, given currently low participation rates for voluntary secondary mobility education.

Infrastructure has a role to play in addressing perceived risks, as well. Chapter Six showed that cyclists feel much more comfortable in separated, rather than shared, space—particularly if the space is barrier-separated. Studies suggest that these facilities are positively associated with decreased cycling risk (Lusk et al., 2011; Reynolds et al., 2009; Teschke et al., 2012), in part due to increased cycling on the roadway (Chen et al., 2012). Ideally, facility mileage would increase in tandem with a more substantial educational effort to teach bicyclists and drivers how to behave around each other on all types of roadways.

Non-risk-related probable barriers included hills, a lack of secure parking, and a lack of bike lanes or routes where one wants to go. Hills are difficult to address, although cycling experience may provide a person with the skills they need to navigate hills more comfortably. Indeed, there was a highly significant ($p \leq 0.001$) association between hills as a barrier and worries about bicycling traffic risk among non-regular cyclists. Secure bicycle parking can be addressed through the provision of sturdy bicycle racks in well-lit locations, indoor locking facilities, and outdoor lockers. Relatively speaking, this should be one of the easier barriers to address, but it is also one of the lower priorities. Finally, the barrier of not having bike lanes or routes where one wants to go needs to be addressed. While this barrier usually or always affected the fewest respondents of the probable barriers, it likely affects many of the other fundamental and probable barriers. For potential and occasional cyclists, for example, not having a bicycle lane where they need to go was highly significantly correlated ($p \leq 0.001$) to worries about traffic risk. This barrier is often difficult to address given the cost of building facilities, space constraints on many major roadways, and, at times, political concerns, but the evidence suggests that building additional bicycle facilities is a critical component of strategies to increase cycling. Many of the cities and counties covered in this study have plans to expand their bike networks and are therefore already working—albeit at varying levels—to address this barrier.

The lowest priority of barriers to be addressed are the possible barriers, which included worries about perceived risks of being hit by a car door, aggressive drivers, and making a mistake that could hurt oneself or others. As suggested above, the perceived risks would likely best be addressed through behavioral change on the part of drivers and cyclists and concerted educational efforts for both parties. A beneficial aspect of the educational efforts is that they may simultaneously mitigate multiple perceived risks. The non-risk-related possible barriers included physical discomfort of roadway quality, weather, embarrassment, and not having the balance to bike without falling—the latter three being cited as usually or always influential by only a small fraction of the survey population. Roadway quality should generally be able to be addressed through the building of bicycle-specific infrastructure, as well as general roadway maintenance. The effects of weather may be addressed in a limited fashion through bicycle-specific gear such as rain jackets and pants and fenders, but may not be able to be completely addressed. Worries about falling may be addressed through bicycle training classes, while feeling embarrassed about bicycling seems to be more of a social perception problem that may only change when the percentage of bicyclists (and likely the diversity of bicyclists) on the streets increases.

The barriers in this chapter were classified based on the responses of the survey sample, but it is clear that the boundaries between them are fluid. This is likely due in part to the way people make decisions about travel. For example, Schneider's (2013) mode choice theory suggests that a mode has to be considered possible or practical before it can be judged for its comfort, enjoyment, etc. For those respondents without a bicycle, for example, bicycling is likely eliminated from the options before a conscious choice is even made. Fear can also play a role in the subconscious decision about whether a mode is practical. For example, my data indicate that potential cyclists who have never biked are more worried about dangerous interactions with cars than potential cyclists who have biked in the past, and previous research has shown that perceptions of safety and comfort affect bicycle ownership (Beck and Immers, 1994; Xing et al., 2008).

Summary of Key Findings

In this chapter, I examined how my survey population viewed various bicycling risks, and how those perceptions related to their own and others' experiences. The findings provide some clarity about how fear interacts with bicycling experience to operate as a barrier for bicyclists of differing experience levels, particularly those who bicycle little or not at all. They also demonstrate that cycling experience may increase perceived risks—even though the risks are no longer necessarily barriers to cycling. These findings may contribute to strategies to increase bicycling safety for all cyclists by illuminating the role of driver and bicyclist actions in making bicycling more or less safe. I also compared perceived risks to the non-risk-related barriers discussed in Chapter Five, in an attempt to understand their relative influence on the decision to bicycle. Key takeaways from this chapter include the following findings.

General Perceptions of Safety

1. A super-majority of my respondents reported feeling safe walking and driving on residential and commercial streets, and even bicycling on residential streets. However, less than 30% of the sample reported feeling safe bicycling on commercial streets, underscoring that perceived bicycling risk is a barrier to bicycling.

Perceived Bicycling Risk

2. Among non-regular cyclists, cycling experience tends to mitigate the strength of influence a perceived risk has on the decision to bike for any purpose. Potential cyclists are more strongly influenced than other cyclists by almost every perceived risk.
3. While cycling experience seems to mitigate the influence of perceived risks on the decision to bicycle, regular cyclists reported frequently worrying about certain perceived risks. Similarly, a much smaller percentage of regular cyclists reported never worrying about risks than the percentage of non-regular cyclists who reported that the risks had no influence on the decision to bike.
4. All cycling groups worry more about certain perceived risks than others. For example, the possibility of encountering a distracted driver or being cut off by a turning driver usually or always worried approximately 50% of regular cyclists. In contrast, only 20% of regular cyclists were usually or always worried about aggressive drivers or making a mistake while cycling.

Influences on Perceived Risks

5. One's own near misses were significantly related to perceived risks, particularly strongly so for weekly cyclists.
6. One-third of the sample had either been hit by a car while cycling, or had a friend or family member who had been hit by a car while cycling. In contrast, less than 10% of the sample had either hit a cyclist while driving or had a friend or family member do so.

7. One's own, friends', and family's experiences while driving were significantly related to worries about perceived risks for monthly and daily cyclists, and particularly so for monthly cyclists.
8. One's own, friends', and family's experiences while cycling were significantly related to worries about perceived risks for monthly and daily cyclists, again particularly so for monthly cyclists. Compared with the results of one's own experiences, this finding suggests that the monthly cyclists in this sample were more affected by others' experiences, while the weekly cyclists were more affected by their own experiences.

Comparing Risk-related and Non-risk-related Barriers

9. There seem to be three basic types of barriers: fundamental, probable, and possible.
10. Fundamental barriers are those that at least 50% of one or more groups of cyclists reported usually or always affecting the decision to bike. These included trip distances being too long, a need to carry things or passengers, and not having regular access to a bike.
11. Probable barriers are those that at least 25% of one or more groups of cyclists reported usually or always affecting the decision to bike. These included worries about distracted drivers and drivers driving too fast, too close, or cutting one off while turning. Non-risk-related barriers in this category included hills, a lack of secure bike parking, and a lack of bike lanes or routes where one needs to travel.
12. Possible barriers include those that were reported by less than 25% of each group as usually or always affecting the decision to bike. These included worries about being hit by a car door, aggressive drivers, making a mistake while cycling, and lacking the balance to bike without falling. Non-risk-related barriers in this category included concerns about personal safety from crime, physical discomfort due to roadway quality, weather, and feeling embarrassed about bicycling.
13. While there are varying strategies to addressing each of these barriers, some with more potential than others, providing better bicycle-specific infrastructure seems to be the key element that could help make progress toward mitigating all of them.

The following chapter expands on these findings through a discussion of how perceived risks associated with bicycling affect support for bicycling.

Chapter 8 – Perceived Risk and Support for Bicycling

The previous chapters examined how perceived risk relates to cycling frequency, personal experience, the built environment, and personal beliefs about cycling. In particular, Chapter Six demonstrated that roadway design is highly significantly related to one's comfort on the roadway, with dramatic differences in the percentage of cyclists (particularly potential cyclists) comfortable bicycling on roadways with physically separated space versus shared space. Chapter Seven examined how perceived risk is informed by experience and found that it is one of the strongest barriers to bicycling, suggesting that addressing perceived risk is important if cities want to encourage cycling.

In this chapter, I use a structural equation model to explore how various factors affect community support for bicycling. I find that bicycling support is significantly correlated with perceived cycling risk for oneself and others, cycling frequency, negative experiences driving near cyclists, and beliefs about the practicality of cycling. These findings suggest that addressing cycling risk is critical to increasing support for bicycling in communities—perhaps particularly so where cycling has gained a foothold. The following sections dissect the modeling results and discuss their implications in detail.

Examining Support for Bicycling

Making physical changes to the roadway to encourage more bicycling is often associated with controversy in the U.S. As cycling continues to increase in many cities, support for cycling facilities that originally led to roadway infrastructure changes has been countered by resistance to such efforts. To date, no studies have sought to understand how perceived bicycling risk—a major influence on whether or not people bicycle—also informs this debate, potentially contributing to support or resistance efforts. My data show that there is a significant relationship, one that I believe should be considered in research and practice going forward.

Data from recent national transportation surveys show that bike commuting has increased an average of 47% in major U.S. cities over the last decade (Flusche, 2012). In some cities, such as Lexington, Kentucky, and Portland, Oregon, the percentage of bike commuters has grown over 300% since 2000, while many other U.S. cities have seen growth in excess of 100-200%. Given this trend toward increased cycling and potentially commensurate increased conflict over limited roadway space, efforts to design and build roadways that accommodate multiple roadway users—whether through bicycle-specific infrastructure, lowered speed limits, or other means—are likely in the best interest of all parties when it comes to safety and comfort. Indeed, my research corroborates multiple other studies showing a clear preference for roadways with bike infrastructure, as seen in Chapter Six.

Yet for all of their perceived benefits and demand, it is often a struggle to build bicycle infrastructure, particularly bike lanes (barrier-separated or not), and sometimes such infrastructure becomes the target of community resistance. Recent anti-bicycle lane efforts in such "bicycle friendly" cities as Portland, Oregon, and New York City,[14] have shown that bicycling infrastructure often depends on community support to be successfully installed and maintained. For example, in Portland, city residents convened a group to resist the installation of

[14] Portland is one of only 4 platinum-level bicycle friendly communities, as designated by the League of American Bicyclists, and New York City is one of 51 cities at the silver level.

bicycle lanes that they believed would further gentrify their neighborhood (Stehlin, 2013). In Brooklyn, a neighborhood group opposed to the traffic a bicycle lane would bring fought successfully to have it relocated to another area (Gootman, 2011). In a separate case, well-connected residents of a wealthy neighborhood unsuccessfully sued the city to try to force removal of bicycle lanes near its local park (Grynbaum, 2011).

The stories behind these efforts suggest that many factors, including worries about loss of parking, changes in property values, and worries about traffic risk, are associated with resistance to the lanes. While some of these factors are neighborhood specific (e.g., property values), others speak to more general concerns about, disinterest in, or dislike of bicycling and perhaps bicyclists. Understanding these larger factors may be critical to increasing bicycling support—defined in this dissertation as a desire to see more cyclists in one's city and a willingness to use public funding for cycling and replace some on-street parking with a bike lane—and reducing inter-modal tension in communities where cyclists continue to grow in numbers.

This chapter uses a structural equation model (SEM) to explore the relationships between bicycling support and demographics, negative experiences driving or cycling, perceptions of risk, built environment characteristics, and other attitudes toward cycling among my survey participants. The SEM allowed me to explore latent effects and endogeneity between variables, in addition to simultaneously modeling multiple equations to determine direct and indirect effects on bicycling support that may otherwise have been masked in more common linear regression models such as ordinary least squares.

Several of the results from the SEM surprised me. I expected to find that demographics and one's perceived risk while cycling, which affect if and how often someone bicycles, would play a larger role in determining support for cycling. While one's own perceived risks are significant in the model, they are overshadowed by worries about cycling risk for others, suggesting that bicycling is perceived as generally dangerous by many of the respondents. This is not helped by negative interactions with cyclists, which led respondents to be significantly less supportive of cycling. As would be expected, the more a person bicycles, the more she supports bicycling, and having friends or family who cycle or who have crashed with a car while cycling significantly increases bicycling support. There is also some evidence connecting the built environment to support: respondents who lived within 2 miles of a bike lane had significantly ($p \leq 0.10$) higher bicycling support scores than those who lived 2 or more miles from a bike lane.

These findings suggest that support for bicycling is a complex construct in which relationships do not function as one might expect. Yet, with the knowledge from this SEM analysis, practitioners can perhaps better understand and begin to address pathways to bicycling support. The SEM findings indicate that improving the perceived and actual safety of cycling is critical to increasing bicycling support. Along the same lines, getting more people to bicycle – through addressing the barriers and perceived risks discussed in Chapters Five and Seven – will also significantly improve bicycling support. An additional pathway is that of improving the behavior of cyclists. Finally, building infrastructure that improves perceived and actual safety for both cyclists and drivers is a key component to addressing these significant variables.

Bi-variate Analyses of Support and Safety

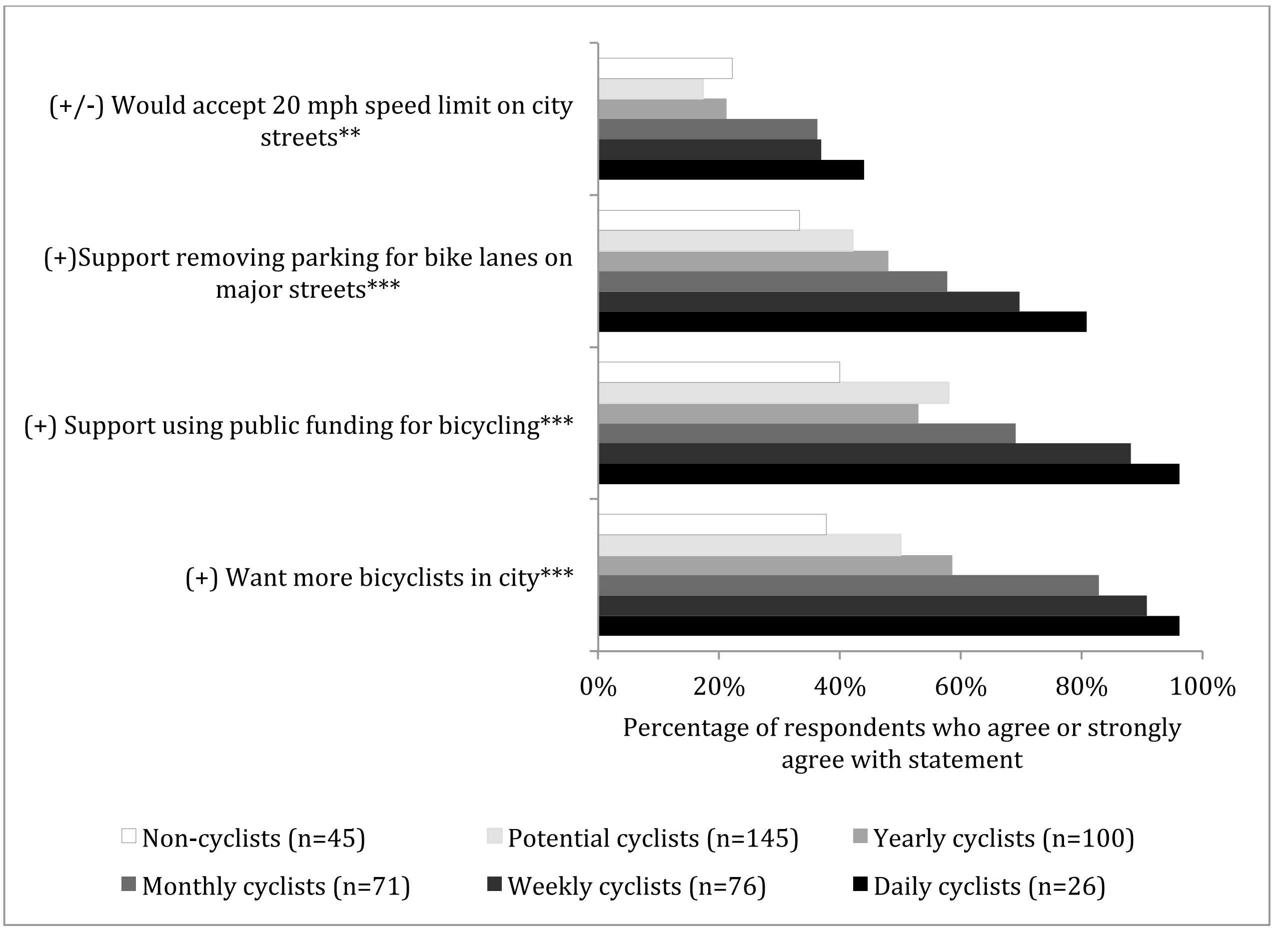
As discussed in Chapter Five, I asked the respondents about their agreement (5-part Likert scale) with the following statements about support for bicycling in their cities:

1) I would like to see more people bicycling in my city;

2) I support using public funding to encourage bicycling;
3) I would support removing some car parking along major streets in order to accommodate a bicycle lane;
4) Bicyclists should ride only on designated bike routes; and
5) Bicycling should be restricted to off-street paths.

Figure 37 displays the percentage of respondents who agreed with questions about various ways to support bicycling in one's city. The amount of general support for bicycling was significantly and positively associated with respondents' bicycling frequency. In particular, non-cyclists were much less enthusiastic about supporting cycling in their cities than other groups, with no more than 40% agreeing with any one of the positive support questions. In contrast, with the exception of lowering the speed limit, which drew a mixed response from every group, at least 70% of weekly and 80% of daily cyclists agreed with each of the positive support questions.

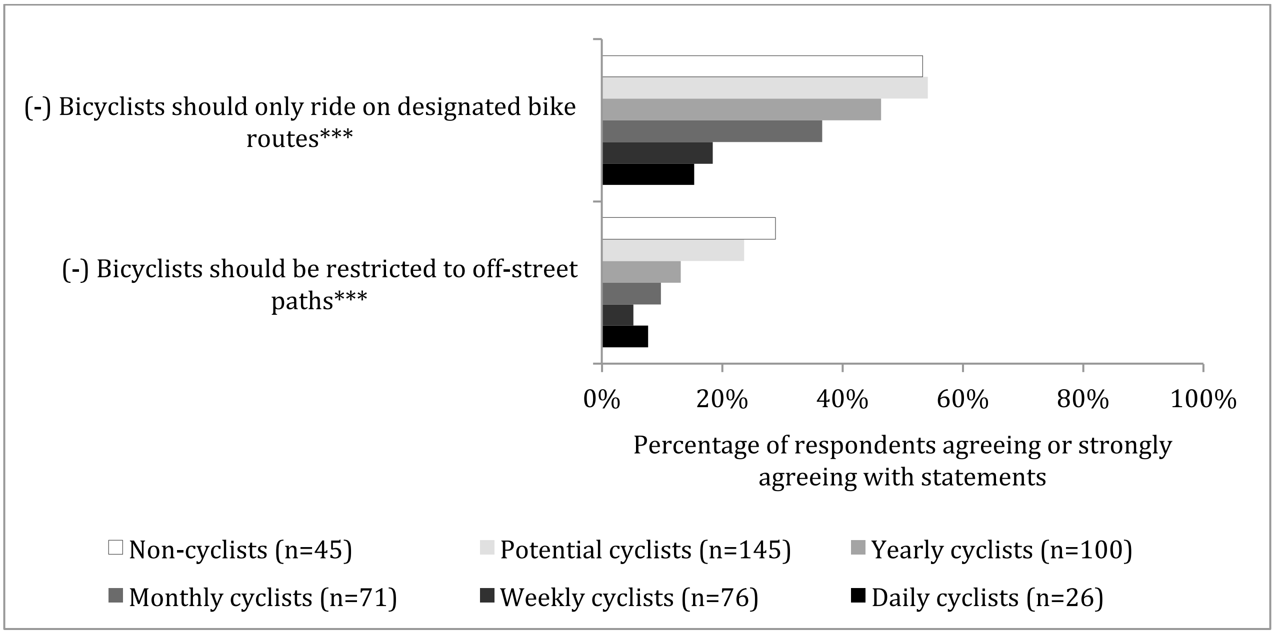
Figure 37. Bicycling Frequency Significantly Affects Support for Bicycling (N=411)



Significant difference between groups at the following levels: ** = $p \leq 0.01$, *** = $p \leq 0.001$

Figure 38 shows that bicycling frequency is significantly and negatively associated with respondents' desires to restrict bicycling to off-street paths or roadways marked as bicycle routes. While a majority of respondents disagree with restricting bicyclists to off-street paths, still nearly 30% of non- and potential cyclists agree with the idea—compared to approximately 7% of regular cyclists. A much higher percentage of respondents agree that bicyclists should be restricted to designated bike routes. In this case, over 50% of non- and potential cyclists agree that cyclists should be restricted, compared to only 18% of regular cyclists.

Figure 38. Bicycling Frequency Significantly Desires to Restrict Bicycling (N=411)



Significant difference between groups at the following level: *** = $p \leq 0.001$

Factor Analysis for Bicycling Support

After noting the clear difference in positive and negative attitudes toward bicycling support, I conducted factor analysis to examine the underlying constructs of the data. I found that the variables measuring agreement that cyclists should ride off-street or only on designated bike paths differed from the pro-bicycling variables (i.e., wanting more bikes and being willing to remove parking and use public funding to encourage bicycling). To test the constructs in a regression model, I combined the three pro-bicycling variables into a new "bike support" variable and used the variable measuring agreement with the statement that bicyclists should be restricted to off-street paths as a predictor in the analysis. Because the variables measuring beliefs about bicyclists belonging off-street or only on designated routes were essentially measuring different scales of the same concept (i.e., restricting bike access), I elected to use the more extreme version of the two.

Developing a Structural Equation Model

In developing the SEM, I tested several hundred variables, many of which I was able to combine through principal components analysis to reduce the dataset.[15] The range of variables tested in

[15] I tried factor analysis in addition to the principal components analysis (PCA) and factor analysis, as I believed that many of the variables were related. The results from both types of analyses were quite similar, so I elected to use the results of the PCA, which are more easily interpretable.

the model included bicycling frequency, negative experiences driving near bicyclists, fears about bicycling for one's self, beliefs about bicycling safety for others, the influence of friends and family, personal demographics, geographic and demographic characteristics near the respondent's home, and knowledge of roadway laws pertaining to cycling.[16] It may seem tautological to use attitudinal variables such as beliefs about bicycling safety to predict other attitudinal variables such as support for bicycling. However, the concept that certain attitudes are predictive of other attitudes is routinely used in psychology research (Ajzen, 2001). This concept was validated in part by the results of the SEM model, which indicate that most attitudinal variables were uni-directional in their predictive capability. Multiple iterations of the model were examined, with only the final model presented in this chapter. For the final model, only variables significant at the 95% level or higher were retained. These variables are described in Table 16.

Table 16. Descriptions and Summary Statistics for Variables in Structural Equation Model

Variable name and description	Mean	Std Dev
Dependent variable (attitudinal)		
Support for bicycling in one's city (sum of three Likert scale (1-5) variables measuring agreement with 1) wanting more bicyclists in one's city, 2) being willing to use public funding to encourage bicycling, and 3) being willing to remove some car parking to provide space for a bicycle lane)	11.08	2.91
Worries about cycling safety for others (attitudinal)		
Cyclists are biggest danger to themselves[#] (Likert scale, 1-5)	3.27	1.16
Feel anxious when see children in bike trailer[#] (Likert scale, 1-5)	3.36	1.25
Cyclists safer on sidewalk[#] (Likert scale, 1-5)	2.86	1.25
Personal cycling habits (experiential)		
Frequency of utilitarian bicycling (0=never, 1=less than once year, but have ridden in past, 2=few times/year, 3=several times/month, 4=several times/week, 5=daily)	1.67	1.63
Beliefs about bicycling (attitudinal)		
Cyclists should only ride off-street[#] (Likert scale, 1-5)	2.20	1.14
Cyclists must always ride in bike lane when present, no exceptions (indicator, 0-1)	0.04	0.20
Low concern about cyclists & pedestrians breaking law (continuous factor-analysis variable ranking the reduction of pedestrian and bicycle traffic violations as a lower transportation priority than reducing driver violations)	0.06	0.98

[16] Appendix C describes the several hundred variables tested in the analysis and shows how they relate to the various safety and support variables via bi-variate regression.

Negative experience driving near cyclists (experiential)		
Has had to avoid hitting a cyclist running a red light (indicator, 0-1)	0.24	0.43
Has had to evade hitting a cyclist in any of multiple situations when cyclist was at fault (indicator, 0-1)	0.62	0.49
Social network characteristics (experiential)		
Self/friends/family have crashed with car while bicycling (indicator, 0-1)	0.39	0.49
Friends/family bike for work/errands (indicator, 0-1)	0.68	0.47
Personal characteristics (experiential)		
Male (indicator, 0-1)	0.46	0.50
Has children under age16 (indicator, 0-1)	0.23	0.42
Worries about cycling safety for self (attitudinal)		
(Moderately or strongly) Worried about aggressive drivers (indicator, 0-1)	0.31	0.46
(Moderately or strongly) Worried about fast drivers (indicator, 0-1)	0.46	0.50
Worries about cycling safety for self (interaction variable)		
Regular cyclist (frequently) worried about drivers passing too close (indicator, 0-1)	0.09	0.29
Non-risk related barriers to bicycling (attitudinal)		
Bicycling (usually or always) impractical due to need to carry things/passengers (indicator, 0-1)	0.66	0.48
Geographic influences (physical)		
Population density (ordinal, quartiles 1-4)	2.18	1.07

# indicates an endogenous variable in the analysis

I also used factor analysis to examine latent constructs of safety for one's self, safety for others, and negative attitudes toward bicycling. Only one factor (modifying bicycling and pedestrian behavior as a low transportation priority) was significant in the final model. Only one of the Census variables and two of the personal demographic variables were significant at the 95% level once beliefs, attitudes, and experiences were accounted for.

The final structural equation model suggests that fears about cycling are among the strongest predictors of bicycling support. These fears manifest themselves through the following channels:

1. Perceived risk for one's self while cycling
2. Perceived risk for others who bicycle ("projected risk")
3. Perceived risk as a driver, which may include worries about injuring a cyclist

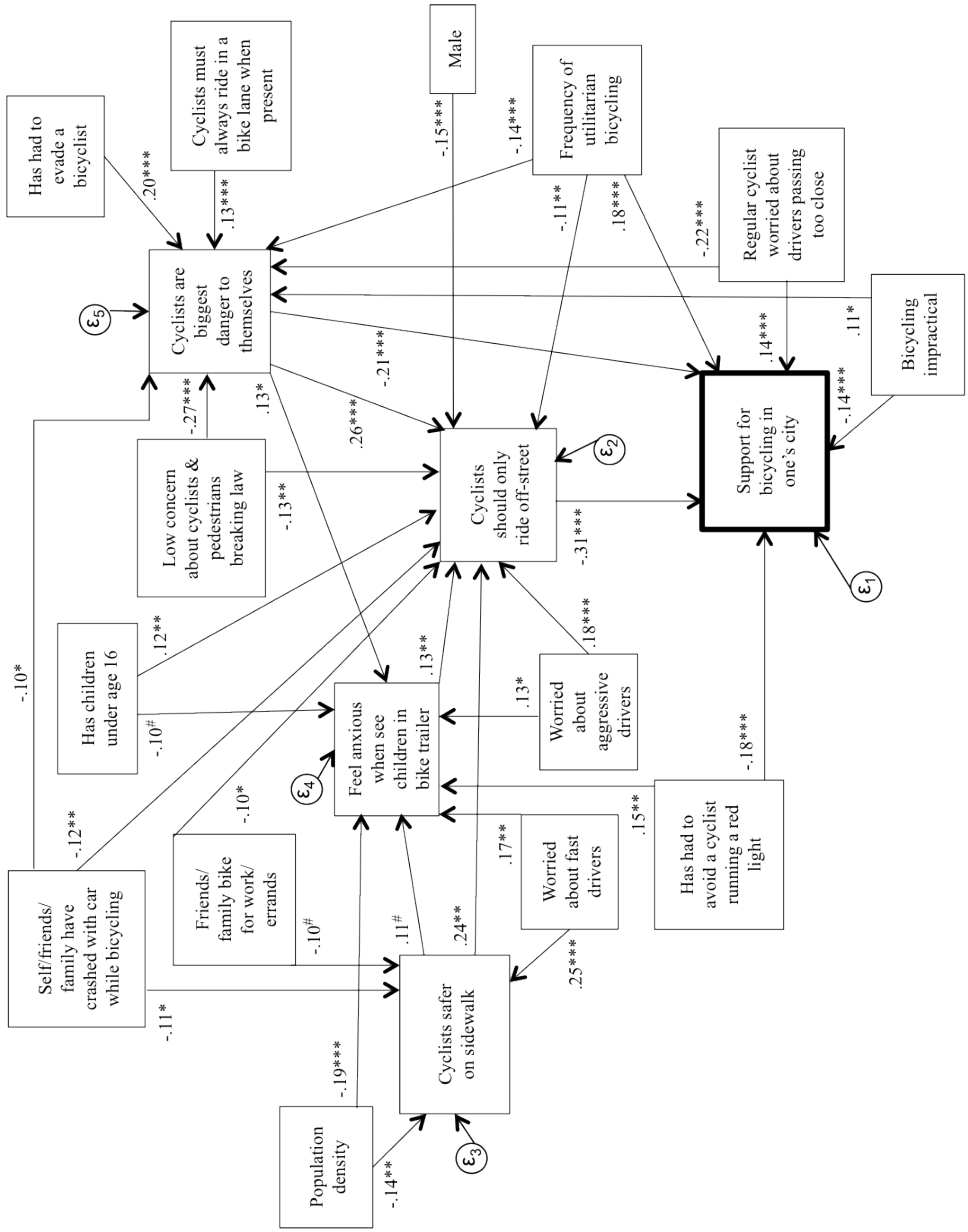
These perceived risks significantly influence support for bicycling in one's city both directly and through the mediating variables of beliefs about where bicyclists should ride (i.e., that bicyclists should be restricted to off-street paths, or that bicyclists are safer on the sidewalk in busy areas). There were seven other significant categories of variables in the analysis, including: cycling frequency, personal characteristics, social network characteristics, beliefs about cycling, negative experiences driving near cyclists, non-risk related barriers to cycling, and geographic influences. With the exception of the GIS variable for population density, all of the data included in this model came from respondents' answers to survey questions.

SEM Results: Direct and Indirect Effects

Figure 39 depicts the final structural equation model for bicycling support. While SEMs have been used to study the relationship between knowledge, attitudes, and behavior regarding driving (Flamm, 2006), this dissertation is the first attempt—to my knowledge—to use a SEM to study attitudes, experiences, knowledge, and behavior regarding bicycling. Note that there are five models within the larger model—four of which contain variables that indirectly predict bicycling support, the main dependent variable (in bold). This highlights one of the unique aspects of SEM: multiple models are simultaneously tested to examine how variables directly and indirectly relate to one another. In this model, a few of the variables are directly and indirectly related to bicycling support, but many more are only indirectly—albeit significantly—related to it.

The results were generally intuitive, if somewhat complex. In the first category, *worries about cycling safety for others*, beliefs that cyclists are the biggest danger to themselves, feeling anxious when seeing children in a bike trailer, and believing bicyclists are safer on the sidewalk are all positively related to wanting to restrict bicyclists to off-street paths, and therefore indirectly negatively related to bicycling support. Believing that cyclists are the biggest danger to themselves is also directly negatively related to cycling support, as one might expect. One might ask why, if someone believes that cycling is unsafe, they don't also want to provide the support/funding for constructing off-street paths for cyclists. To my knowledge, no research has fully investigated this topic, but conversations with my focus group participants suggest that some of the non-cycling drivers struggled between wanting cycling to be safer and also not wanting to spend what they considered to be scarce public resources on a small segment of the population. This inconsistency may also represent an attitude that it would be easier if there weren't any cyclists to deal with—an attitude easy enough to maintain when cycling was extremely low, but untenable with increasing numbers of cyclists on the roadway.

Figure 39. Path Diagram of Factors Influencing Bicycling Support, Standardized Coefficients (N=335)



Statistical significance indicated at the following levels: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

As we would expect, frequency of utilitarian bicycling was negatively related to believing that cyclists are the biggest danger to themselves and to wanting to restrict bicyclists to off-street paths (and therefore indirectly positively related to bicycling support). It was also directly positively related to bicycling support.

Beliefs about bicycling were also as expected. A desire to restrict bicyclists to off-street paths was directly negatively related to bicycling support (the largest direct coefficient). Believing that bicyclists must always ride in the bike lane (i.e., no exceptions for debris, left turns, etc.) was positively directly related to restricting bicyclists to off-street paths, and therefore indirectly negatively related to bicycling support. Believing that addressing pedestrian and bicyclist law breaking was a lower transportation policy priority than addressing driver violations was negatively directly associated with both restricting cyclists and believing that cyclists are the biggest danger to themselves, and therefore positively, albeit indirectly, associated with bicycling support.

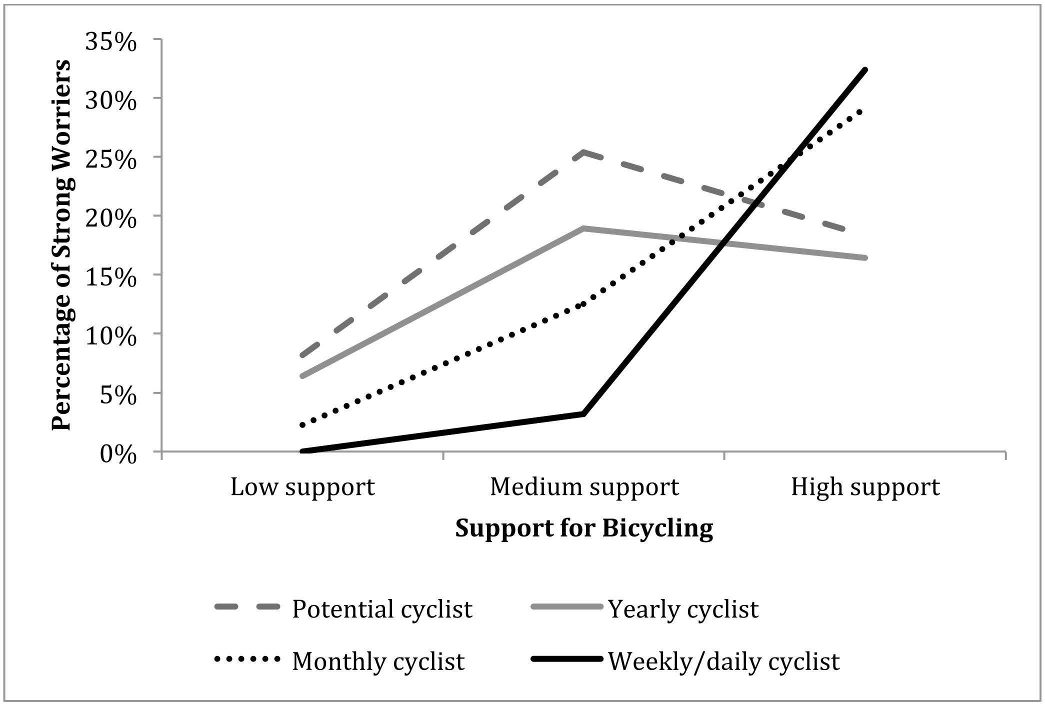
Negative experiences driving near cyclists such in general, and particularly in the case of having to avoid a cyclist running a red light, were directly and indirectly negatively related to bicycling support, as would be expected.

Having friends or family who bike to work or for errands was negatively directly related to believing cyclists were safer on the sidewalk and that they should be restricted to off-street paths, and therefore positively indirectly related to bicycling support. Having crashed—or having friends or family who had crashed—with a car while cycling was negatively directly related to believing cyclists were the biggest danger to themselves, cyclists were safer on the sidewalk, and cyclists should be restricted to off-street paths. In this way, crash experiences were positively indirectly related to bicycling support.

Being a male was negatively directly associated with restricting bicyclists to off-street paths, and therefore positively indirectly associated with bicycling support. This is not surprising, given that males tend to bicycle more than women. The results for having children under age 16 were less clear. While negatively related to feeling anxious when seeing children in a bicycle trailer, they were positively related to believing that bicyclists should be restricted to off-street paths, and therefore negatively correlated with bicycling support overall. There is not much research on parents with children specifically pertaining to bicycling, so it is unclear if this result contradicts expectations or not (e.g., that parents would want to bicycle with their children versus that parents with young children tend to be risk averse, and therefore unsupportive of potentially risky activities). This result should be further investigated in future research to understand if this is a general trend among parents of young children, or if it was a reflection of this particular sample.

I was not clear what to expect from worries about cycling safety. The results suggest that worries about aggressive drivers are positively directly related to feeling anxious when seeing children in a bike trailer and wanting to restrict cyclists to off-street paths, and therefore indirectly negatively related to support for bicycling. Similarly, worries about fast drivers are positively directly related to believing that cyclists are safer on the sidewalk and feeling anxious when seeing children in a bike trailer, and therefore negatively indirectly related to bicycling support. While this may seem counter-intuitive—i.e., we might expect that worries about cycling safety would make one more likely to support it through public funding or dedicated space, it actually fits with the risk assessment theory cited earlier that suggests that viewing something as risky makes one less likely to feel favorably toward it, or, in this case, to support it (Alhakami and Slovic, 1994; Finucane et al., 2000; Slovic et al., 2007). Moreover, there is a significant ($p \leq 0.0001$) correlation between support for bicycling in one's city and the percentage of each cycling group who are strongly influenced by worries about bicycling, as shown in Figure 40. Monthly and weekly cyclists with strong safety concerns are much more likely to report high support for bicycling than potential and yearly cyclists. This significant association is born out in the results for the single significant interaction variable in the model: regular (i.e., weekly or daily) cyclists who are worried about drivers driving too close are significantly more likely to support bicycling in their city.

Figure 40. Cycling Frequency Affects Bicycling Support Among Strong Worriers



The final two significant variables in the model are also intuitive. Believing that bicycling is impractical both directly and indirectly negatively affects bicycling support. In addition, living in a city with a higher population density is directly negatively related to believing that cyclists are safer on the sidewalk and feeling anxious when seeing children in a bike trailer. The cities with higher bicycle mode shares in the Bay Area (Berkeley, San Francisco, and Oakland) all have a high population density relative to the rest of the area, so this finding makes sense.

Table 17 presents the total, direct, and indirect effects and shows the relative predictive power of each of these variables for the final SEM. Summary statistics gauging goodness-of-fit are presented below the table.

Table 17. Structural Equation Model Summary Dependent Variable: Bicycling Support (Standardized Effects)

Independent variables	Direct coef	Indirect coef	Total coef	Correlation coef
Worries about cycling safety for others				
Cyclists are biggest danger to themselves	-0.21	-0.09	-0.30***	-0.46***
Feel anxious seeing children in bike trailer		-0.04	-0.04**	-0.25***
Bicyclists are safer on sidewalk		-0.08	-0.08***	-0.12*
Personal cycling habits				
Frequency of utilitarian bicycling	0.18	0.04	0.21***	0.43***
Beliefs about bicycling				
Bicycles should be restricted to off-street paths	-0.31		-0.31***	-0.49***
Cyclists must always ride in bike lane when present		-0.04	-0.04***	-0.06
Lowest transportation priority is reducing pedestrian and bicycle traffic violations		0.12	0.12***	0.17**
Negative experience driving near cyclists				
Has had to avoid hitting a cyclist running a red light	-0.18	-0.01	-0.19***	-0.27***
Has had to avoid hitting a cyclist in any of multiple situations when it was the cyclist's fault		-0.06	-0.06***	-0.16**
Social network characteristics				
Friends/family/self have crashed with car while biking		0.07	0.07***	0.21***
Have friends or family who bike to work/run errands		0.04	0.04*	0.21***
Personal characteristics				
Male		0.05	0.05**	0.03
Have children younger than age 16		-0.04	-0.04*	-0.07
Worries about cycling safety for self				
Worried about aggressive drivers		-0.06	-0.06***	-0.14**
Worried about fast drivers		-0.03	-0.03***	-0.09#
Regular cyclist worried about drivers passing too close	0.14	0.06	0.20***	0.31***
Non-risk related barriers to bicycling				
Bicycling impractical due to need to carry things/passengers	-0.15	-0.03	-0.18***	-0.34***
Geographic influences				
Population density in quartiles		0.02	0.02**	0.09

Statistical significance indicated at the following levels: # $p \leq 0.10$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Summary statistics
N=335
LR test of model vs. saturated: $chi^2(47) = 46.061$, Prob > $chi^2 = 0.511$
Coefficient of Determination (CD) = 0.636 (R^2 equivalent)
AIC = 10466.552
BIC = 10630.559
CFI (> 0.90) = 1.000
TLI (> 0.90) = 1.003
RMSEA (<~ 0.05) = 0.000

A valid SEM should not be statistically different (according to the chi^2) than the saturated model, and this model meets that criterion (Salas-Wright, 2012). In addition, this model satisfies the following generally recommended goodness of fit measures:

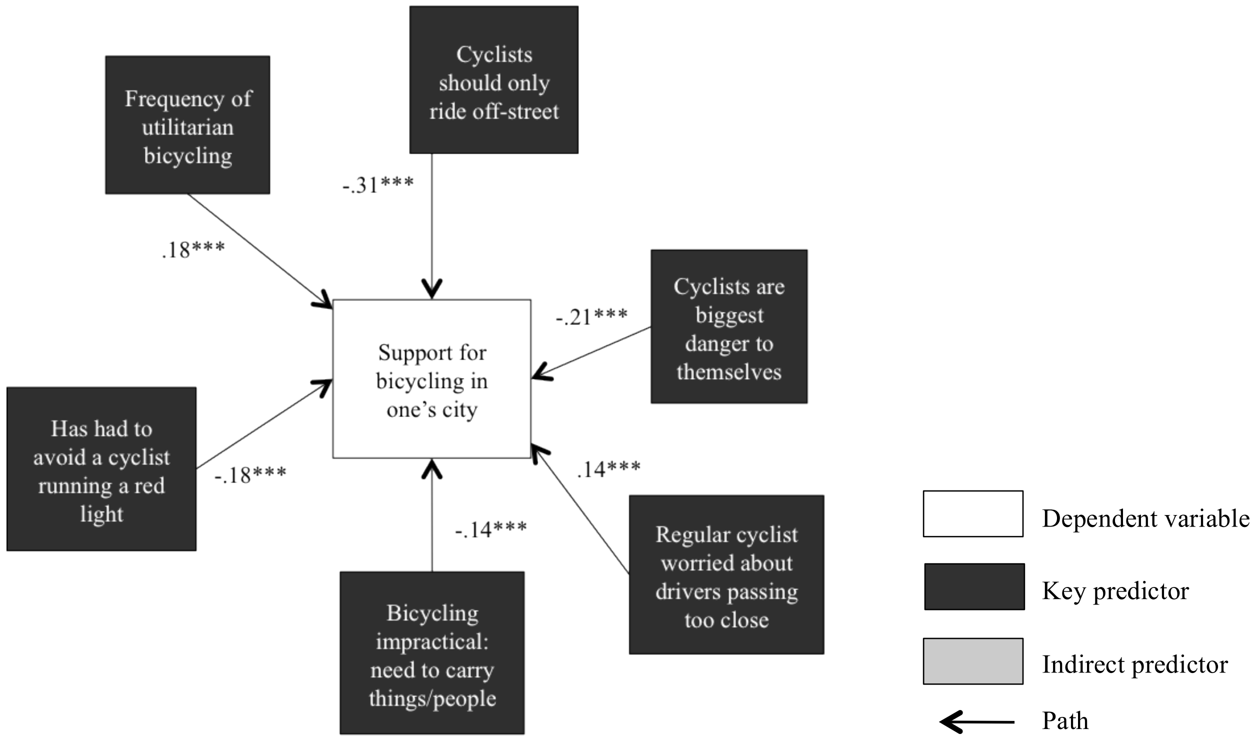
- Comparative fit index: CFI (> 0.90),
- Tucker-Lewis Index (non-normed fit index): TLI (> 0.90),
- Root mean square error of approximation: RMSEA (< ~ 0.05).

Partial Path Models

Figure 41, Figure 42, and Figure 43 depict a series of reduced path models that show how various categories of variables affect the outcome of bicycle support. In each model, the numbers next to the arrows indicate the standardized coefficients, with asterisks denoting statistical significance. Figure 41 shows the variables with direct effects on the outcome of bicycle support. Not surprisingly, the frequency of utilitarian bicycling is highly significant ($p \leq 0.001$) and relatively powerful (0.18) in terms of direct effects predicting one's bicycling support. However, the scale of agreement with the statement that "bicyclists should be restricted to off-street paths" is even more powerful (-0.31), and just as significant. I had initially hypothesized that believing that cyclists should be restricted to off-street paths would be influenced by negative experiences with cyclists, such as evading a cyclist running a red light. While none of the "negative experience"[17] variables were directly significantly related to beliefs about bicycling off-street in the final model, two were significantly related to beliefs about bicycling safety for others, which then indirectly affected agreement about bicycling off-street, as can be seen in Figure 41 through Figure 43. The negative experience of having had to evade a cyclist running a red light was significantly and directly related to support for bicycling (direct effect of -0.18).

[17] Negative experiences included, for example, honking or yelling at a cyclist, driving aggressively around a cyclist, hitting or almost hitting a cyclist, and having to evade a cyclist running a stop sign or red light, riding unexpectedly off the curb, or traveling the wrong way down the street.

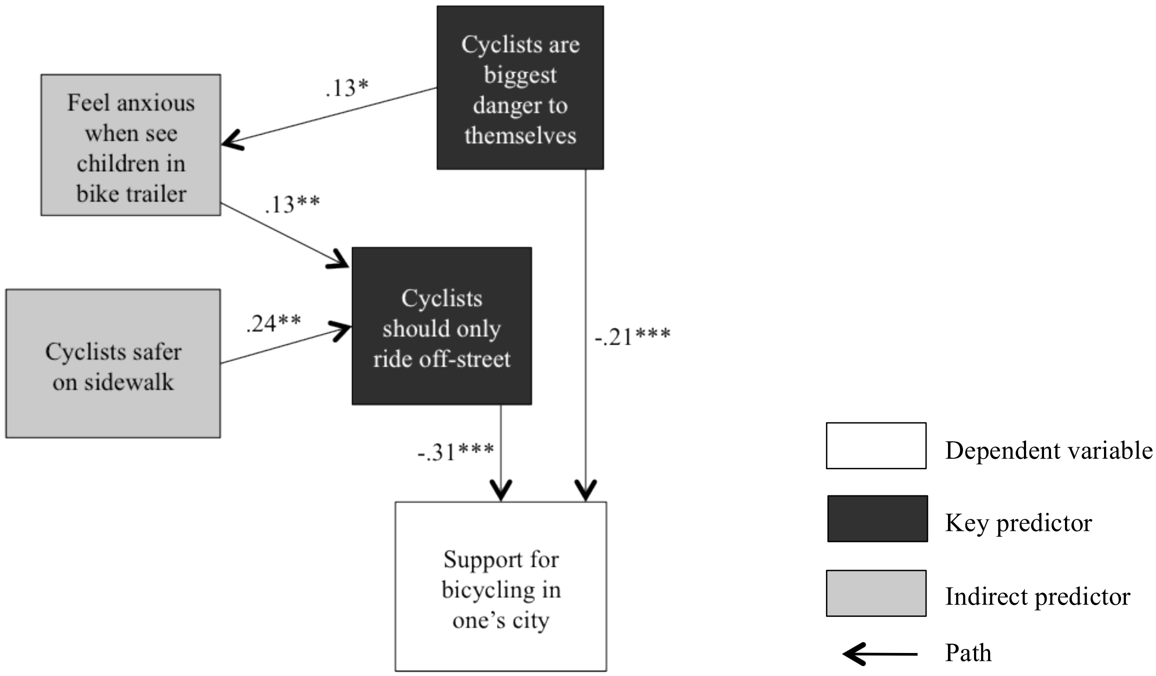
Figure 41. Path Model Showing Direct Effects on Bicycle Support



Statistical significance indicated at the following levels: *** $p \leq 0.001$

Several variables measuring perceived risk were significantly and directly related to bicycle support. First, the scale of agreement that "the biggest threat to a cyclist's safety is his or her actions" was highly significant and relatively powerful (direct effect of -0.21). There was also an interaction variable (regular cyclists worried about drivers passing too close) with a significant direct effect. These findings suggest that the perceived risk of cycling includes one's perception of her own risk, her perception of risk for other bicyclists, and the role the other bicyclists play in creating that risk. As Figure 42 and Figure 43 show, many of the direct effects are significantly affected by other worries about bicycling risk, further underscoring the influence of bicycle risk on bicycling support.

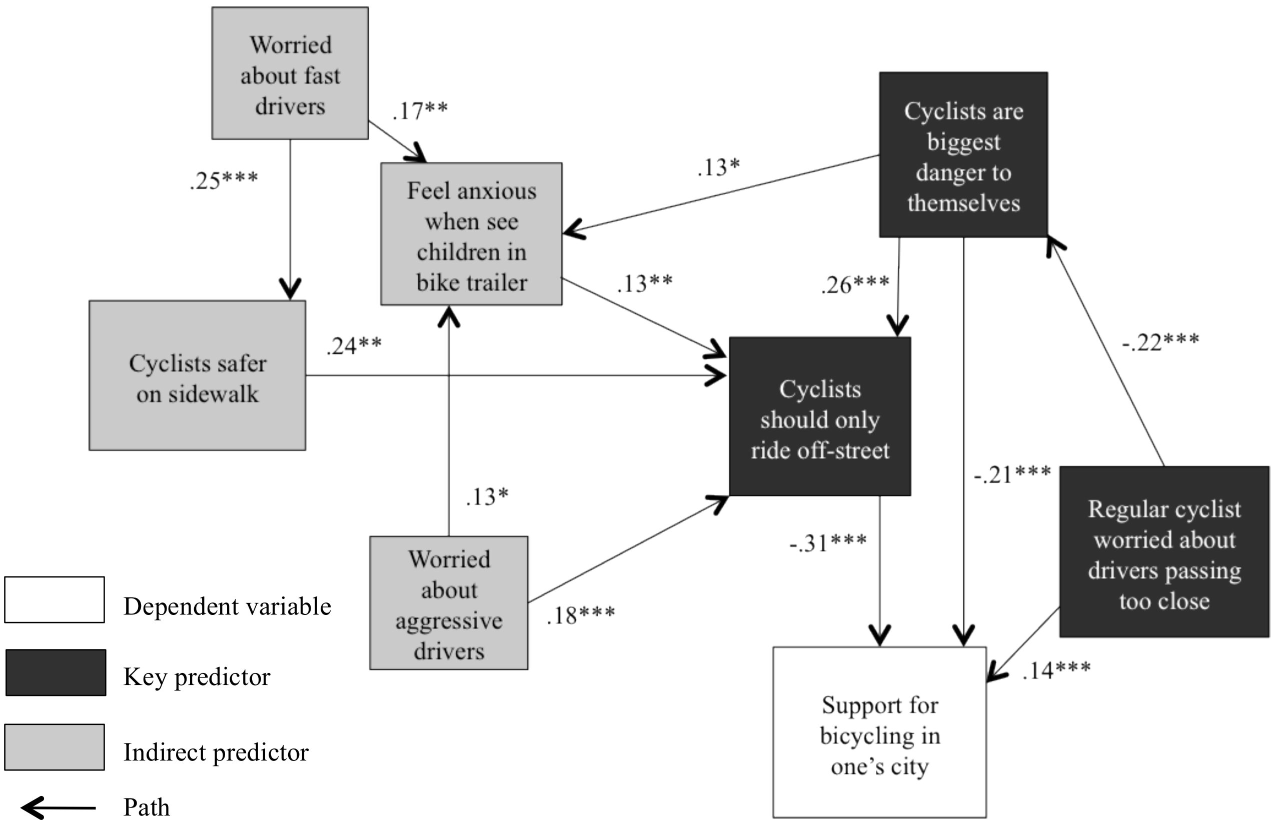
Figure 42. Path Model Showing the Effects of Worries for Others on Bicycle Support



Statistical significance indicated at the following levels: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Figure 42 shows that concerns about bicycling risk for others indirectly affect bicycling support through the anxiety one feels upon seeing a child in a bicycle trailer and the belief that bicyclists are safer on the sidewalk than on the street in busy areas. Figure 43 depicts how worries about fast and aggressive drivers affect beliefs about bicycling safety on the sidewalk and anxiety about seeing children in bicycle trailers. This path model also shows how the interaction variable for regular cyclists directly and indirectly influences bicycling support.

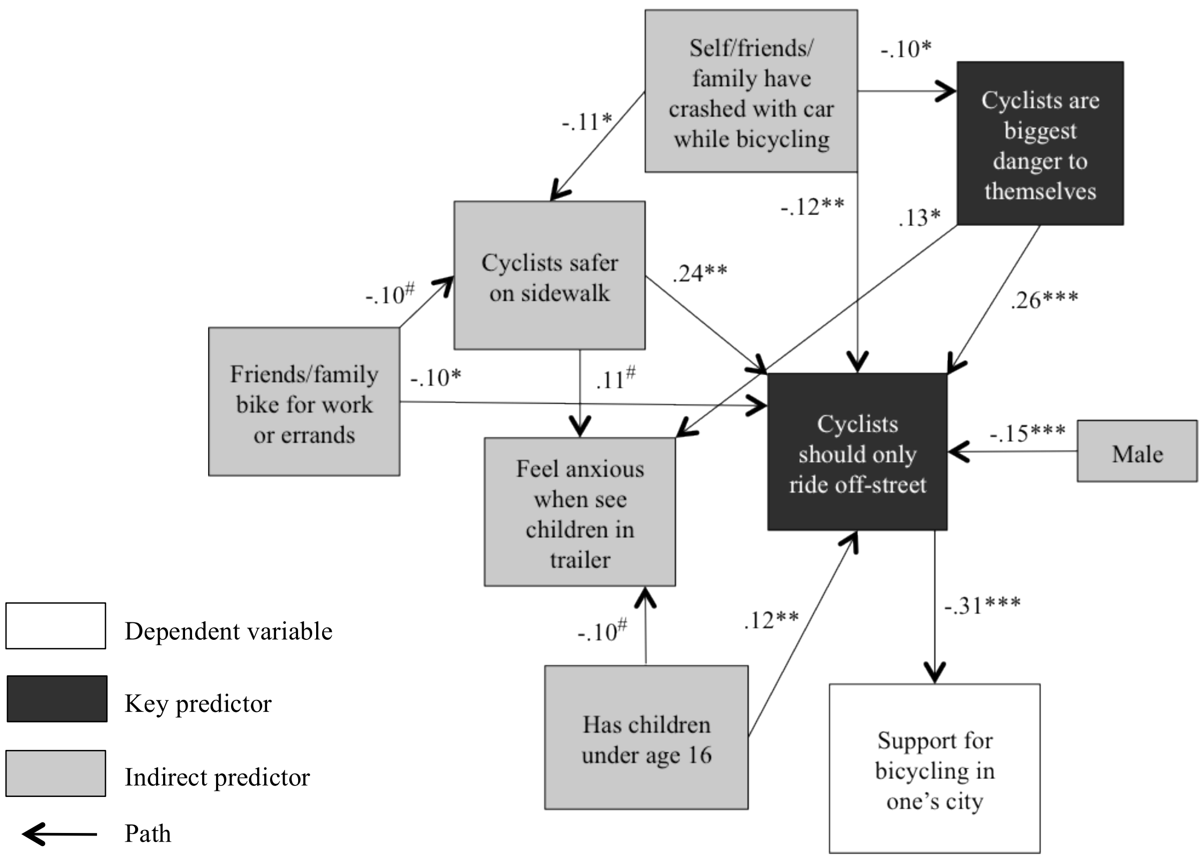
Figure 43. Path Model Showing the Direct and Indirect Effects of Worries for One's Own Safety on Bicycle Support



Statistical significance indicated at the following levels: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Other significant, although smaller, effects include the influence of friends and family and their experiences. If the survey respondent, or his friends or family had crashed with a car while bicycling, he had a significantly higher bicycling support score. In contrast, respondents with children under age 16 had a significantly lower score for bicycling support. These pathways can be seen in Figure 44.

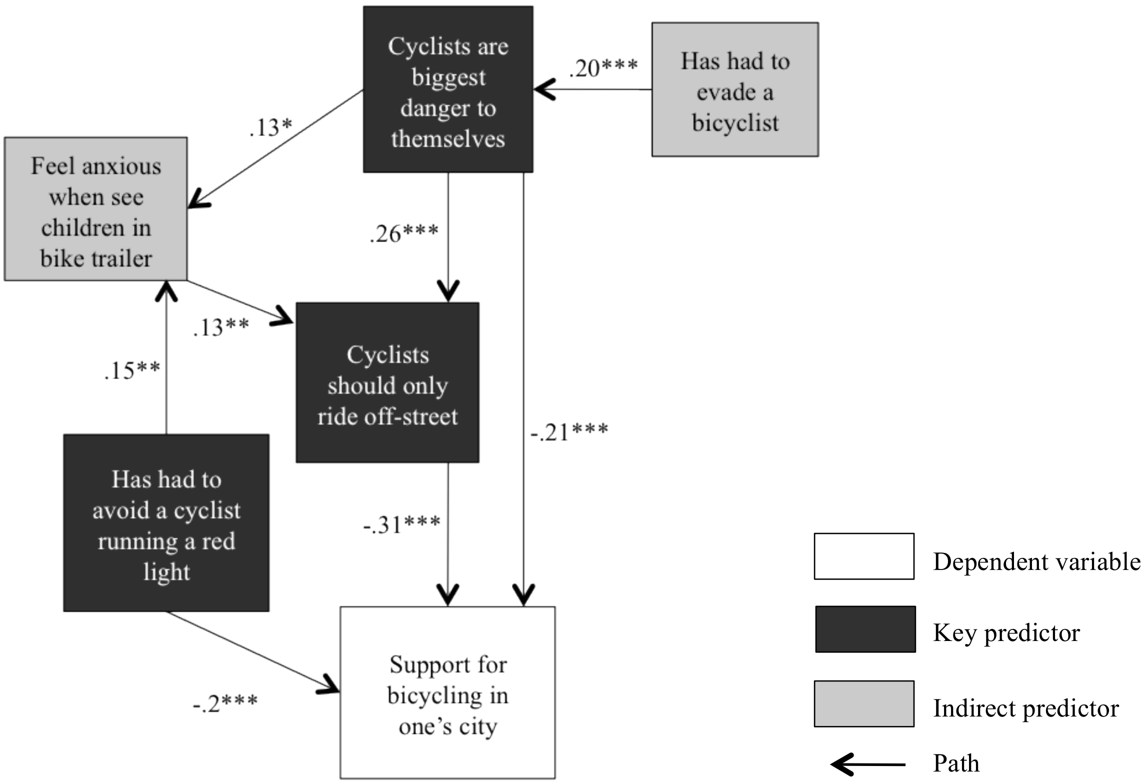
Figure 44. Path Model Showing the Indirect Effects of Personal and Social Network Characteristics on Bicycle Support



Statistical significance indicated at the following levels: # $p \le 0.10$; * $p \le 0.05$; ** $p \le 0.01$; *** $p \le 0.001$

Figure 45 shows how negative experiences driving near cyclists—having had to avoid hitting a cyclist for any reason, and having had to avoid a cyclist running a red light in particular—directly and indirectly influence bicycling support.

Figure 45. Path Model Showing the Direct and Indirect Effects of Negative Experiences Driving Near Cyclists on Bicycle Support



Statistical significance indicated at the following levels: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Discussion of Modeling Results

The model suggests that there are several categories of variables that affect bicycling support, including cycling frequency, perceived risks of bicycling, beliefs about bicycling, personal and social network characteristics, and the built environment. Of these, the variables measuring aspects of perceived risks of cycling were among the strongest in the model. There are multiple ways in which perceptions of cycling risk affect support for cycling. The first category is **fears about drivers' actions** and the risk they impose on the respondent, exemplified through worries about drivers driving too fast, passing too close, and behaving aggressively. These actions affect survey respondents' beliefs that bicyclists are safer bicycling on the sidewalk in busy areas, or should be restricted to off-street paths. Actions to address driver behavior may include greater driver education about the rights of cyclists and how to drive safely around them. In addition, roadway designs that more effectively separate bicyclists from drivers (as seen in Chapter Six) may mitigate some of these worries, although the designs would need to be carefully implemented (for example, to ensure that turning conflicts are not exacerbated through reduced visibility).

The second risk category affecting cycling support includes **bicyclists' risky behaviors** and the danger they pose to drivers, such as bicyclists running red lights. It may also reflect beliefs that bicyclists are the biggest dangers to themselves. Efforts to address this aspect may do well to include more substantial bicycle training. Addressing this area is likely to be complex, as cyclists who run red lights or stop signs likely already know that it is illegal to do so, but do so in order to save time or energy while bicycling. This issue may be addressed by changing traffic laws to more effectively accommodate the physics of cycling (such as allowing cyclists to yield at stop signs when no car is present, something that a majority of the survey respondents supported and which has been implemented in Idaho). However, focus group participants suggested that any change in these laws would need to be accompanied by greater enforcement of the laws and immunity for drivers so that they could operate with predictability.

A third category of risk seems to be the **perceived risk for other bicyclists**. This category is exemplified through feelings of anxiety upon seeing a child pulled in a bicycle trailer and believing that bicyclists are safest bicycling on the sidewalk in busy areas. The data indicate that worries about one's own safety significantly affect these categories, so addressing worries about driver behavior may sufficiently address this category.

Many of the other significant predictors may only be able to be addressed through policy in complicated ways. For example, males were significantly less likely to believe that bicyclists should be restricted to off-street paths, which may result from the fact that males are in general more likely to bicycle and feel comfortable doing so. Efforts to reduce this gender difference may involve targeted encouragement or perhaps educational efforts directed toward women, but would likely have to confront the barriers that keep more women from bicycling in the first place (Garrard et al., 2012).

Addressing the impracticality of bicycling will likely also be complex, although generating less expensive options for carrying loads/passengers by bicycle would help. In addition, as discussed in Chapter Seven, addressing safety concerns may open up the possibility of more trips by bicycle. Addressing safety concerns may also encourage cycling frequency, which was significantly positively correlated with bicycling support.

Another option may be that of the physical environment. Though not in the model, respondents who reported not having a bicycle lane within two miles of their home were significantly ($p \leq 0.10$) more likely to believe that bicyclists should be restricted to off-street paths, suggesting that the presence of bicycle lanes may communicate legitimacy for bicyclists, possibly encouraging people to believe that bicyclists belong on the roadway. Because believing that bicyclists should be restricted to off-street paths was the largest direct—albeit negative—affect on bicycling support, encouraging perceptions of bicycling legitimacy through infrastructure could contribute to a virtuous cycle for bicycling—particularly since this support itself may affect whether future bicycle infrastructure is built. Building the infrastructure may also contribute to mitigating fears about bicycling, as seen with the roadway design preferences in Chapter Six.

No other research has explicitly investigated support for bicycling in this way. However, these results are congruent with past research findings showing that perceived risk negatively influences one's overall perceptions of an activity (Finucane et al., 2000). In addition, the influence of fear is consistent with research on barriers to bicycling (Dill and Voros, 2007; Winters et al., 2010).

These suggestions will be further discussed in Chapter Ten, which summarizes the findings from this dissertation and proposes policy actions and a future research agenda. These findings may contribute to strategies to increase bicycling safety for all cyclists by illuminating the role of bicyclist and driver actions in making bicycling more or less safe.

Summary of Key Findings

The models and summary statistics presented in this chapter suggest that worries about cycling risk significantly affect support for bicycling. The results also suggest that worries about other people's safety while cycling affect all types of cyclists. Together, these concerns about cycling safety directly and indirectly affect a person's support for bicycling in one's city, which manifests itself in a desire for more cyclists and funding and actions to encourage cycling, as well as a belief that cyclists either do or don't belong on the street. Key takeaways from this chapter include the following findings.

Perceptions of Personal Bicycling Risk as a Result of Driver Behavior

1. Fears about drivers' actions and the risk they impose on the respondent—exemplified through worries about drivers driving too fast, passing too close, and behaving aggressively—affect perceptions of personal bicycling risk, beliefs about where bicyclists should ride, and support for bicycling.

Perceived Risk as a Result of Bicyclist Behavior

2. Perceptions of risky behaviors among bicyclists—such as bicyclists running red lights—and the danger they pose to drivers also significantly affect support for bicycling. These perceptions are reflected in the belief that bicyclists are the biggest dangers to themselves.

Perceptions of Bicycling Risk for Others

3. Perceived risks for others also emerged as significantly related to support for bicycling. This category is exemplified through feelings of anxiety upon seeing a child pulled in a bicycle trailer and believing that bicyclists are safest bicycling on the sidewalk in busy areas. These perceived risks are significantly related to worries about one's own safety.

Other Significant Factors Affecting Support for Cycling

4. Males were significantly less likely than females to believe that bicyclists should be restricted to off-street paths.
5. Having friends or family who bicycle to work or run errands—particularly if they have been hit by a car while biking—significantly affects one's beliefs about cycling safety and where cyclists should ride, and is positively correlated with support for cycling.
6. Believing that bicycling was impractical was significantly negatively correlated with bicycling support.
7. The population density of the city where the respondent lived was significantly positively associated with bicycling support, albeit indirectly.
8. Utilitarian cycling frequency had the strongest positive effect on bicycling support.

Chapter 9 – Bicycling Risk by the Numbers

In this chapter, I explore how perceived risks are related to one's own collision and near miss experiences. The findings I presented in Chapter Seven indicate that there are many aspects of bicycling risk that worry or influence riders, and that perceived bicycling risk is a serious barrier for some potential and current bicyclists. My findings also suggest that perceived risks are significantly related to one's own crash experiences, as well as those of family and friends, and that both perceived and experienced risk significantly relate to bicycling support. In this chapter, I further explore this connection between perceived risk and experience by examining the prevalence of near misses and collisions within my survey sample. In addition, I present a high-level analysis of official crash statistics and explore how these statistics reflect the self-reported crashes and perceived risks of my survey respondents. The data presented in this chapter could help jurisdictions prioritize actions for addressing experienced and perceived danger while bicycling.

Reported Crash Analysis Methodology

The data examined in this chapter come from both my survey respondents and the California Highway Patrol. First, I describe my findings about self-reported near misses and collisions from my survey data—what I am terming "experienced risk"—and examine how respondents' experienced risk relates to their perceptions of risk. The perceived risks match those explored in Chapter Seven.

I then compare the experienced and perceived risks with official crash statistics to see how well reported crashes reflect my survey respondents' experiences. The crash data came from the California Highway Patrol Statewide Integrated Traffic Records System ("SWITRS"), which aggregates data on traffic collisions from local police records and is the official and most comprehensive crash record system for the state of California. SWITRS data has been widely used to analyze traffic safety in California, and has been the base of multiple studies on pedestrian and bicyclist crash risk and frequency (Johnson et al., 2005; Sanders and Cooper, 2013; Schneider et al., 2009). I chose the five cities with the most survey respondents (Berkeley, Oakland, San Francisco, Vallejo, and Walnut Creek) to serve as the case cities for this analysis. I looked at the five most recent years of crash data (2006-2010), which I accessed through the tims.berkeley.edu data warehouse. From there, I downloaded the crash files and analyzed the data in Microsoft Excel and STATA IC. I referenced the California Vehicle Code when interpreting traffic violations and codes, as well as to match the perceived and experienced risks to potential traffic violations.

Near Misses and Collisions Among Survey Respondents

In Chapter Seven, I showed that several of the perceived risks were significantly related to one's own experiences and the experiences of family and friends. The findings in this chapter further explore the experiences of my survey respondents. Table 18 displays the percentage of respondents who have experienced any of a list of dangerous incidents as a near miss or a collision. The lower sample size (n=273) is due to having asked this question only of those respondents who bicycle at least once per year. Because this research was not undertaken using travel diaries, I opted not to ask for a count of occurrences in order to mitigate recall bias.

Table 18. Dangerous Incidents for Bicyclists – Bicyclist Self-Report (n=273)

	Incidence	Actually hit?	Incident: Hit Ratio
Aggressive incidents			
A driver passed you with fewer than 3 feet of space between you and the car	65%	2%	29
A driver drove aggressively around you	42%	2%	23
A driver honked or yelled at you when you had done nothing wrong	40%	2%	18
A driver did not let you into his/her lane when you signaled to move over	25%	1%	34
A driver tried to beat you to a turn and hit or almost hit you	23%	3%	8
Discourteous incidents			
A driver blocked a bicycle lane you were using while s/he was waiting for someone or parking	54%	2%	37
Distracted incidents			
A driver or passenger opened a car door without looking and hit or almost hit you	45%	6%	8
A driver hit or almost hit you while turning	41%	8%	5
A driver merged into a lane and hit or almost hit you	31%	4%	8
I have never bicycled on city streets	6%		

Table reflects responses from respondents who indicated that they bike at least once per year for any purpose.

The results in Table 18 convey several important findings about perceived bicycling risk among the survey respondents. First, nearly 70% of the bicycling respondents in my sample had experienced some type of endangerment, and 14% had been hit in one of the situations. In contrast, less than a third of the drivers in the sample (n=446) admitted to endangering cyclists in these ways, suggesting that cyclists may experience these incidents differently than the drivers who are also involved. These percentages may be influenced by response bias, and they may also result from the highly divergent numbers of bicyclists and drivers on the roadways in the

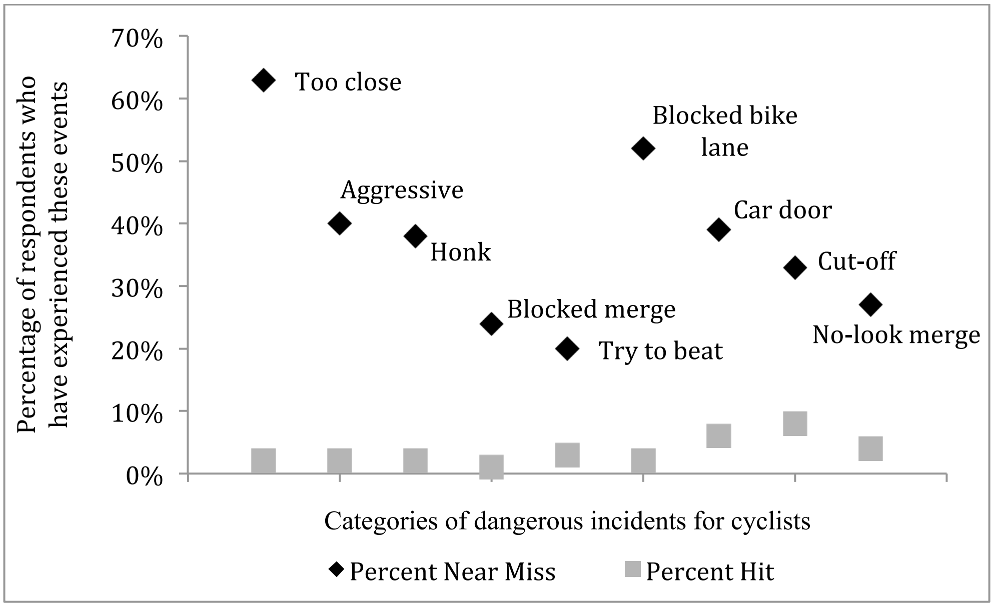
Bay Area. With so many more drivers on the road than bicyclists, there are many more opportunities for risk per bicyclist.

Second, the numbers suggest a wide range in how common some near misses and collisions are compared to others. For example, 65% of the bicyclists in my sample had experienced being passed by a car with fewer than three feet of clearance (colloquially known as "being buzzed"). Over half of the respondents had been blocked by a car while bicycling in a bicycle lane. In contrast, less than half of the cyclists had experienced being threatened by an aggressive driver, and only about one-quarter had experienced a driver trying to beat them to a turn and hitting or almost hitting them.

The third column of Table 18 shows that collisions occurred for only a fraction of the sample that had experienced a near miss, ranging from 1-8% of the cyclists in the sample per incident type. This translates to a range of 7-32 times as many "near misses" for each time someone reported being hit. Thus, official crash statistics likely seriously underestimate the risk experienced by each cyclist and cyclists as a group—each incident of which could contribute to feelings of danger while bicycling. This corroborates earlier research on near misses for bicyclists, which found that bicyclists in the U.K. experienced a need to take evasive action and/or an incident that annoyed or scared them every five miles of travel, compared to motorists, who experienced a similar incident every 47 miles of travel (Joshi et al., 2001). It also fits with the general "iceberg model" of near misses and accidents, which proposes that accidents often reflect the "tip of the iceberg" in terms of systematic risk (Van der Schaaf et al., 1991).

Fourth, while the incidents with a higher percentage of collisions are not necessarily the most commonly occurring incidents, their ratios of near-miss-to-hit (NMTH) tend to be smaller. People who have experienced the incidents with smaller NMTH ratios are therefore more likely to have been hit and may have a greater—or at least different—perception of danger than the overall incident numbers (which include near misses) might suggest. For example, if only 23% of people have experienced a driver trying to beat them to a turn, one might conclude that this is less of a risk than being passed too closely by a car, which 65% of the sample has experienced. However, the latter resulted in a collision approximately 1 in 30 times, whereas the former resulted in a collision 1 in 8 times. Thus, the danger of being hit—what I call *acute risk*—is greater in the latter case, even though the former case—which represents a consistent, *pervasive risk*—is experienced more often. In addition, there is no clear pattern between the percentage of near misses and resulting collisions for each incident type, as illustrated by **Figure 46**, which contrasts the fairly steady pattern of percent of collisions with the random pattern of near misses.

Figure 46. No Correlation between Near Misses and Collisions for Bicycling Respondents



Recall that Figure 32 in Chapter Seven showed that many potential and current bicyclists reported being "strongly influenced" or "usually or always worried" about distracted driving, drivers coming too close or driving too fast near them, and drivers cutting them off while turning. The findings in Table 18 validate those worries, showing that 41-65% of the sample had experienced the latter three. Chapter Eight elaborated on how the perceived risk of cycling is not monolithic, but rather is influenced by perceptions of one's own risk as well as others' risk. The near miss and hit statistics presented here suggest a further nuance: that perceived risk for oneself is itself based on acute *and* pervasive experienced risk—that is, risk that is derived not just from incidents that result in injury, but also incidents that could have resulted in injury, even if they did not. This duality of risk seems to substantiate bicycling fear and discomfort.

Finally, some of these crash types match those reported in crash statistics as some of the most common for bicyclists, as seen in Table 21, but others do not—suggesting that reported crash statistics are likely limited in how accurately they reflect bicyclists' experienced and perceived risk. This may be a limitation of the crash reporting, which, as Table 23 and Table 24 show, varies by city and relies on catch-all categories like "other." It may also reflect incidents that tend to result in more serious injuries, as serious crashes are more likely to be reported and entered into the SWITRS database than non-serious ones. Future research should further investigate this disconnect.

Cycling Frequency Positively Associated with Experienced Risk

Whether a respondent reported having experienced a near miss or collision was significantly correlated ($p \leq 0.001$) with bicycling frequency, as shown in Table 19. Note that there is a range between each cycling group regarding the percentage of respondents who had experienced the incident. For example, 83% of daily cyclists had experienced someone opening a car door in their path, compared to only 25% of yearly cyclists. This is expected given the increased opportunity for such an occurrence with greater cycling frequency. However, it is alarming that such a high percentage of both groups had experienced even a near miss—particularly when yearly cyclists theoretically have so many fewer opportunities due to bicycling so few times during the year. This is the case for many of the other categories, as well—over 50% of each group had been passed too closely by a driver, and no less than one-quarter had experienced an aggressive driver and had been hit or almost hit by a turning driver.

Table 19. Bicyclist Self Report –Dangerous Incidents by Bicycling Frequency (n=273)

	Bicycling Frequency			
Action	"Yearly" Few times/year (n=100) %	"Monthly" Several times/month (n=71) %	"Weekly" Several times/week (n=76) %	"Daily" Every day (n=26) %
A driver passed you with fewer than 3 feet of space between you and the car***	51	59	80	85
A driver blocked a bicycle lane you were using while s/he was waiting for someone/ parking***	33	51	74	78
A driver or passenger opened a car door without looking and almost/hit you***#	25	39	67	83
A driver drove aggressively around you**	28	46	62	61
A driver almost/hit you while turning**	26	46	54	65
A driver honked or yelled at you when you had done nothing wrong**	26	41	54	70
A driver merged into a lane and almost/hit you***	18	31	50	57
A driver did not let you into his/her lane when you signaled to move over**	13	26	39	35
A driver tried to beat you to a turn and almost/hit you***	12	18	34	54

Significant difference between groups at the following levels: * $p \leq 0.10$; ** $p \leq 0.01$; *** $p \leq 0.001$
Significant difference between groups for who was hit at $p \leq 0.10$

Equally alarming is the lack of significant difference between the groups for who has been hit in any of the incidents other than being hit by a car door. This means that the yearly cyclist was statistically as likely as the monthly, weekly, or daily cyclist to have been hit in almost every incident. This finding may reflect the relatively small sample size of people who had been hit or the gain in cycling skills (and thus ability to preclude or avoid a collision) that presumably accompanies greater cycling frequency—but the lack of connection between cycling frequency may also reflect the randomness with which the collisions occur—a factor underscoring the concept of pervasive risk.

Finally, the data in Table 19 show a range within each cycling group for which incidents had been experienced more or less. For example, while 83% of daily cyclists had experienced a car door opening in their path, only 35% had experienced a driver blocking them from merging into a lane. A similar pattern exists within the other cycling groups. These statistics further underscore the concept of pervasive risk, suggesting that some incidents pose a more consistent threat to cyclists than others.

Analysis of Reported Bicycle Crash Data in the Bay Area

The self-reported near miss and collision data in combination with the perceived risks paints a picture of bicycling risk that is multi-layered and complex. However, self-reported data on experienced and perceived risk is neither routinely collected nor widely available to the practitioners and policymakers who make decisions on behalf of bicyclists and bicycle safety. Instead, professionals rely on the data available to them, such as the SWITRS data in California. In this section, I compare the self-reported risk statistics of my survey respondents with the SWITRS multi-party bicycle crash data from the years 2006-2010 for the five cities with the most survey respondents.[18]

Translating Risks into Crash Categories

In a typical crash record, the crash is classified in a number of different ways, including crash type, violation category, California vehicle code ("CVC") violation, party at fault (e.g., motorist, pedestrian, bicyclist, etc.), number and type of parties involved, number and type of victims, demographic characteristics of the parties and victims, vehicle type, movement preceding collision, day, time, location, and additional characteristics. For example, a record might indicate that the crash type was a broadside, sideswipe, or rear-end, and an associated traffic violation might be "other improper driving", "improper passing, or "improper turning" (a list of all crash types and traffic violations can be found in Appendix E). While this information gives a researcher categories to analyze, most crashes may be associated with a number of different violation categories (and vice versa), so they do not always map well to the experience—or the resulting perceived risk—of the victim.

Due to this potential ambiguity, I chose to query my respondents about specific driver actions that I accumulated through the literature review, focus groups, and pilot testing of the survey. Thus, instead of "improper passing", I asked my survey respondents about a driver "passing too close" or "driving too fast while passing." These are distinct experiences, with potentially distinct ways of being addressed, but both could have been classified as "improper passing", and could result in multiple crash types. My choice to ask about specific actions complicated the process of matching perceived and experienced risks to the reported crash data, but my focus groups and pilot testing suggested that this tactic would provide a more accurate understanding of bicyclists' experienced and perceived risks. Table 20 represents my effort to match the two categories that most closely related to the self-reported risks in the survey: crash types and traffic violations for multi-party[19] bicycle crashes.

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[18] Berkeley, Oakland, San Francisco, Vallejo, and Walnut Creek

[19] This section examines multi-party crashes because the results in Chapter Seven indicate that current and potential bicyclists are much more worried about most crashes with motorists than they are about crashing by themselves. In addition, solo crashes represent less than 15% of bicycle crashes for each example city.

Table 20. Self-Reported Risks Mapped to SWITRS Traffic Violations and Crash Types

Survey Respondents' Self-Reported Experienced and Perceived Risk	SWITRS Traffic violation	SWITRS Crash type
Motorist drove too close while passing	Unsafe lane change Improper passing Following too closely	Sideswipe Rear-end
Driver blocked bicycle lane	Other hazardous violation	Other
Car door opened into path	Other hazardous violation, specifically dooring	Other
Intentionally aggressive driving/ Unprovoked honking or yelling	Unsafe speed Improper turning Improper passing Other hazardous violation Other improper driving Following too closely Auto ROW	Rear-end Broadside Sideswipe Other
Driver almost hit cyclist while turning	Auto ROW Improper turning	Broadside Sideswipe Other
Driver merged without looking	Unsafe lane change Improper turning Auto ROW	Sideswipe
Driver blocked bicyclist lane change/merge	Unsafe lane change	Rear-end Sideswipe Broadside
Driver tried to beat to a turn and almost hit cyclist	Improper turning Improper passing	Rear-end Sideswipe Broadside
*Inattentive driver	Unsafe lane change Improper turning Wrong side of road Auto ROW	Sideswipe Broadside Head-on
*Motorist driving too fast while passing	Unsafe speed Improper passing	Rear-end Sideswipe Broadside
*Cyclist fears making mistake and hurting self/others	Unsafe lane change(?) Improper turning(?)	Sideswipe Broadside

*Respondents were only asked about this as their perceived risk, not experienced risk.

The results in Table 20 suggest that the SWITRS data, while the best available, often do not directly reflect bicyclists' perceived and experienced crash risk for several reasons. First, crash records are designed for police officers to report data from crashes for the sake of analyzing trends (particularly among automobiles). Each crash type can be associated with multiple traffic violations and codes, and vice versa, so the classifications often offer little clarity about what, exactly, happened. For example, a violation of "unsafe speed" could indicate that a driver or bicyclist was operating too fast or too slowly for conditions, etc. The violation code provides more clarity in some cases, like being hit by a car door (CVC 22517). However, even many of the violation codes provide only brief descriptions of the violator's action, for instance "u-turns in business areas" or "failure to heed regulatory sign", which give limited insight into how a bicyclist may have experienced the associated risk.

A more detailed analysis of SWITRS data would likely provide greater insight to the crash by illuminating that weather conditions may have contributed to the crash, or revealing the party "at fault" (e.g., the driver or the cyclist), but Table 24 shows that even fault is often unattributed. In addition, while the crash records contain geographic information in the form of geo-codes, they do not contain information on roadway characteristics such as the number of travel lanes, presence and type of bicycle facility, presence of on-street parking, speed limit, etc.—all potentially important aspects for understanding crash trends. Any thorough analysis of bicycle crashes in a city or area would therefore need multiple data sources, and would still be limited by the openness and/or opacity of many of SWITRS' categories.

Despite these limitations, I still wanted to examine how well the most frequently reported and most injurious crash types and traffic violations in SWITRS reflected the reported experienced and perceived risks of the survey respondents. Table 21 shows the order of traffic violations for multi-party bicycle crashes in terms of frequency and severity of incident (ranked by number of fatalities in the middle column and number of severe injuries in the third column) among the five test cities. Below Table 21 are two lists—one of survey respondents' reported near misses and the other of their reported collisions, both in order of frequency. In turn, Table 22 displays the perceived risks for people who bicycle different amounts, ranked by the number of people identifying the worry as "strongly influential" or "always worrisome." The tables suggest that using SWITRS data to try to understand experienced and perceived bicycling risk may paint an accurate picture about 50% of the time. For example, two of the five most prevalent near misses are reflected in the most frequent and most fatal traffic violations, as are three of the top five most prevalent collisions. In terms of perceived risk, three of the top five worries for monthly and weekly cyclists are found in the most frequent and most fatal or injurious traffic violations, while two of the five appear for yearly and potential cyclists. Overlap between the most frequent perceived and experienced risks and the SWITRS data is indicated by gray shading in Table 21 and Table 22 and in the numbered lists.

Table 21. Crash Types and Traffic Violations Associated with Multi-party Bicycle Crashes, by Greatest Frequency and Severity in SWITRS

Most Frequent Traffic Violations (% of crashes)	Most Fatal Traffic Violations (%, n=15)	Most Severe Injury Traffic Violations (%, n=239)
Auto ROW[20] (19%)	Auto ROW (27%)	Auto ROW (18%)
Improper turning (17%)	Wrong side of road (27%)	Traffic signal/sign (15%)
Traffic signal/sign (13%)	**Dooring (7%)**	**Improper turning (14%)**
Wrong side of road (11%)	Traffic signal/sign (7%)	**Unsafe speed (11%)**
Dooring (10%)	**Improper turning (7%)**	Wrong side of road (9%)

Survey Respondents' Self-Reported Near Misses, By Frequency

1. Motorist drove too close while passing
2. Driver blocked bicycle lane
3. **Car door opened into path**
4. Intentionally aggressive driving
5. **Driver almost hit cyclist while turning**

Survey Respondents' Self-Reported Collisions, By Frequency

1. **Driver hit cyclist while turning**
2. **Driver hit cyclist with car door**
3. Driver merged into a lane and hit cyclist
4. **Driver tried to beat cyclist to a turn and hit her**[%]
5. Driver honked or yelled at cyclist unprovoked

% Depending on when the cyclist was hit, this action may be cited as improper passing, improper turning, or another violation. For the purpose of this exercise, we assume improper turning, which would make reported crash statistics more likely to reflect experienced risk.

[20] Right of Way is defined in the California Vehicle Code as the "privilege of the immediate use of the highway." Auto ROW as a traffic violation is thus the violation of this right.

Table 22. Survey Respondents' Self-Reported Perceived Risks, by Frequency

Potential Cyclists	Yearly Cyclists	Monthly Cyclists	Weekly Cyclists
Distracted driver	Distracted driver	Distracted driver	Distracted driver
Driver will drive too fast near me	**Driver will drive too fast near me**	**Driver will cut me off**	**Driver will cut me off ***
Driver will cut me off *	Driver will pass too close	Driver will pass too close	**I'll be hit by a car door***
Driver will pass too close*	**Driver will cut me off**	**Driver will drive too fast near me**	**Driver will drive too fast near me****
I'll make a mistake	Aggressive driver	**I'll be hit by a car door** / Aggressive driver	Driver will pass too close**

*Sets of asterisks (*) and (**) indicate ties.

One way the SWITRS data seems to fall short is capturing the types of risk that are not easily tied to a discrete category—particularly risks associated with aggressive driving and distracted driving. Officers can currently check a box on the traffic report to indicate inattentive driving, but inattention was cited in only 1% of all crashes in this sample, so it would be difficult to determine ties to any specific violations. This is not to say that distracted driving doesn't contribute to increased risk: the California Office of Traffic Safety has found that 60% of Californians in a representative sample report having been hit or nearly hit by a driver distracted by a cell phone, and nearly 45% admit to making a driving mistake while distracted by a cell phone (California Office of Traffic Safety, 2012).

Another issue with using SWITRS data to examine bicycle danger is the seeming lack of control for local idiosyncrasies in crash reporting. For example, the data in Table 23, which displays the percentage of multi-party crashes for each major crash type in selected cities, show that a much higher percentage of crashes in Oakland than in other cities are classified as "other." This suggests a lack of consistency in data reporting and makes comparisons between other cities and Oakland difficult. There also seem to be systematic differences between the numbers of sideswipes and broadsides in Berkeley and San Francisco versus those in Vallejo and Walnut Creek. While this difference may reflect the effect of urban form on crash type frequency, it may also reflect crash-reporting styles. These differences merit further study in future research.

Table 23. Percentage of Multi-party Bicycle Crashes by Crash Type in Test Cities

	Berkeley (n=701) %	Oakland (n=793) %	San Francisco (n=2215) %	Vallejo (n=101) %	Walnut Creek (n=97) %
Not stated	5	3	4	3	5
Head-on	5	3	6	5	3
Sideswipe	19	10	23	9	9
Rear-end	6	4	6	7	4
Broadside	45	22	41	60	64
Hit object	2	0	2	2	1
Vehicle/Ped	2	5	4	5	6
Other	15	**54**	16	9	7
Total	100	100	100	100	100

Urban form may also affect the way fault is attributed in multi-party bicycle crashes. As shown in Table 24, the percentage of crashes by fault varies dramatically between the three more urban cities (Oakland, Berkeley, and San Francisco) and the two more suburban areas (Walnut Creek and Vallejo) with much more attribution to bicyclists in the latter. Future research should investigate whether this is due to a much higher percentage of bicyclists making mistakes, systematic differences in reporting, or something else, such as systematic bias against cyclists.

Table 24. Percentage of Multi-Party Bicycle Crashes for Test Cities, by Fault

	Bicyclist (%)	**Other (%)**	**Not assigned (%)**	**Total (%)**
Berkeley (n=701)	38	48	14	100
Oakland (n=793)	44	39	17	100
San Francisco (n=2215)	42	38	21	100
Vallejo (n=101)	**71**	8	21	100
Walnut Creek (n=97)	**67**	16	16	100

Discussion and Limitations

There are several limitations to the analysis presented in this chapter. First, the SWITRS data examined in this chapter include reported crashes only. Studies have found that reported crash statistics underestimate the total crash occurrence, and are likely biased toward more serious crashes, which are more likely to be reported (Stutts and Hunter, 1998). In addition, my own analysis found that crash risk in the form of near misses is pervasive, but is completely unreported. Thus, reported crash risk can only be said to represent a portion of the risk bicyclists face—and even that risk is not uniformly proportional to the various near-miss risks that likely inform a person's perceptions of danger while cycling.

Second, many of the reported crash data categories are too vague as to be helpful. There are several "other" categories that can be interpreted to mean different crash types or violations. In addition, preliminary analysis of the SWITRS data presented in this chapter found that there is often missing data that precludes segments of crashes from being thoroughly analyzed. There may also be biases or differences in crash reporting that are not formally recognized, as seen in Table 23 and Table 24.

Third, the perceived and experienced risk categories did not always cleanly match with the traffic violations in SWITRS. It is not clear how this should be remedied in future research, as the experienced and perceived risks were derived from input from focus group participants and respondents to the pilot surveys. However, the mismatch frustrated attempts at direct comparison. Furthermore, analyzing a subjective concept like risk using objective data like absolute numbers or crash severity is bound to be problematic. The severity of reported crashes often does not directly translate to perceived traffic risk, and determining that risk based on the highest absolute numbers of associated fatalities and severe injuries may belie the potential impact of crash experiences on one's comfort or perceived risk. Data in Chapter Seven showed that having experienced a crash or near miss was significantly related to various perceived risks—and that this held true even for crashes experienced by friends or family. When someone is able to walk away seemingly unharmed from a bicycle collision, the mental and emotional consequences of a bicycle collision may be much greater—and harder to measure—than they seem. If a person never again bicycles after suffering what crash data tells us is a minor injury for them, friends, or family, then the consequences are indeed greater than what is reported.

Finally, there was no timeframe specified for these incidents, nor a count of the number of times they occurred. Thus, findings correlating bicycling exposure to each event should be interpreted at the ecological, rather than individual, level. A more intensive effort to catalogue "near misses", such as the travel diary study by Joshi, Senior et al. (2001) would be necessary to understand how exposure relates to incidence in a detailed manner. This limitation also applies to driver-reported incidents. Even with those limitations, however, this data helps to indicate what overall trend may exist—and that is one of possibly routine dangers from interactions with drivers that are not reported unless they end in a collision.

Summary of Key Findings and Policy Implications

Before dissecting the findings, it is important to note that there is very little research on the scope or magnitude of near misses while bicycling. As discussed in Chapter Two, the limited research suggests that near misses are much more prevalent than collisions, as one would expect (Joshi et al., 2001). However, they have also been found to be much more prevalent for bicyclists and pedestrians than for drivers, which may mean that they also have greater impact on perceived risks for bicyclists and pedestrians than for drivers. The research presented here is thus a contribution to an under-studied aspect of bicycling danger.

There are several key take-aways from the analysis presented in this chapter. First, the self-reported collision and near miss data presented in this chapter suggest that *a large percentage of bicyclists have experienced near misses while bicycling.* While exposure was significantly positively associated with experiencing a near miss, even bicyclists who bicycle only a few times a year have experienced many different types of near misses. This suggests that near misses may present a *pervasive risk* for bicyclists. In addition, *bicyclists experience near misses to a much greater extent than actual crashes*. While this is not a necessarily surprising finding, these near misses may be particularly problematic, as they represent risks for bicyclists that are generally not reflected in official crash statistics, and may therefore not be considered serious or even known. As discussed in Chapter Seven, these near misses also significantly affect one's perceived cycling risk, which affects whether and how often people bicycle. Knowledge of that which influences perceived and experienced risk for current cyclists and future cyclists is critical to crafting successful policies to address the risk.

Third, *the percentage of people who have been hit in the various circumstances does not systematically correlate with the percentage of people who have had a near miss in the circumstance.* Thus, some incidents happen frequently but rarely end in a collision, while others happen less frequently but are more likely to end in a collision. In contrast to the pervasive risk, this latter type of risk represents a more *acute risk* for the cyclist. *Nevertheless, both the pervasive risk and acute risk seem to influence cyclists' perceptions of risk.*

Matching the perceived and experienced risks to each other and to the SWITRS data proved challenging. Perceived and experienced risks often did not match, although they more closely mirrored each other for weekly cyclists than for other cyclists. *Official crash statistics reflect experienced risks to a degree*, but not completely. The official statistics more accurately represented experienced collisions than experienced near misses.

Official crash statistics were also limited in how accurately they reflect perceived risks. As with experienced risks, official crash statistics more accurately reflected perceived risks for weekly and monthly cyclists than for other cyclists. In particular, risks attributable to inattention and aggression were not well differentiated in the official crash data, despite factoring heavily into perceptions of risk for many of the survey respondents.

The findings presented here suggest that attempts to reduce bicycle crashes may be well guided by an examination of official crash statistics, but that these statistics do not fully represent perceived or experienced risks. Instead, surveys like the one conducted for this dissertation seem to provide a better way to gauge perceived risks and the influence and prevalence of near misses. Travel diaries would allow for even more specific information about near misses and incidents, and could establish a better idea of the risk through exposure. In combination with observational studies of near misses and collisions, policymakers and practitioners could use these methods to form a much more holistic idea of risk and how to address it.

In addition, crash data could be further explored to understand the role of bicyclists and drivers, particularly certain demographics in each group, in causing various types of crashes or traffic violations. This type of analysis was conducted for a related study and could be used to make policy recommendations about targeted efforts to improve driver and bicyclist behavior. However, the results were not particularly enlightening for understanding perceived and experienced risk and were therefore not presented here.

In the following chapter, I discuss specific suggestions for addressing risk through policy and design.

Chapter 10 – Conclusions & Policy Implications

In this dissertation, I set out to improve our collective knowledge of perceived and actual cycling risk. In particular, I attempted to dissect perceived bicycling risk into its component parts; explore how perceptions are affected by experiences, beliefs, attitudes, and behavior; examine roadway design preferences among cyclists and drivers—and how perceived cycling risk affects those preferences; and investigate how perceived risks match with reported crash statistics. I found that risk is a deeper and more complex aspect of cycling than the literature has heretofore captured. In this chapter, I review the key findings presented in Chapters Four through Nine and recommend next steps for addressing the findings via policy or further study.

There are limitations to this study that resulted from time and resource constraints, in addition to survey design. However, I believe that the findings presented in this dissertation can help planners, engineers, public health practitioners, and policymakers better address risk to make cycling safer for those who currently do it and more attractive for those who may cycle in the future.

Key Findings

This dissertation presents six major findings about perceived risk for bicyclists. Each finding is presented below, along with a brief discussion of the supporting data from the various chapters and policy recommendations.

Barriers to bicycling

1. The influence of perceived risk on the decision to bicycle is commensurate with other commonly-cited impediments like topography and lack of secure bike parking. Perceived risk may be even more important than the data indicate, due to its potential influence on several other barriers like trip distance and the need to carry passengers or loads.

Only one other study has examined whether risk is as much of a barrier to cycling as trip characteristics like distance, the need to carry loads, etc. (Winters et al., 2010), yet even that study did not dissect risk into its component parts to understand what driver actions elicit the most fear among potential and current cyclists. My research investigated how non-risk barriers compared to the perceptions of risk associated with multiple specific driver actions and respondents' fears about their own lack of ability while cycling with regard to influencing the decision to bicycle. The data presented in Chapter Four show that focus group respondents were affected by concerns about traffic risk and other barriers to cycling. The survey data presented in Chapter Seven suggests that there are three main categories of barriers to cycling:

1. Fundamental barriers – these are barriers to a majority of potential and occasional cyclists, and are very difficult to overcome, at least for certain trips. These barriers include not having regular access to a bicycle, trip distance, and the need to carry things or people.

2. Probable barriers – these are barriers to a large minority of potential and occasional cyclists, and are moderately to very difficult to overcome. Risk-related barriers in this category include worries about drivers who drive too fast or too close to cyclists, distracted drivers, and being cut off by drivers who are turning. Non-risk barriers include topography, a lack of bike lanes or routes, and a lack of secure bicycle parking.

3. Possible barriers – these are barriers to a small minority of potential and occasional cyclists, and may be difficult to overcome for some people. Risk-related barriers in this category include worries about being hit by a car door, aggressive drivers, and making a mistake leading to injury while cycling. Non-risk barriers include weather, discomfort due to roadway quality, concerns about personal safety from crime, and embarrassment.

My data indicate that worries about traffic risks compose the majority of the "probable" barrier category, but do not qualify as fundamental barriers. This finding implies that addressing risk is important to encouraging cycling, but that some trips—particularly those that are too long or for which a person needs to carry loads or people—may be unlikely to occur by bicycle until bicycling is better integrated into society through the provision of high-quality, connected infrastructure direct to key destinations, improved access to load-carrying bicycles, and connections to other modes of transportation such as trains and buses. There is some evidence that concerns about traffic risk influence the fundamental barriers. For example, previous research has found that bicycle ownership is significantly related to perceptions of safety and comfort while cycling (Beck and Immers, 1994; Xing et al., 2008).

Policy recommendations for addressing perceived risk:

A key strategy to mitigate both the fundamental and probable barriers may be the installation of high-quality, densely-connected bicycle facility networks. Not only are the perceived risks significantly associated with (and thus likely to be affected by the availability of) various bicycle facilities, but the presence of such a network could make bicycling for certain trips a consideration, rather than an impossibility (e.g., by shortening the travel time for trips using bicycle infrastructure, making more areas of the city accessible, and increasing perceived safety such that a trip with one's children would no longer be considered unsafe along certain routes).

Another option to decrease travel time for cyclists could be to implement the "stop-as-yield" law, which allows cyclists to treat stop signs as yield signs at which they must stop when other traffic is present, but otherwise can slow down and ride through to save energy. Any implementation of this law would necessitate public education to communicate the revised rights and responsibilities of cyclists and drivers in various circumstances.

In the same vein, driver and cyclist education likely needs to be revised to include more substantial instruction about how to safely drive near cyclists and bicycle near drivers. The data on perceived risks suggest that cyclists are particularly worried about distracted drivers and drivers passing too close, cutting one off while turning, and driving too fast—all behaviors that are currently illegal, but clearly common enough to inspire fear. Indeed, several of these worries were significantly associated with the cyclists' experiences of risk. To ensure the success of this strategy, driver education programs likely need to be revamped to include consistent and thorough information about bicycling, which preliminary analysis for this dissertation suggests is not the case. Incentives for participation may also be necessary, particularly for bicycling education programs, given currently low participation rates for voluntary secondary mobility education.

Roadway Design Preferences

2. For multi-lane commercial roadways, drivers and cyclists both prefer designs with separated space, especially barrier-separated space, regardless of cycling frequency of type of cycling.

The data in Chapter Six show that the vast majority of drivers and cyclists feel comfortable on multi-lane commercial roadways with separated space for bicyclists—particularly if the space is separated by barriers. In fact, roadway designs with barrier-separation were the only designs for which cycling frequency was not significantly related to one's perceived comfort. In other words, people who don't currently bike, but would consider doing so in the future (and who also tend to be more influenced by perceived bicycling risks than current cyclists), reported the same comfort levels as people who bicycle every day.

3. In contrast, striped bicycle lanes next to on-street parking—one of the most common bicycle treatments in the U.S.—received mixed reviews.

The mixed reviews resulted from perceived benefits and increased risks from cycling in a striped bike lane next to on-street parking. On the one hand, a large majority of the sample thought that bicycle lanes communicated that drivers should expect cyclists on the roadway, and increased drivers' perceptions of predictability when driving near cyclists. On the other, bicycle lanes were seen by some respondents—particularly non- and potential cyclists—as communicating that drivers should not expect cyclists on non-bicycle routes. In addition, some focus group and survey participants commented that a striped bicycle lane in the "door zone" of a car may actually increase, rather than mitigate, traffic risk. Less than 50% of the sample—and only 20% of potential cyclists—would feel at least moderately comfortable bicycling on a multi-lane roadway with a striped bicycle lane next to parking.

4. Furthermore, so few potential cyclists feel comfortable with shared space designs on commercial streets—including sharrows—that they may be essentially useless in attracting new riders. Just a small minority of current cyclists feel comfortable riding on commercial roadways where cyclists and drivers share space.

Chapter Six also showed that drivers' and cyclists' comfort levels diverged when it came to multi-lane commercial roadway designs where they share space. Drivers tended to prefer no or minimal treatment, which comments from the focus groups suggested is based in a lack of understanding about how they or cyclists are supposed to behave when there are shared space markings. Cyclists preferred paint to nothing at all, but only a small portion reported feeling comfortable in any of the shared spaces. Potential cyclists, in particular, were averse to any shared space: only 10% of potential cyclists indicated they would feel comfortable on a commercial street with sharrows, and only 3% would feel comfortable on a street with no bicycle markings at all.

Policy recommendations for roadway design:

My data lead me to recommend policy for roadway design at both the local and national level. First, my findings suggest that local transportation agencies would do well to identify the types of riders they seek to attract or satisfy when installing bicycle infrastructure on the roadway. The trend among cyclists of all experience levels is to prefer greater separation from moving traffic and parked cars. However, potential cyclists seem to be the most affected by the facility design, with dramatic drops in the percentage of people who feel comfortable bicycling once physical barriers are removed, then again when parallel parking is introduced, and even further when high-visibility (e.g., green) paint is removed. For these cyclists, shared lane markings are little better than no markings at all; any shared space scenario on a multi-lane, commercial roadway is considered unattractive.

While not as dramatic as for the potential cyclists, these same preferences exist for cyclists of all experience levels, suggesting that cities with serious policy goals to increase bicycling will likely need to find some space—whether from parking, a travel lane, or the sidewalk—for separated facilities for cyclists on major roads. A common response has been to paint bicycle lanes at the edge of the roadway, within the door zone of cars, but the respondents of the focus groups and survey—including the drivers—expressed concerns about the increased risk of a cyclist being hit by a car door and knocked into oncoming traffic in that scenario. Aside from the general lack of popularity for striped bike lanes among my survey respondents, my data show that concerns about being hit by a car door are significantly related to having been hit or almost hit by a car door, suggesting that this risk has been undervalued and understudied for cyclists.

This leads to my recommendations for national policy, which center around design guidelines. Despite their apparent appeal, barrier-separated bicycle lanes—the single bicycle facility that several studies (this dissertation included) have documented as overwhelmingly popular among potential and current cyclists, irrespective of gender, age, and cycling frequencies—are still not in the official AASHTO Bikeway Design Guide, and have therefore been installed only with special permission from FHWA. This could be remedied through a special edition of the AASHTO guidelines, or even AASHTO's recognition of the guidance provided through the NACTO design guidance. AASHTO's resistance to providing or sanctioning guidance on barrier-separated bicycle lanes has been based in concerns that there is not enough research on such facilities in the United States to create such guidance (Furth, 2012). This has led to a catch-22, where the facilities have not been built due to the lack of guidance, and the lack of guidance has precluded the facilities from being built. Recent and ongoing studies on barrier-separated bike lanes in the U.S. suggest that barrier-separated bike lanes are no more hazardous (and may be less so) than other approved bicycle facilities, and should provide the evidence that AASHTO seeks (Lusk et al., 2011; Teschke et al., 2012).

I also suggest that the risk of injury from collisions or near misses in the "door zone" be further studied, including observational data that can give a better idea of the frequency of such incidents on streets with and without bicycle lanes and other infrastructure types. My data suggest that bicycle lanes convey benefits in the form of increased comfort for cyclists (over shared space designs) and increased awareness for drivers. However, my data also indicate that the risk of being hit by a car door is a consistent worry for regular cyclists, many of whom have been hit or almost hit in the situation. If riding in a bicycle lane augments this risk, the aforementioned benefits may be neutralized or reversed, but further research is needed to understand this balance. In the meantime, one immediate solution could be to require a "door zone" clearance between the parking lane and a striped bike lane where one is installed. This would remove cyclists from the real and perceived risk of the situation.

A complementary recommendation is that driver and cyclist education be revised to include emphasis on checking for cyclists before opening car doors, backing into parking spaces, pulling out of parking lots, etc. The overwhelming comfort that is associated with barrier-separated facilities comes from the elimination of the potential conflicts in these areas, but education about appropriate behavior is necessary for those streets (currently the vast majority of streets in the U.S.) where cyclists and drivers interact without such separation. Increasing awareness of cyclists may also help address this issue, such as technological innovations that can sense oncoming movement and alert drivers to a cyclist's presence. However, any solution requiring special equipment is likely longer-term.

Lessons can be learned from international experience. Drivers in the Netherlands are taught to open car doors with their far hand, necessitating looking over their shoulder and checking for bicyclists. In addition, it is common for cities in Denmark and the Netherlands to address the risk of dooring by placing the bicycle lane between parked cars and the curb, often with a buffer for an opening door. Moving parking away from the curb or taking space away from a travel or parking lane to provide sufficient space for cyclists will likely be difficult battles to fight in cities where people are accustomed to on-street parking, and may result in new conflicts, such as those between car passengers and bicyclists. Trade-offs and compromise in these areas will likely be necessary if city officials and practitioners truly want to make strides to increase cycling.

Cyclists' Experienced Risk

5. Cyclists experience two types of risk on the roadway: pervasive risk in the form of near misses that happen or threaten to happen frequently, and acute risk that occurs when a cyclist is struck—a less frequent, but more injurious occurrence. Both types of risk significantly affect a cyclist's perceptions of risk for herself and within her social network, although there does not seem to be any systematic correlation between them.

The data in Chapter Nine show that 70% of the bicyclists in my sample, regardless of how often they bicycle, had experienced at least one of several dangerous incidents involving drivers. The percentage of bicyclists who had experienced each incident as a near miss ranged from 23% to 65%. I categorize the risk of a near miss as "pervasive", given how many cyclists in the sample had experienced each incident. Whether a respondent had experienced a near miss was significantly associated with cycling frequency, my measure of exposure. While this research did not ask for a count of experiences, the highly significant relationship to exposure suggests that regular cyclists likely also experience these incidents more often than occasional cyclists.

In contrast, each incident resulted in a collision for only 1% to 8% of cyclists. I therefore categorize being hit as "acute" risk, given that collisions are relatively rare, but potentially fatal when they occur. In addition, with the exception of being hit by a car door, there was no significant relationship between cycling frequency and whether one had been in a collision associated with each incident.

There was also no systematic correlation between the incident type and how often it resulted in a collision. In addition, both types of risk, but particularly near misses—perhaps because they are more common—significantly affected one's perceptions of risk. Perceived risks for potential and current cyclists were also affected by collisions experienced by friends and family, whether as a cyclist with a driver or vice versa.

6. Data on near misses are not captured in any systematic way, resulting in near complete ignorance of the extent of their occurrence. In addition, data on reported crashes provide only limited insight into the near misses and even the collisions that cyclists experience.

Despite the evidence presented in this dissertation that the pervasive risk experienced through near misses is strongly associated with perceived risk while cycling, practitioners and policymakers know little to nothing about the frequency of near misses on a cyclist's journey, as data on near misses are not systematically captured and rarely sought out for examination. This study is one of the first to provide evidence that knowing about the extent of near misses could be critical to understanding perceived risk.

In addition, reported crashes only partially reflect cyclists' experienced risk, whether categorized by frequency or severity. Not only are near misses not systematically correlated with resulting collisions in this sample, but neither the near misses nor the collisions matched more than 60% of the time with the reported crash statistics analyzed in this dissertation. Reported crashes also inconsistently reflected perceived risks, although they more accurately reflected perceived risks for weekly and monthly cyclists than for other cyclists. In particular, risks attributable to inattention and aggression were not well differentiated in the official crash data, despite factoring heavily into perceptions of risk for many of the survey respondents. These findings suggest that basing policies or roadway designs on ideas about risk gathered from reported crash statistics may exclude crucial information about cyclists' experienced and perceived risks.

Crash records also indicated inconsistency in categorization of fault and class type, at times by city characteristics, but other times seemingly randomly. Many of the categories were too broad or general to indicate what had actually happened, hindering determination of the risk the cyclist would have experienced. Finally, the crash records analyzed for this dissertation lack information on the built environment like the presence of on-road bicycle facilities, on-street parking, etc. While this information can be gathered separately, including it in the crash record would facilitate analysis on the relationship between these potentially important factors and crash results.

Policy recommendations for understanding experienced risk:

I believe the findings in this dissertation provide strong evidence that risk-related experiences—in particular, cyclists' near misses—should be further studied to understand who is affected, how often each incident occurs, and what factors lead them to occur at all, be avoidable when they occur, or end in a collision. As there is no mechanism currently in place to systematically gather data on near misses, nor to correlate them to perceived risks, I recommend that experienced risk studies be conducted annually or biennially, to generate enough data to measure trends as well as understand the cross-sectional view of this type of risk. Continuing to neglect the influence of near misses will almost assuredly prohibit policymakers and practitioners from understanding how often these risks are experienced, how they affect perceptions of cycling risk, and ultimately, how they affect a person's decision to bicycle. This lack of knowledge may also perpetuate currently dangerous, but under-examined conditions for cyclists.

In addition, I recommend that crash records available to the public be modified to provide additional data to understand trends in reported crashes. Additional study is needed before specific recommendations can be made, but it is clear from the data presented in Chapter Nine that reported crashes do not always clearly convey the risk that a cyclist faced when the collision occurred. Efforts could also be made to better train officers who record the data. As this dissertation showed, one of the five cities classified 50% more crashes as "other" than the comparison cities, and two of the five cities cited bicyclists nearly twice as often as the other three cities. It is possible that these seeming inconsistencies truly reflect the data, but not unreasonable that police officers trained to deal mostly with automobiles may lack a thorough understanding of rules applying to cyclists. More consistent crash reporting would allow for more direct comparison of crash data between cities. Providing additional data about the built environment, such as whether there was a bicycle lane or parking on the street where the collision occurred, would facilitate crash analysis looking at major trends related to bicycle risk.

Efforts to more consistently and thoroughly capture the prevalence of distracted and aggressive driving—particularly when either contribute to a crash—would benefit not just cyclists, but general public safety. While State-sponsored surveys have found that nearly 50% of people admit to having texted while driving, inattention of any kind was only cited in 1% of crashes in this subset of data. Yet worries about being hit by distracted drivers were among the strongest for all cyclists, regardless of cycling experience. Thus, knowing the true risk of such an incident may assuage these fears—or may spur officials to take stronger actions to prevent such infractions. Similar recommendations apply to the prevalence of aggressive driving, which is almost wholly unknown.

In addition, crash data could be further explored to understand the role of bicyclists and drivers, particularly certain demographics in each group, in causing various types of crashes or traffic violations. This type of analysis was conducted for a related study and could be used to make policy recommendations about targeted efforts to improve driver and bicyclist behavior.

I also recommend that driver and cyclist educational standards be revised to include more substantial training about how to behave in either role, particularly when sharing the roadway with the other party. The vast majority of my sample either did not remember or was never taught how to drive near bicycle traffic, yet every driver in the sample reported seeing bicyclists when they drive. Only a small percentage of the bicycling respondents knew all of the roadway laws that apply to them while cycling, and only a few had ever taken a bicycle-specific traffic safety course. Driver education classes are likely the most convenient avenue to teach bicycling education, given the high proportion of cyclists who also drive, but efforts to encourage people to take bicycle safety courses could also be developed in the model of insurance rebates for defensive driving courses. While the specifics of these solutions are beyond the scope of this study, it is important to address the lack of training to navigate multi-modal roadways, which applies to both drivers and cyclists and contributes to the experienced and perceived risks of bicyclists and drivers.

There are some areas of overlap where policy and design could be engaged to reduce risk and improve safety for specific risks posed by drivers to cyclists. Every incident listed below could be partially addressed through improved driver education classes and public service campaigns that teach and remind drivers and cyclists how to safely operate near each other on the roadway. In addition to those efforts, the following actions may address particular risks:

- *Drivers passing too close* – This risk could be mitigated by a three-foot passing law, as is currently codified in Colorado (Colorado State General Assembly, 2009) and Arizona (Arizona State Legislature, 2000). Passing in California is governed by Vehicle Code section 21750 and states that vehicles should pass "at a safe distance without interfering with the safe operation of the overtaken vehicle or bicycle." However, perceptions of safety differ dramatically for someone in a car versus someone on a bicycle, so the vagueness of this code offers little guidance for what a bicyclist might actually need to feel safe. Specifying a distance may help drivers better gauge how much room they are legally required to leave while passing.

- *Being cut off by a driver* – This risk may be addressed through a combination of redesigned intersections and roadway treatments to communicate where bicyclists and cars should be when making turns versus proceeding straight. For example, "bicycle boxes" at the front of intersections in Portland, Oregon, have created a space where cyclists can gather and move ahead of cars. A right-turning driver then places himself behind the box to make a turn after the cyclists have cleared the space.

- *Being hit by a car door*– This risk could be addressed through redesigned right-of-ways that provide space for bicyclists outside of the door zone, and clearly communicate to bicyclists where they should ride. Facilities with painted door zones are common in Amsterdam and Copenhagen, and have recently been built in U.S. cities like New York and San Francisco. In addition to building a door zone buffer, certain types of infrastructure—such as the green painted bicycle lane—may increase driver awareness more than others, as reported in Chapters Three and Five.

- *Distracted driving* – Statewide efforts are underway to reduce the prevalence of distracted driving, although research from the California Office of Traffic Safety (2012) suggests that the prevalence has been increasing—despite widespread acknowledgement of the danger to oneself and others. Less forgiving roadway designs, such as those with traffic calming, may help retain drivers' attention. For cyclists, the findings in Chapter Six suggest that barrier-separated bicycle lanes may be the best roadway design to assuage this perceived risk.

- *Aggressive driving* – There is little research on aggressive driving toward bicyclists, so it is unclear how effective various strategies would be to combat it. Data from my focus groups suggest that many drivers feel frustrated about what they see as a lack of predictability among cyclists, and, at times, a disregard for the cyclist's and others' safety. In addition, a majority of my survey respondents reported having had to evade a cyclist doing something dangerous, such as running a stop sign or red light, or riding without lights at night. However, I was not able to link these findings to aggressive driving in my data—perhaps because of response bias, but perhaps because there is a different underlying cause for the aggression. Additional research is therefore needed to better understand what factors affect and lead to aggressive driving.

  In terms of immediate actions, separating drivers from bicyclists through bicycle-specific infrastructure may help by providing greater predictability, but my survey data indicate that this would need to be accompanied by educational efforts to teach drivers that bicyclists are still legally allowed on all roadways (except where expressly prohibited). Ultimately, increasing the number of cyclists on the roadway may be the best way to combat such aggression, as research shows that drivers who bicycle are more empathetic to cyclists than non-cycling drivers (Basford et al., 2003). My data support these findings by showing a significantly positive association between having friends and family who bicycle and supporting bicycling in one's city.

- *Unsafe speed* – Roadway design offers the most promise to address speed. Research comparing arterials with livability elements (e.g., street trees, benches, trash cans, etc.) to otherwise similar arterials without such elements found that the livability elements were associated with slower driving speeds and fewer crashes for all roadway users (Dumbaugh, 2005). In the event that the entire street cannot be redesigned for slower speeds, barrier-separated bicycle lanes may offer the best way to mitigate this perceived risk for cyclists.

Perceived Cycling Risk and Bicycling Support

7. Perceived cycling risk is broader than previously imagined. Cycling is seen as dangerous not just for oneself, but also for other cyclists and even for drivers who share the roadway with cyclists. This multi-pronged belief in the danger of cycling significantly negatively affects people's support for bicycling, and is countered only seriously by utilitarian cycling frequency.

In Chapters Four and Seven, I explore perceptions of general bicycling risk and support for bicycling in one's city. In Chapter Five, I present the results of bi-variate analyses showing that cycling frequency is positively significantly associated with a desire for (and willingness to support) more cycling in one's city, and negatively significantly associated with a desire to restrict cyclists from parts or all (in some cases) of the roadway. I also found significant differences between non-cyclists, occasional cyclists, and regular cyclists regarding beliefs about how to safely bicycle in urban areas. In particular, a much higher percentage of non-cyclists and potential cyclists believed it was safer to bicycle on the sidewalk than on the street in urban areas (a behavior that is not only illegal in many places, but that can also be dangerous due to drivers not expecting fast-moving cyclists to be on the sidewalk). In addition, a majority of non-cyclists and yearly cyclists, and half of potential cyclists, believed that the biggest danger to a bicyclist was his own actions. Non-cyclists and potential cyclists were also significantly more likely than regular cyclists to feel anxious when seeing a child pulled in a bicycle trailer.

In Chapter Eight, I describe the results of a structural equation model employed to further examine the connections between bicycling support and perceived and experienced risk, bicycling habits, beliefs about bicycling safety, the built environment, and demographics. I found that variables associated with bicycling risk were the most predictive in the model, although often indirectly. The strongest direct affect for bicycling support is the belief that bicyclists should be restricted to off-street paths, which was significantly and negatively associated with bicycling support. Many of the significant variables in the model directly affect this belief, and therefore indirectly affect bicycling support.

For example, fears about drivers' actions and the risk they impose on the respondent—in particular, worries about drivers driving too fast, passing too close, and behaving aggressively—significantly and directly affect perceptions of bicycling risk for oneself and others and beliefs about where bicyclists should ride (e.g., on the sidewalk and/or off-street paths), and significantly but indirectly affect support for bicycling. Perceptions of risky behaviors among bicyclists—such as bicyclists running red lights— and the danger they pose to drivers also significantly affect support for bicycling, both directly and indirectly. These perceptions are reflected in the belief that bicyclists are the biggest dangers to themselves and feelings of anxiety when seeing children in a bicycle trailer. Believing that bicycling is impractical is also significantly negatively correlated with bicycling support.

Other significant factors in the model include being male, having friends or family who bicycle to work or run errands—particularly if they have been hit by a car while biking, and population density—all of which are significantly positively correlated with support for cycling, albeit indirectly. The most powerful positive direct affect for cycling support is utilitarian bicycling frequency, although it is still not as powerful as the belief that bicyclists should ride off-street.

Policy recommendations for increasing bicycling support:

As defined in this dissertation, support for bicycling includes a willingness to use public funding to encourage cycling and a willingness to remove some on-street parking on major roadways to provide space for bicycle facilities. Today, altering the roadway to entice more bicycling is a contested topic. As cycling continues to increase in many cities, support for cycling facilities that originally led to roadway infrastructure changes has been countered by resistance to such efforts. To date, no studies have sought to understand how perceived bicycling risk—a major influence on whether or not people bicycle—also informs this debate, potentially contributing to support or resistance efforts. My data show that there is a significant relationship, one that should be considered in research and practice going forward.

The model suggests that there are several categories of variables that affect bicycling support, including cycling frequency, perceived risks of bicycling, beliefs about bicycling, personal and social network characteristics, and the built environment. Perceptions of cycling risk affect support for cycling in multiple ways, including fears about drivers' actions, fears about bicyclists' risky behaviors, and worries about cycling risk in general. Because of the substantial connection between risk and bicycling support, all of the policy recommendations discussed previously have some application to this specific section. The recommendations with particular salience are covered again here.

Actions to address driver behavior will likely need to include more substantial driver education about the rights of cyclists and how to drive safely around them. In addition, roadway designs that more effectively separate bicyclists from drivers may mitigate some of these worries, although the designs would need to be carefully implemented (for example, to ensure that turning conflicts are not exacerbated through reduced visibility) and accompanied by clear messaging about cyclists' rights to all roadways, regardless of the roadway design.

Policies to address bicyclists' risky behaviors may do well to include more substantial bicycle training. Addressing this area is likely to be complex, as cyclists who run red lights or stop signs likely already know that it is illegal to do so, but do so in order to save time or energy while bicycling. This issue may be addressed by increased law enforcement where resources exist, but a longer-term solution may include changing traffic laws to more effectively accommodate the physics of cycling (such as allowing cyclists to yield at stop signs when no car is present, something that a majority of the survey respondents supported and which has been implemented in Idaho). Any change in laws would almost certainly need to be accompanied by comprehensive public information campaigns, as well as consistent enforcement of the laws to preclude abuse. While changes in certain laws were supported by a majority of my survey respondents, my focus group participants suggested that they would only support such changes if they were granted immunity as drivers—essentially placing the onus for safe behavior solely on the cyclist.

Policies to address general perceptions of cycling risk may also focus on driver and cyclist education to teach roadway users what is expected of them. My data also suggest that worries about one's own bicycling risk significantly affect general perceptions of bicycling risk. Perceived risks for oneself may be addressed through roadway design that physically separates bicyclists from drivers, given that my data show a significant relationship between comfort levels on the various roadways and perceived risks. Building more physically-separated bicycle facilities may also lead to increased bicycling overall, which tends to decrease one's own perceptions of risk (via one's cycling frequency) and one's "actual" (i.e., statistically-determined) risk, given the concept of "safety in numbers." In addition, the presence of bicycle infrastructure itself seems to influence bicycling support. Though not in the model, respondents who reported not having a bicycle lane within two miles of their home were significantly ($p \leq 0.10$) more likely to believe that bicyclists should be restricted to off-street paths, suggesting that the presence of bicycle lanes may communicate legitimacy for bicyclists and, at the least, may increase cycling support.

Many of the other significant predictors of bicycling support may only be addressed through policy in complicated ways. For example, males were significantly less likely to believe that bicyclists should be restricted to off-street paths, which may result from the fact that males are in general more likely to bicycle and feel comfortable doing so. Efforts to reduce this gender difference may involve targeted encouragement or perhaps educational efforts directed toward women, but would likely have to confront the barriers that keep more women from bicycling in the first place, such as the tendency to do more childcare-related tasks, run more household errands, and be more risk-averse (Garrard et al., 2012).

Addressing the impracticality of bicycling will likely also be complex, although one option is to work with the bicycle manufacturing industry to create less expensive options for carrying loads/passengers by bicycle. In addition, as discussed in Chapter Seven, addressing safety concerns—particularly through the provision of conveniently-located bicycle-specific infrastructure—may reduce perceptions of impracticality and open the possibility for more bicycle trips.

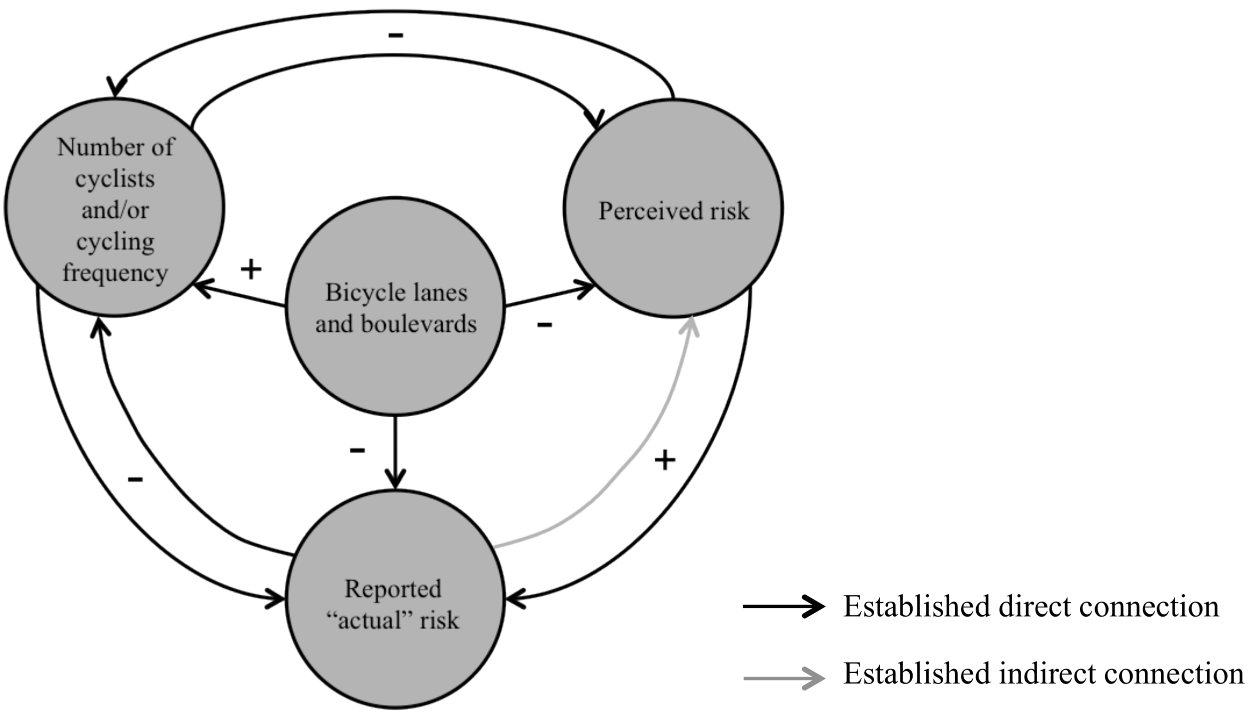
The following section presents a modified theory of bicycling risk that I hope will guide future efforts to address it.

A New Theory for the Cycle of Bicycling Risk

In this section, I discuss the current—albeit informal—theory of bicycling risk, as established through dozens of studies on cycling risk, barriers to bicycling, and preference for bicycle facilities. I then demonstrate how my research informs this cycle and propose expanding current concepts to include more nuance. Finally, I propose add a new link to cycle to account for bicycling support within a community.

For years, scholars have informally discussed a vicious cycle of bicycling ridership, which is that bicycling is more dangerous than walking or driving in part because fewer people bicycle—the concept of "safety in numbers" (Jacobsen, 2003). Several studies have also found that perceived risk plays a role in discouraging people from bicycling in the first place (Dill and Voros, 2007; Winters et al., 2010), leading to perpetually low numbers of cyclists and relatively high risk.[21] Studies have also found that people desire to bicycle on bicycle boulevards or roadways with bicycle lanes (Dill and McNeil, 2012; Tilahun et al., 2007; Winters and Teschke, 2010), as they consistently perceive them to be safer. Recent research has found that bicycle lanes, particularly physically-separated lanes, are associated with lower crash risk (Lusk et al., 2011; Teschke et al., 2012). These feedback loops are illustrated by Figure 47.

Figure 47. Established Cycle of Bicycling Risk

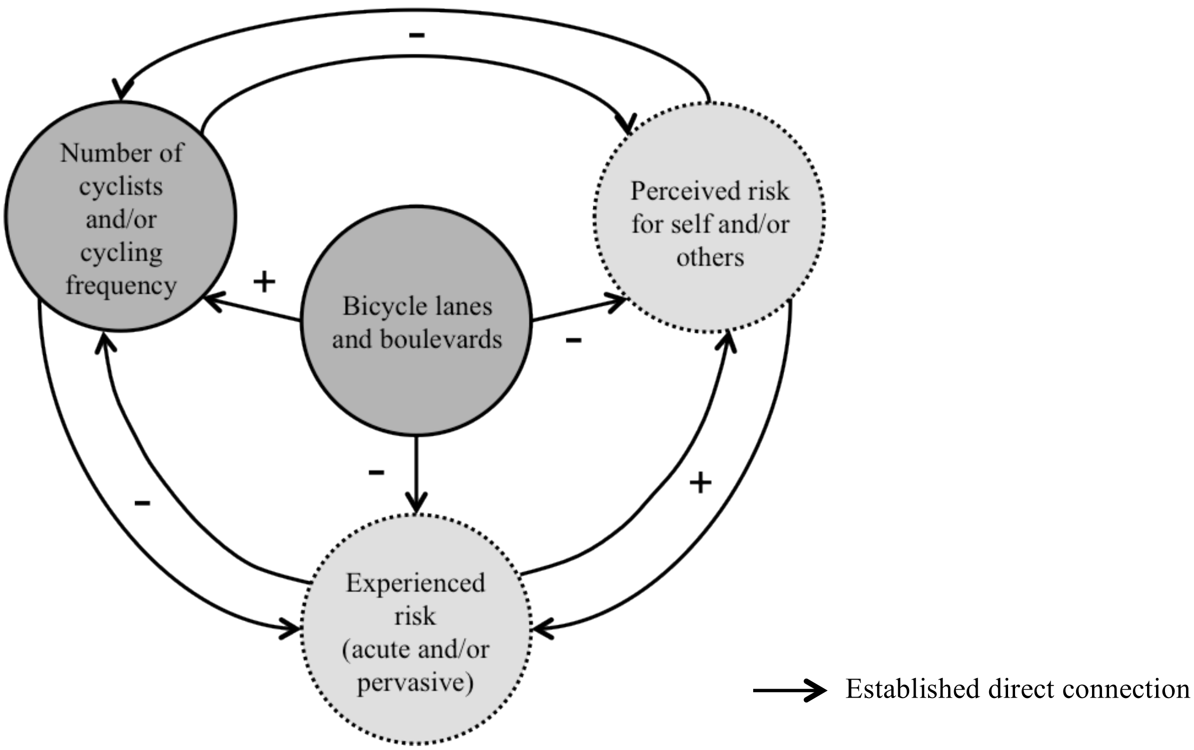


The findings presented in this dissertation suggest that, while these basic connections hold true, they are more nuanced than previously realized. For example, my data suggest that perceived risk is not a monolithic category, but instead seems to be composed of perceived risk for oneself and perceived risk for others. In addition, my findings indicate that reported crash risk does not fully reflect the extent or type of risk ("experienced risk") cyclists face on the roadway. Cyclists seem to face acute risk in the form of collisions, but pervasive risk in the form of near misses—and reported crashes don't capture the extent of either category. In particular, pervasive risk is not well captured by statistics. My data also provides evidence for the direct connection between experienced risk and perceived risk, in contrast to the original theoretical cycle. I therefore

[21] Cycling risk is also affected by vehicle volumes and speed, built environment characteristics such as land use patterns, slope, and street width, and other factors. For the sake of keeping these figures relatively digestible, they are limited to the concepts studied in this dissertation, including, in this case, reported crash risk and bicycle-specific infrastructure (but not a detailed analysis of the roadway and driver characteristics for each crash).

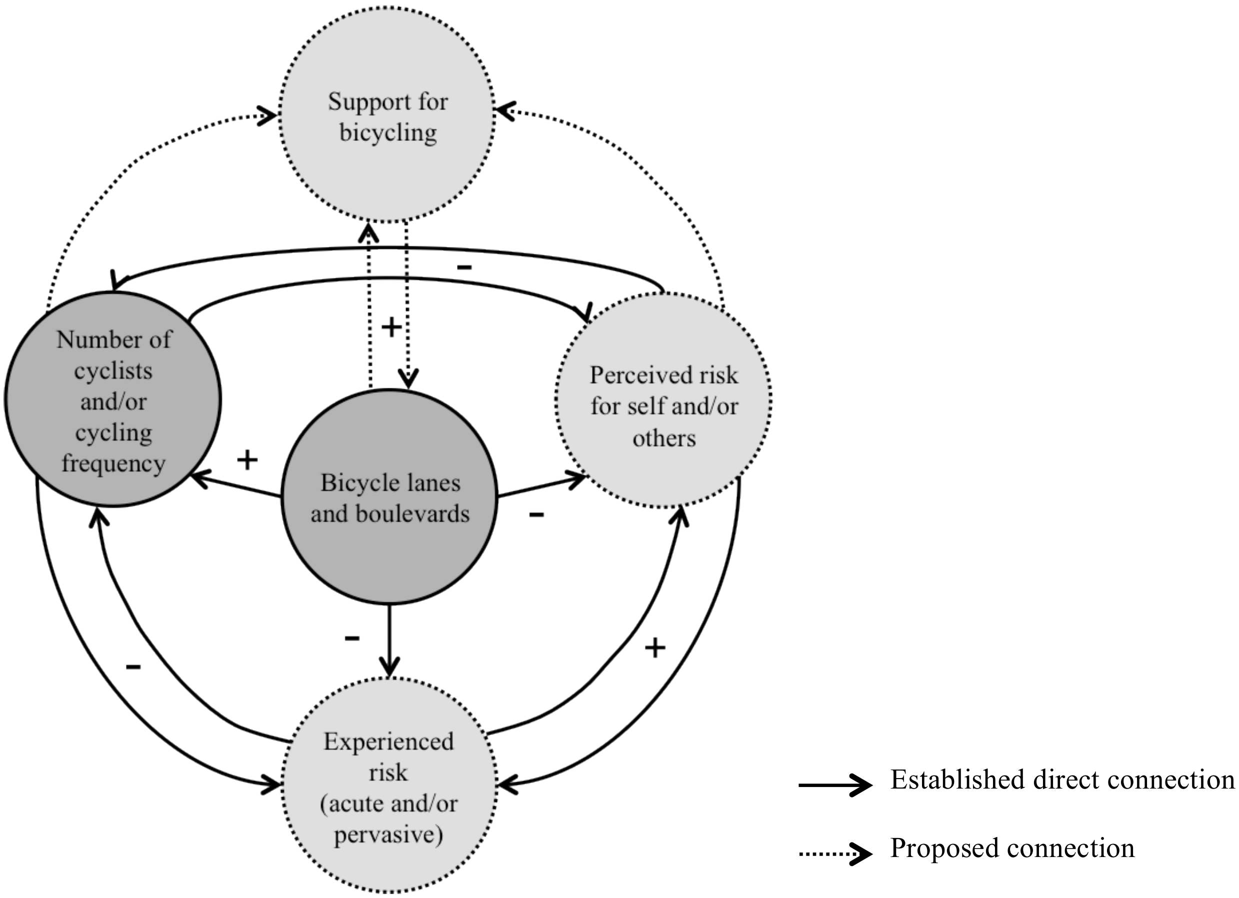
propose modifying the cycle to include two categories of perceived risk and replace reported risk with two categories of experienced risk, as indicated by the light gray circles with hashed outlines in Figure 48.

Figure 48. Revised Cycle of Bicycling Risk



My findings also provide evidence that both perceived cycling risk and cycling frequency significantly influence support for bicycling in one's city—a construct that is becoming increasingly important as more people bicycle and more infrastructure is demanded and provided. Therefore, I propose adding the construct of bicycling support to the cycle, as shown by the third light gray circle in Figure 49.

Figure 49. Proposed Cycle of Bicycling Risk



While this is certainly not the last word on bicycling risk, I hope that the findings presented in this dissertation, in addition to the revised theoretical model encapsulating the findings and showing their relationship to previous research, can help practitioners and policymakers better understand the complexity of the subject and be better equipped to accomplish their goals of increased bicycling and improved bicycling safety.

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Appendix A – Focus Group Script for Non-Cycling and Cycling Drivers

Good evening, and thank you so much for being here tonight to share your thoughts and feelings about driving near bicyclists on public roads. Please make sure you've signed a consent form for your participation and turned off your cell phone before we begin. Your opinions will be kept completely confidential and will help inform a larger survey we will be conducting later this spring. I value your input.

First, some ground rules for our discussion. The group discussion will last about one hour and I have a set of questions I would like you to discuss. There are no right or wrong answers to the questions, so you may find that you don't always agree with one another--and that is fine. We want to bring out the full range of viewpoints, whatever they are. Also, you do not have to answer anything you don't want to.

I have two requests. First, please be polite to one another. Second, don't feel that you have to be called on; feel free to speak up, but one person at a time.

Two other points: If you are being quiet, I may call on you. If you are talkative, I may have to suggest we go on so that we can give everyone a chance to talk and still finish on time.

Engagement Questions for NON-CYCLING GROUP

First, I'd like to hear a little about your personal experience with bicycling.

1. Did any of you bicycle as a child or at another point in your life?

2. How many of you have friends or family members who bicycle? Would you say you know "a lot", "some", or "few" other adults who bicycle?
3. Do you see these people bicycling on a regular basis?

4. What type of bicycling trips do friends or family members who cycle make – errands and work trips, recreational rides, or both?

5. Do you know if they ride on public roads, on bike paths, or both?

6. Do you see any benefits to having more bicyclists in urban areas? If so, can you name a couple?

Exploration Questions

Now let's talk about your feelings about and experiences with driving on the roadway with bicycle traffic.

1. I'm going to show you several photos. Please tell me what types of users you would expect on each road (show A-G).

2. How do you feel when you drive near bicyclists on streets like this one (show A-B) (e.g., confident, worried, etc.)? What about on streets with lots of traffic, such as (C)? Are there specific actions that bicyclists or other drivers do to lead to those feelings?

3. Does having bicycle markings affect your experience driving near bicycle traffic on roadways? For example, (D-G)? Are there specific actions that bicyclists or other drivers do to lead to those feelings?

4. When you are approaching an intersection and need to make a turn, do you tend to look for bicyclists before turning? If "sometimes", what affects whether or not you look? Do you perform other maneuvers to avoid them (e.g., speed up)?

5. Have you ever had a near miss or a crash with a bicyclist while you were driving? If so, can you briefly describe what happened?

6. How have past experiences driving near bicyclists (if applicable, also bicycling near drivers) influenced your opinions about bicyclists on the roadway?

7. Have any of your friends or family had experiences driving near bicyclists or bicycling near drivers that strongly affect your opinions about bicyclists on the roadway?

8. What are some things that would make you feel more comfortable driving near bicyclists in urban areas?

9. If you knew that there would be proper enforcement, would you support a stop-as-yield law?

<u>Exit Question</u>

10. Is there anything else you would like to add about driving near bicyclists in urban areas?

Thank you so much for your time!

<u>Code</u>

A=Channing revised
B=Channing regular
C= Telegraph (no treatment)
D= Telegraph (sharrow)
E= Telegraph (bike lane)
F= Telegraph (green shared lane)
G= Telegraph (green bike lane)
H= Telegraph (no parking cycletrack)
I = Telegraph (parking cycletrack)

Engagement Questions for CYCLING GROUP

First, I'd like to hear a little about your personal experience bicycling.

1. How often do you bicycle?

2. How many of you have close friends or family members who bicycle?

3. What sorts of trips do you make by bicycle, e.g., commute to work, shopping or errands, social trips, recreation?

4. When you cycle, do you tend to do so on the public roads, bike paths, or both? About how much of your cycling time would you say is on roads shared with traffic?

5. When you ride on public roads, do you try to ride on a quiet residential street (like this one – show photo A) or do you ride on whatever road is most direct and fastest, even if there is traffic (like this – show photo C)?

6. Who would you expect to be using the street in each of these cases (show photos A-I)?

7. Have you ever been in a bike crash? Was a motor vehicle involved, or did you have another sort of accident, e.g. fall? What about a near miss with a car?

8. Have you ever crashed with a cyclist or had a near miss with a cyclist while you were driving?

Exploration Questions

Now let's talk about your feelings about driving on the roadway with cyclists.

9. How do you feel when you drive near bicyclists on residential streets like this (show photo A) (e.g., confident, worried, etc.)? What about on streets with lots of traffic, such as this (show photo C)? Are there specific actions that bicyclists do to lead to those feelings? What about other drivers' actions?

10. How do you experience driving with bicycle traffic on roadways with bicycle lanes (show photo E) or bicycle shared lane markings (show photos D, B) versus roads without any lane markings (show photos A & C again)?

11. When you are approaching an intersection and need to make a turn, do you tend to look for bicyclists before turning, or perform other maneuvers to avoid them (e.g., speed up)?

12. How have past experiences bicycling influenced your opinions about bicyclists on the roadway? What about past experiences driving near bicyclists?

13. Have any of your friends or family had experiences driving near bicyclists or bicycling near drivers that strongly affect your opinions about bicyclists on the roadway?

14. What are some things that would make you feel more comfortable driving near bicyclists in urban areas?

15. If you knew that there would be proper enforcement, would you support a stop-as-yield law?

Exit Question

16. Is there anything else you would like to add about driving near bicyclists in urban areas?

Thank you so much for your time!

Appendix B – Internet Survey

WELCOME!

Thank you for taking our survey today! Your participation is crucial to helping us understand the experiences and perceptions associated with driving a car near bicyclists and bicycling in traffic on Bay Area streets. Your answers will help inform policies that could improve travel experiences for drivers and bicyclists throughout the Bay Area and beyond.

Your participation in this research is completely voluntary. There are no right or wrong answers to any questions on this survey, and you may skip or choose "decline to say" for any question you do not want to answer. If you are one of the first 500 respondents, you will be redirected to a separate form at the end of the survey where you can choose your $5 gift card (one entry per household). All responses received after the first 500 will be entered into a raffle for one of ten $5 gift cards. This information will not be tied to any of your survey responses. All information will be kept strictly confidential and will never be sold or used to contact you without your permission. The University's confidentiality policies were outlined in the consent form you received via your introductory email. If you'd like to review the form, click here. You can verify the authenticity of the study by contacting me via email at driversurvey@berkeley.edu.

For the entire survey, an asterisk (*) after a question indicates that a response is required. To navigate the survey, use the "next" and "back" buttons at the bottom of the page. If you have any technical problems or questions, please email driversurvey@berkeley.edu.

Do you consent to participate in this survey? By clicking Yes, you acknowledge that you received a copy of the consent form.*

a. Yes

b. No

Are you at least 18 years old as of the date of this survey?*

a. Yes

b. No

[If "no", the following message appears: "You must be at least 18 years old and agree to take the survey in order to qualify. If you received this message as a result of a technical error, please email driversurvey@berkeley.edu for a new link."]

Are you using a mobile phone to take this survey?*

a. Yes
b. No
c. Decline to say

[If "no" or "decline to say", the following message appears: "We do not recommend taking this survey on a mobile phone due to formatting issues. If you are using a mobile phone, please select "Yes" on the question above to be redirected to a mobile-specific version."]

In which of the following cities do you live?* *(Respondent chooses from drop-down menu.)*

Alameda
Albany
Antioch
Berkeley
Brentwood
Clayton
Concord
Danville
Dublin
El Cerrito
Emeryville
Fremont
Hayward
Hercules
Lafayette
Livermore
Martinez
Moraga
Newark
Oakland
Oakley
Orinda
Piedmont
Pinole
Pittsburg
Pleasant Hill
Pleasanton
Richmond
San Francisco
San Leandro
San Pablo
San Ramon
Union City
Vallejo
Walnut Creek
Decline to say
Other ______________________

DRIVING ON LOCAL STREETS

To begin the survey, please tell us about your experiences driving a car on city streets.

1. In the average week, how many days do you drive a car?*
    a. Four or more days per week *(skip to q3)*
    b. 1-3 days per week *(skip to q3)*
    c. Occasionally, but less than one day per week *(skip to q3)*
    d. Never
    e. Decline to say *(skip to q3)*

2. Do you have a current driver's license?
    a. Yes
    b. No

3. Based on your experiences driving a car on city streets, please rank the following concerns in terms of their importance for local transportation policy. Choose "1" for the most important and "7" for the least important. If two options are tied, rank them the same.

	1	2	3	4	5	6	7
Reduce driving under the influence							
Reduce stop sign & light running among bicyclists							
Reduce excessive driving speed							
Reduce aggressive driving							
Reduce distracted driving							
Reduce wrong-way riding among bicyclists							
Reduce jaywalking among pedestrians							

4. How often do you see bicyclists while driving a car on local streets?
    a. Always
    b. Usually
    c. About half the time
    d. Rarely
    e. Never

5. Please indicate how often you do the following things when driving a car.

	Always	Usually	About half the time	Occasionally	Never
I pass bicyclists with at least three feet of space.					
If I pass a bicyclist on the roadway, I check behind me for him/her before making a turn.					
When I park on the street, I check for bicyclists before opening my car door.					

6. Would you like to elaborate on any of your answers?

You have completed 12% of this survey.

YOUR OPINIONS ABOUT BICYCLING

On this page, we would like to know your thoughts about promoting bicycling in your city and among your friends and family..

7. Please indicate the extent to which you agree or disagree with the following statements.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I would like to see more people bicycling in my city.					
I support using public funding to encourage bicycling.					
I would be willing to accept a speed limit of 20 mph on city streets in order to encourage bicycling.					
I would support removing some car parking along major streets in order to accommodate a bicycle lane.					
If bicyclists ride on the road, they should stay on roads designated as bicycle routes.					
Bicycling should be restricted to off-street paths.					

8. Please indicate whether you agree or disagree with the following statements.

	Agree	Disagree
I would discourage my close friends or family members from considering bicycling to work/school or to run errands.		
I have close friends or family members who currently bicycle to work/school or run errands.		
I regularly see people I know riding their bicycles.		

9. Would you like to elaborate on any of your answers?

You have completed 20% of this survey.

YOUR THOUGHTS ON BICYCLE SAFETY

Now we would like to know your impressions of bicycle safety.

10. Please indicate the extent to which you agree or disagree with the following statements.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I feel anxious when I see bicyclists pulling children in a trailer.					
The biggest threat to a cyclist's safety is his or her actions.					
Bicycle markings on the street remind me that bicyclists may be present.					
I feel safer driving near bicyclists who follow traffic laws than those who do not.					
Bicyclists are safer riding on the sidewalk than on the street in busy areas.					

11. In general, how safe do you think it is to bicycle, drive, and walk on <u>neighborhood/residential streets</u> in your city?

	Very safe	Safe	Neutral	Unsafe	Very unsafe
Bicycling on the street					
Driving on the street					
Walking on the sidewalk					

12. In general, how safe do you think it is to bicycle, drive, and walk on <u>busy streets</u> in your city?

	Very safe	Safe	Neutral	Unsafe	Very unsafe
Bicycling on the street					
Driving on the street					
Walking on the sidewalk					

13. Would you like to elaborate on any of your answers?

You have completed 30% of this survey.

DRIVING NEAR BICYCLISTS

On this page, please tell us about your experiences driving a car near bicyclists on local roadways.

14. While driving, have you ever had to perform an evasive action (e.g., swerving, braking suddenly) to avoid hitting a bicyclist when it was your right of way?
    a. Yes
    b. No *(skip to q16)*

15. What happened? Circle all that apply.
    a. The cyclist ran a stop sign.
    b. The cyclist ran a red light.
    c. The cyclist was not using lights at night.
    d. The cyclist merged into your lane without looking or using a turn signal.
    e. The cyclist was traveling against the flow of traffic on the street.
    f. The cyclist rode unexpectedly off the sidewalk into the street.
    g. Other (please explain): ____

    ____

16. To your knowledge, have you ever done something that could have endangered a bicyclist while driving?
    a. Yes
    b. No *(skip to q18)*
    c. Decline to say

17. What happened? Circle all that apply.

a. I honked or yelled at him/her.

b. I passed the cyclist with fewer than 3 feet of space between us.

c. I merged into a lane and hit or almost hit him/her.

d. I tried to beat him/her to a turn and hit or almost hit him/her.

e. I blocked a bicycle lane while waiting for someone or while parking.

f. I hit or almost hit a cyclist while turning.

g. I did not let the bicyclist into my lane when he/she signaled to move over.

h. I purposefully drove aggressively around him/her.

i. I opened a car door after parking and hit or almost hit him/her.

j. Other (please explain):

____

____

18. When you drive on local streets (i.e., not the highway), how often do you do the following things?

	Always	Usually	About half the time	Occasionally	Never
Wear a seatbelt					
Use a turn signal to indicate turning or lane changing movements					
Proceed through a stop sign without coming to a complete stop					
Drive more than 5 miles above the speed limit					
Turn right on a red light without stopping completely					
Talk on a cell phone without a hands-free device					
Text on a cell phone					

19. (Hidden if person answered "yes" to q16): To your knowledge, have any of the following situations occurred while you have been driving near bicycle traffic? Check all that apply.
    a. I tried to beat a cyclist to a turn and hit or almost hit him/her.
    b. I passed a cyclist with fewer than 3 feet of space between us.
    c. I purposefully drove aggressively around a cyclist.
    d. I hit or almost hit a cyclist while turning.
    e. I blocked a bicycle lane while waiting for someone or while parking.
    f. I merged into a lane and hit or almost hit a cyclist.
    g. I did not let a bicyclist into my lane when he/she signaled to move over.
    h. I honked or yelled at a cyclist.
    i. I opened a car door after parking and hit or almost hit a cyclist.
    j. None of the above

20. Would you like to elaborate on any of your answers?

You have completed 42% of this survey.

BICYCLING ON LOCAL STREETS

Thank you for your participation thus far! After this page, you will have completed half of the survey. On this page, please tell us how often you bicycle.

21. Weather permitting, how often do you ride a bicycle to work/school or for errands?
    a. Daily *(skip to q23)*
    b. Several times per week *(skip to q23)*
    c. Several times per month *(skip to q23)*
    d. A few times per year *(skip to q23)*
    e. Less than once a year, but have ridden in the past
    f. Never

22. Would you consider bicycling to work/school or for errands in the near future?
    a. Yes
    b. No

23. Weather permitting, how often do you ride a bicycle for recreation?
    a. Daily *(skip to q25)*
    b. Several times per week *(skip to q25)*
    c. Several times per month *(skip to q25)*
    d. A few times per year *(skip to q25)*
    e. Less than once a year, but have ridden in the past
    f. Never

24. Would you consider bicycling for recreation in the near future?
    a. Yes
    b. No

25. Would you like to elaborate on any of your answers?

If respondent does not currently bicycle and would not consider bicycling in the future, skip to q37.

INFLUENCES ON THE DECISION TO BICYCLE

On this page, please tell us your opinions about influences on the decision to bicycle and how often you bicycle. *(This page hidden if respondent does not currently bicycle and would not consider doing so in the future.)*

26. (Hidden if respondent bicycles "daily" or "several times per week" for any purpose): Please indicate the degree to which the following statements influence your consideration of riding a bicycle for any purpose.

	Strongly influence	Somewhat influence	Slightly influence	Does not influence
I worry that drivers will drive too close to me while passing.				
I worry that drivers will cut me off while they are turning.				
I worry that drivers will be intentionally aggressive toward me while cycling.				
I worry that I'll be hit by someone opening a car door.				
I worry that I'll be hit by a driver who isn't paying attention to the road.				
I worry that I will make a mistake while bicycling that could endanger me or someone else.				
I am not balanced enough to ride a bike without falling.				
I worry that drivers will drive too fast near me while passing.				

Skip to 28

27. (Hidden unless respondent bicycles "daily" or "several times per week" for any purpose): As someone who bicycles regularly, please indicate how often you experience the following:

	Always	Usually	About half the time	Occasionally	Never
I worry that drivers will drive too close to me while passing.					
I worry that drivers will cut me off while they are turning.					
I worry that drivers will be intentionally aggressive toward me while bicycling.					
I worry that I'll be hit by someone opening a car door.					
I worry that I'll be hit by a driver who isn't paying attention to the road.					
I worry that I will make a mistake while bicycling that could endanger me or someone else.					
I worry that drivers will drive too fast while passing me.					

28. Please indicate the extent to which they influence your consideration of riding a bicycle to work/school or run errands.

	Always	Usually	About half the time	Occasionally	Never
Bicycling is physically uncomfortable due to local roadway quality.					
Lack of secure bicycle parking at my destination.					
There are no bicycle lanes or routes near enough for me to ride where I want to go.					
The weather where I live discourages me from bicycling.					
I would feel embarrassed if rode my bike other than for exercise.					
There are too many hills where I live.					
I do not own or have access to a bicycle.					
Bicycling is impractical for me because I need to carry things or people when I travel.					
My trip distance is too long to bicycle.					
I am concerned about my personal safety from crime.					

29. Are there things that worry you about or deter you from bicycling that are not listed in the questions above? If so, please elaborate.

You have completed 64% of this survey.

PERSONAL EXPERIENCE BICYCLING

Now we would like to hear about your experiences bicycling. *(This page hidden if respondent does not currently bicycle and would not consider doing so in the future.)*

30. *(Hidden unless respondent bicycles at least yearly for work or errands):* When you ride a bike for work/school or errands, where do you ride? Circle all that apply. *
    a. City streets without bicycle lanes, markings, or signage
    b. City streets with bicycle lanes, markings, and signage
    c. Off-street paths
    d. Other (please specify) ___________________________________
    e. Decline to say

31. *(Hidden unless respondent bicycles at least yearly for recreation):* When you ride a bike for recreation, where do you ride? Circle all that apply. *
    a. City streets without bicycle lanes, markings, or signage
    b. City streets with bicycle lanes, markings, and signage
    c. Off-street paths
    d. Other (please specify) ___________________________________
    e. Decline to say

32. Have any of the following situations occurred while you have been bicycling on city streets? Circle all that apply.
    a. A driver drove aggressively around you.
    b. A driver passed you with fewer than 3 feet of space between you and the car.
    c. A driver or passenger opened a door without looking and hit or almost hit you.
    d. A driver tried to beat you to a turn and hit or almost hit you.
    e. A driver did not let you into his/her lane when you signaled to move over.
    f. A driver honked or yelled at you when you had done nothing against the law.
    g. A driver merged into a lane and hit or almost hit you.
    h. A driver blocked a bicycle lane you were using while he/she was waiting for someone or parking.
    i. A driver hit or almost hit you while turning.
    j. Other (please explain) ____
    k. I have never bicycled on city streets.

33. Were you actually hit in any of the situations? If so, circle all that apply.

a. A driver drove aggressively around you.
b. A driver passed you with fewer than 3 feet of space between you and the car.
c. A driver or passenger opened a door without looking and hit or almost hit you.
d. A driver tried to beat you to a turn and hit or almost hit you.
e. A driver did not let you into his/her lane when you signaled to move over.
f. A driver honked or yelled at you when you had done nothing against the law.
g. A driver merged into a lane and almost hit you.
h. A driver blocked a bicycle lane you were using while he/she was waiting for someone or parking.
i. A driver hit or almost hit you while turning.
j. Other (please explain) ____
k. I have never been hit in any of these situations.

34. Do you ever bicycle after dark?

a. Yes
b. No
c. Decline to say

35. When you ride a bicycle, how often do you do the following things?

	Always	Usually	About half the time	Occasionally	Never
Wear a helmet					
Proceed through a stop sign without yielding to present traffic					
Use lights at night					
Proceed through a red light in the presence of cross traffic					
Bicycle against the flow of traffic					
Use hand signals to indicate turning or lane changing movements					
Bicycle on the sidewalk					
Wear reflective clothing at night					

36. Would you like to elaborate on any of your answers?

You have completed 70% of this survey.

PREFERENCES FOR ROADWAY DESIGN WHEN DRIVING AND BICYCLING

Please indicate how comfortable or uncomfortable you would feel driving a car in the presence of bicyclists and/or bicycling in traffic on each of the following roadways. Assume that the car traffic is traveling 25-30 mph. *(This section was optional for people who bicycle currently or would consider bicycling in the future, as they had a longer survey overall. Respondents who do not currently bicycle and would not consider bicycling in the future were only asked about their preferences as drivers. All photos randomized in this section.)*

37. How comfortable or uncomfortable would you feel driving and bicycling on the following roadway?

	Very comfortable	Moderately comfortable	Slightly comfortable	Neutral	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable
As a driver							
As a cyclist							

38. How comfortable or uncomfortable would you feel driving and bicycling on the following roadway?

	Very comfortable	Moderately comfortable	Slightly comfortable	Neutral	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable
As a driver							
As a cyclist							

39. How comfortable or uncomfortable would you feel driving and bicycling on the following roadway?

	Very comfortable	Moderately comfortable	Slightly comfortable	Neutral	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable
As a driver							
As a cyclist							

40. How comfortable or uncomfortable would you feel driving and bicycling on the following roadway?

	Very comfortable	Moderately comfortable	Slightly comfortable	Neutral	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable
As a driver							
As a cyclist							

41. How comfortable or uncomfortable would you feel driving and bicycling on the following roadway?

	Very comfortable	Moderately comfortable	Slightly comfortable	Neutral	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable
As a driver							
As a cyclist							

42. How comfortable or uncomfortable would you feel driving and bicycling on the following roadway?

	Very comfortable	Moderately comfortable	Slightly comfortable	Neutral	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable
As a driver							
As a cyclist							

43. How comfortable or uncomfortable would you feel driving and bicycling on the following roadway?

	Very comfortable	Moderately comfortable	Slightly comfortable	Neutral	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable
As a driver							
As a cyclist							

44. How comfortable or uncomfortable would you feel driving and bicycling on the following roadway?

	Very comfortable	Moderately comfortable	Slightly comfortable	Neutral	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable
As a driver							
As a cyclist							

45. Are there things you particularly like about any of these roadway designs?

46. Are there things you particularly do not like about any of these roadway designs?

OPINIONS ABOUT BICYCLE LANES

On this page, please answer the following question about your impressions of bicycle lanes. *(This section was optional for people who bicycle currently or would consider bicycling in the future, as they had a longer survey overall.)*

47. Please indicate your agreement or disagreement with the following statements about bicycle lanes.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Bike lanes tell drivers that bicyclists don't belong on non-bicycle routes.					
Bike lanes tell drivers to expect bicyclists on the roadway.					
Bike lanes make it more difficult for bicyclists to turn left.					
Bike lanes allow bicyclists to ride at their own pace.					
Bike lanes give bicyclists their own space.					
Bike lanes encourage drivers to drive closer to bicyclists.					
Bike lanes increase the chance of being hit by someone opening a car door.					
Bike lanes unnecessarily restrict fast bicyclists.					
Bike lanes make bicyclists more predictable on the roadway.					

OPINIONS ABOUT POTENTIAL BICYCLING LAWS

On this page, please tell us your opinions about potential changes to bicycling-related laws. Similar laws to these exist elsewhere in the U.S. and the world. *(All questions randomized on this page.)*

48. Currently, children under age 18 are required to wear bicycle helmets in California. Do you think adult bicyclists should also be required to wear helmets?
    a. Yes
    b. No opinion
    c. No

49. Would you support a law allowing bicyclists to yield (slow but not fully stop) at stop signs when no cross traffic were present? If traffic (e.g., a car or pedestrian) were present at the cross street, the bicyclist would be required to stop at the stop sign.
    a. Yes
    b. No opinion
    c. No

50. Would you support a law allowing bicyclists to proceed through a red light--after stopping completely--when no cross traffic were present? If traffic (e.g., a car or pedestrian) were present at the cross street, the bicyclist would be legally required to stop and wait until the light turned green or the traffic cleared.
    a. Yes
    b. No opinion
    c. No

51. Would you support a law allowing bicyclists to travel against the flow of traffic on a one-way street if a bicycle lane in the opposite direction of traffic were clearly marked?
    a. Yes
    b. No opinion
    c. No

52. Would you like to elaborate on any of your answers?

You have completed 75% of this survey.

TRAFFIC LAW IN CALIFORNIA

This page contains questions about some commonly misunderstood traffic laws in California. In order to gauge how well bicyclists and drivers know the current law, please answer these as you assume the law to be. *(All questions randomized on this page.)*

53. Which of the following driving rules also apply to bicyclists? Circle all that apply.

    a. Bicyclists are required to use hand signals when turning or merging lanes
    b. Bicyclists are required to bicycle with, not against, traffic
    c. Bicyclists are required to use lights after dark
    d. None of the above
    e. Don't know

54. Bicyclists are allowed to ride side-by-side (two abreast) when the vehicle lane is not wide enough to safely share with a car.

    a. True
    b. Don't know
    c. False

55. Bicyclists are required to ride in a bicycle lane if one is present, except in which of the following circumstances? Circle all that apply.

    a. When the bicyclist needs to overtake another, slower vehicle.
    b. When the bicyclist is able to travel the normal speed of traffic.
    c. When the bicyclist needs to leave the lane to avoid hazardous conditions, such as debris or an open car-door.
    d. When the bicyclist is preparing for a left-hand turn.
    e. Bicyclists must always ride in the bicycle lane.
    f. Bicyclists are never required to ride in a bicycle lane.
    g. Don't know

56. When a driver is making a right-hand turn from a street with a bicycle lane, she is required to pull into the bicycle lane before making the turn.
    a. True
    b. Don’t know
    c. False

57. Would you like to elaborate on any of your answers?

You have completed 80% of this survey.

FINAL QUESTIONS

Please answer these final questions about your experience as a driver and a bicyclist.

58. How long have you lived in your current city?
    a. Less than 1 year
    b. 1-3 years
    c. More than 3 years

59. Are there any bicycle lanes or routes in your city?*
    a. Yes
    b. No *(skip to q61)*
    c. Don't know *(skip to q61)*

60. How close is the nearest bicycle lnae or bicycle route to your home?
    a. Within a few blocks
    b. Between a few blocks and one mile
    c. Between 1 and 2 miles
    d. Over 2 miles

61. For mapping purposes only: please list the closest intersection to your house (e.g., Spruce St. & Oak Ln).

    ____

62. Have you ever lived in a city where bicycling was more common than where you live now?
    a. Yes
    b. No

63. In which U.S. state did you learn to drive or get your first US driver's license? (*Choose from drop-down menu.)*

Have international driver's license
Alabama
Alaska
American Samoa
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
District of Columbia
Federated States of Micronesia
Florida
Georgia
Guam
Hawaii
Idaho
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Marshall Islands
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Montana
Nebraska
Nevada
New Hampshire
New Jersey
New Mexico
New York
North Carolina
North Dakota
Northern Mariana Islands
Ohio
Oklahoma
Oregon
Pennsylvania
Puerto Rico
Rhode Island
South Carolina
South Dakota
Tennessee
Texas
Utah
Vermont
Virgin Islands
Virginia
Washington
West Virginia
Wisconsin
Wyoming

64. Did your driver's education class cover bicycling?

    a. Yes
    b. No
    c. Don't remember
    d. Didn't take driver's ed

65. Have you ever taken a class specifically on bicycling safety?

    a. Yes
    b. No

66. Have you or any of your family members or close friends ever crashed with a motor vehicle while bicycling?

    a. Yes
    b. No *(skip to q68)*
    c. Don't know *(skip to q68)*
    d. Decline to say *(skip to q68)*

67. Was anyone seriously injured (requiring hospitalization) or killed as a result of the crash?

    a. Yes: the bicyclist
    b. Yes: the driver
    c. Yes: the cyclist and the driver
    d. No
    e. Don't know

68. Have you or any of your family members or close friends ever crashed with a bicyclist while driving a car?

    a. Yes
    b. No *(skip to q70)*
    c. Don't know *(skip to 70)*
    d. Decline to say *(skip to q70)*

69. Was anyone seriously injured (requiring hospitalization) or killed as a result of the crash?

a. Yes: the bicyclist
b. Yes: the driver
c. Yes: the cyclist and the driver
d. No
e. Don't know

70. If you could change one thing about how drivers and bicyclists share Bay Area roads, what would it be?

71. Would you like to elaborate on any of your answers?

You have completed 92% of this survey.

DEMOGRAPHIC INFORMATION

You made it to the last page! Please answer these final questions to help us understand how our survey responses may be applicable to the general population.

72. What is your gender?*

a. Male
b. Female
c. Other (please identify) ___________________________________
d. Decline to say

73. Which of the following best describes your age range?*

a. 18-24
b. 25-29
c. 30-34
d. 35-39
e. 40-44
f. 45-49
g. 50-54
h. 55-59
i. 60-64
j. 65-69
k. 70-74
l. 75-79
m. 80-84
n. 85 or older
o. Decline to say

74. Do you have any children?

a. Yes
b. No *(skip to q77)*
c. Decline to say *(skip to q77)*

75. How many of your children are under age 16?

    a. 0
    b. 1 child
    c. 2 children
    d. 3 children
    e. 4 or more children

76. Do any of your children bicycle on the street or sidewalk?

    a. Yes
    b. No

77. Are you a member of or associated with any organizations that advocate for Bay Area bicyclists?

    a. Yes
    b. No
    c. Decline to say

78. How do you identify yourself racially and ethnically? Circle all that apply.

    a. Asian
    b. American Indian or Alaska Native
    c. Black or African American
    d. Native Hawaiian or Other Pacific Islander
    e. Hispanic or Latino
    f. White or Caucasian
    g. Other (please specify) ______________________________________
    h. Decline to say

79. Which of the following best represents your pre-tax household income (i.e., you and your spouse/partner, if applicable)?
    a. Less than $15,000
    b. $15,000 - $34,999
    c. $35,000 - $49,999
    d. $50,000 - $74,999
    e. $75,000 - $100,000
    f. $100,000 - $149,999
    g. $150,000 - $199,999
    h. $200,000 or more
    i. Decline to say

80. Is there anything you would like to add before completing the survey?

Thank you so much for taking our survey! Your response is very important to us. Click (hyperlink to separate online survey form) to enter your information and choose your $5 gift card. When you enter your information, you can also indicate your willingness to participate in future research exploring the results of the survey.

*Please note that you will receive survey reminders if you do not fill out the gift card form. This is because the anonymity of the survey ensures that I do not know that you've completed the survey unless you list your email address. I apologize for this inconvenience. If you do not want a gift card or to be contacted for future research, you can indicate both of those on the form.

Appendix C –Variable Information

Table C1. Summary Statistics of Variables in Dataset

Variable Name	Description	Range	Mean	Std. Dev	# Obs
General Information & Driving Habits					
rept_city	Self-reported home city				
r_city	encoded version of reported home city	3-67			457
city	all cities with pop > 5 in my survey, rest coded to county				
county					457
freq_dr	How frequently one drives (categories of times per week)	0-3	2.52	0.73	462
drv_daily	1=drives 4+ days/week	0-1	0.64	0.48	463
drv_1_3	1=drives 1-3 days/week	0-1	0.26	0.44	463
driv_weekly	1=drives at least once/week	0-1	0.90	0.30	463
dl	have driver's license	0-1	0.99	0.08	463
freq_seebik	How often do you see bicyclists while driving on city streets?	1-5	4.24	0.91	450
Transportation priorities					
red_drunk	priority reduce drunk driving (1 for most important, 7 for least important)	1-7	2.78	2.05	449
red_agg	priority reduce aggressive driving	1-7	3.03	1.83	450
red_spd	priority reduce speeding	1-7	3.33	1.85	448
red_dist	priority reduce distracted driving	1-7	2.75	1.89	449
red_run	priority reduce cyclists' stop sign and red-light running	1-7	3.93	2.04	446
red_ww	priority reduce cyclists' wrong-way riding	1-7	4.45	1.99	443
red_jay	priority reduce jaywalking	1-7	4.41	2.05	446
Driver Behavior					
chk_turn	If I pass a bicyclist on the roadway, I check behind me for him/her before making a turn.	1-5	4.62	0.78	451
pass_3	I pass bicyclists with at least three feet of space.	1-5	4.30	0.83	449

Variable Name	Description	Range	Mean	s.d.	# obs
chk_pk	When I park on the street, I check for bicyclists before opening my car door.	1-5	3.96	1.19	448
awaredriver	additive varb from aware driving behav (check for cyclist while turning, check when parking, pass by three feet) varb	1-5	4.29	0.69	447
stblt	Wear a seatbelt	1-5	4.95	0.27	451
turn_sig	Use your turn signal to indicate turning or lane changing movements	1-5	4.71	0.54	447
comp_stp	Proceed through a stop sign without coming to a complete stop	1-5	1.86	1.00	443
ovr_lim	Drive more than 5 miles above the speed limit	1-5	2.77	0.99	446
ror	Turn right on a red light without stopping completely	1-5	1.68	0.84	444
talk_cell	Talk on a cell phone without a hands-free device	1-5	1.56	0.75	446
text_cell	Text on a cell phone	1-5	1.38	0.64	444
safedriver	additive varb from safe driving (wear seatbelt, use turn sig, come to complete stop, alt_speed, alt_talk on cell, alt_text on cell, alt_right on red) behav varb/divided by # varb	1-5	4.02	0.32	429
carefuldriver	additive varb from careful driving behav (count of number of things driver has done from endanger varb)	0-5	0.69	0.85	463
Support for Cycling					
mor_bik	I would like to see more people bicycling in my city.	1-5	3.87	1.04	460
fund_bik	I support using public funding to encourage bicycling.	1-5	3.70	1.19	463
low_spd	I would be willing to accept a speed limit of 20 mph on city streets in order to encourage bicycling.	1-5	2.63	1.25	458
rmv_pkg	I would support removing some car parking along major streets in order to accommodate a bicycle lane.	1-5	3.22	1.34	463

Variable Name	Description	Range	Mean	s.d.	# obs
bik_desrt	If bicyclists ride on the road, they should stay on roads designated as bicycle routes.	1-5	3.10	1.37	461
bik_offst	Bicycling should be restricted to off-street paths.	1-5	2.25	1.18	461
bik_supp	additive varb composed of (fund_bik, mor_bik, low_spd, rmv_pkg, alt_bikdesrt, alt_bikoffst)	6-30	20.08	5.16	454
neg_funding	0 if (strongly) disagree with public funding for cycling; else, 1	0-1	0.18	0.39	463
neg_morbik	0 if (strongly) disagree with wanting more cycling in one's city; else, 1	0-1	0.09	0.28	463
neg_lowspd	0 if (strongly) disagree with supporting 20 mph streets; else, 1	0-1	0.54	0.50	463
neg_rmvpkg	0 if (strongly) disagree with removing parking to allow space for a bike lane; else, 1	0-1	0.37	0.48	463
neg_bikdesrt	0 if (strongly) disagree with bikes belonging only on designated routes; else, 1	0-1	0.41	0.49	463
neg_bikoffst	0 if (strongly) disagree with bikes needing to ride only offstreet; else, 1	0-1	0.65	0.48	463
Bike Network					
disc_bik	I would discourage my close friends or family members from considering bicycling to work/school or to run errands.	0-1	0.14	0.35	462
ff_bik	I have close friends or family members who currently bicycle to work/school or to run errands.	0-1	0.68	0.47	463
know_bik	I regularly see people I know riding their bicycles.	0-1	0.52	0.50	462
netwk_bik	composite score for (alt_dis_bik, ff_bik, know_bik)	0-3	2.06	0.92	461
Beliefs about Bike Safety					
bik_pres	Bicycle markings on the street remind me that bicyclists may be present.	1-5	4.16	0.82	461

Variable Name	Description	Range	Mean	s.d.	# obs
safer_laws	I feel safer driving near bicyclists who follow traffic laws than those who do not.	1-5	4.45	0.70	462
anx_trail	I feel anxious when I see bicyclists pulling children in a trailer.	1-5	3.39	1.23	462
bik_safsw	Bicyclists are safer riding on the sidewalk than on the street in busy areas.	1-5	2.90	1.27	462
bik_sdang	The biggest threat to a cyclist's safety is his or her actions.	1-5	3.34	1.16	462
drv_biksafety	composite score for safer_laws, anx_trail, bik_safsw, bik_sdang)	4-20	14.1	2.66	461
neut_bikpres	0 if neut or (strongly) disagree that bike lanes tell drivers that bikes might be present; else, 1	0-1	0.14	0.35	463
mk_bikpres	0 if (strongly) disagree that bike lanes tell drivers that bikes might be present; else, 1	0-1	0.95	0.22	463
Beliefs about One's Own Safety while Traveling					
bik_res	Bicycling on the street	1-5	3.88	0.89	463
drv_res	Driving on the street	1-5	4.20	0.71	461
wlk_res	Walking on the sidewalk	1-5	4.36	0.74	460
bik_com	Bicycling on the street	1-5	2.78	1.02	462
drv_com	Driving on the street	1-5	3.77	0.79	463
wlk_com	Walking on the sidewalk	1-5	4.02	0.83	460
lowval_bikres	1 if feel (very) unsafe bicycling on residential streets; else, 1	0-1	0.09	0.29	463
Driver Interactions with Cyclists					
evade	While driving, have you ever had to perform an evasive action (e.g., swerving, braking suddenly) to avoid hitting a bicyclist when it was your right of way?	0-1	0.63	0.48	451
bik_ranss	The cyclist ran a stop sign.	0-1	0.35	0.48	453
bik_ranrl	The cyclist ran a red light.	0-1	0.26	0.44	453

Variable Name	Description	Range	Mean	s.d.	# obs
bik_nlt	The cyclist was not using lights at night.	0-1	0.15	0.36	453
bik_nlk	The cyclist merged into your lane without looking or using a turn signal.	0-1	0.36	0.48	453
bik_ww	The cyclist was traveling against the flow of traffic on the street.	0-1	0.16	0.37	453
bik_sw	The cyclist rode unexpectedly off the sidewalk into the street.	0-1	0.21	0.41	453
ct_evade	count of number of categories for which a driver has had to evade a cyclist	0-6	1.50	1.69	453
endang_bik	To your knowledge, have you ever done something that could have endangered a bicyclist while you were driving?	0-1	0.30	0.46	446
driver_notadmit	count of number of categories a driver has endangered a cyclist without realizing it	0-6	0.83	0.96	320
driv_endang	has driver ever endangered a cyclist (both those who admitted and those who answered follow-up question)? (yes=1, no=0)	0-1	0.67	0.47	453
door_hit_3	whether driver has ever hit cyclist with car door	0-1	0.15	0.36	453
pass_clos_3	whether driver has ever passed a cyclist with fewer than 3 feet	0-1	0.37	0.48	453
beat_turn_3	whether driver has ever tried to beat a cyclist to a turn	0-1	0.02	0.15	453
block_bl_3	whether driver has ever blocked bike lane	0-1	0.20	0.40	453
disal_mg_3	whether driver has ever not let cyclist merge when he signaled to come over	0-1	0.00	0.05	453
honk_3	whether driver has ever honked at cyclist when cyclist did nothing wrong	0-1	0.13	0.33	453
mg_hit_3	whether driver has ever merged and hit/almost hit cyclist	0-1	0.04	0.18	453
purp_agg_3	whether driver has ever driven purposefully aggressively around cyclist	0-1	0.03	0.17	453
turn_hit_3	whether driver has ever hit a cyclist while (driver was) turning	0-1	0.10	0.30	453

Variable Name	Description	Range	Mean	s.d.	# obs
Bicycling Frequency					
freq_bik_util	Weather permitting, how often do you ride a bicycle to work/school or for errands? (0=never, 1=less than once year, but have ridden in past, 2=few times/year, 3=sev times/month, 4=sev times/week, 5=daily)	0-5	1.53	1.64	463
bik_util_fut	Would you consider bicycling to work/school or for errands in the near future?	0-1	0.51	0.50	261
freq_bik_rec	Weather permitting, how often do you ride a bicycle for recreation? (0=never, 1=less than once year, but have ridden in past, 2=few times/year, 3=sev times/month, 4=sev times/week, 5=daily)	0-5	1.73	1.31	463
bik_rec_fut	Would you consider bicycling for recreation in the near future?	0-1	0.75	0.43	199
never_bik	1=never bike for rec or util; 2=never bike util, but bike rec < 1x/year; 3=never bike rec, but bike util < 1x/year; 4=bike util and rec less than once/year	1-4	1.85	1.16	190
bik_freq	Frequency of bicycling for either util or rec	0-5	2.01	1.55	463
subset	Non-EBBC folks	1-5			
bik_month	Person bikes a few times/month	0-1	0.15	0.36	463
bik_week	Person bikes a few times/week (same as freq_cyclist)	0-1	0.22	0.41	463
bik_year	Person bikes a few times/year	0-1	0.22	0.41	463
noncyclist	Person hasn't biked in over a year	0-1	0.41	0.49	463
never_cyclist	Person who hasn't biked in over a year and wouldn't consider biking again in the future	0-1	0.10	0.30	463
pot_cyclist	Person hasn't biked in over a year, but would be willing to bike in the future	0-1	0.31	0.46	463
infreq_cyclist	Person bikes yearly, but not weekly	0-1	0.37	0.48	463
freq_cyclist	Person bikes weekly (same as bik_week)	0-1	0.22	0.41	463

Variable Name	Description	Range	Mean	s.d.	# obs
cyclist_type	noncylist, occasional, regular cyclist	0-2	0.81	0.77	463
cyclist_type2	noncylist, yearly, monthly, and weekly cyclist	0-3	1.18	1.19	463
cyclist_type3	noncyclist, potential, yearly, monthly, weekly/daily	0-4	2.09	1.32	463
cyclist_type4	noncyclist, potential, yearly, monthly, weekly, daily	0-5	2.14	1.41	463
cyclist_type5	noncyclist, potential who never bikes, potential who bikes <1x/yr, yearly, monthly, weekly, daily	0-6	2.89	1.72	463
never_bik_bin	1=those who never bike at all	0-1	0.23	0.42	463
like_bike	either currently bike or would consider biking again	0-1	0.90	0.30	463
bik_wk_month	0=non, potential, and yearly; 1=monthly, weekly, daily	0-1	0.37	0.48	463
Perceived Traffic Risk while Cycling					
w_close	I worry that drivers will drive too close to me while passing (potential & infrequent cyclists)	1-4	2.56	1.11	313
w_cut	I worry that drivers will cut me off while they are turning (potential & infrequent cyclists)	1-4	2.44	1.16	312
w_mistk	I worry that I will make a mistake while bicycling that could endanger me or someone else (potential & infrequent cyclists)	1-4	2.05	1.10	312
w_door	I worry that I'll be hit by someone opening a car door (potential & infrequent cyclists)	1-4	2.19	1.06	314
nobal	I am not balanced enough to ride a bike without falling (potential & infrequent cyclists)	1-4	1.34	0.75	310
w_attn	I worry that I'll be hit by a driver who isn't paying attention to the road (potential & infrequent cyclists)	1-4	2.77	1.11	314
w_agg	I worry that drivers will be intentionally aggressive toward me while bicycling (potential & infrequent cyclists)	1-4	2.08	1.11	311
w_fast	I worry that drivers will drive too fast near me while passing (potential & infrequent cyclists)	1-4	2.54	1.15	310

Variable Name	Description	Range	Mean	s.d.	# obs
w_fast_2	I worry that drivers will drive too fast while passing me (frequent cyclists)	1-5	2.64	1.29	94
w_cut_2	I worry that drivers will cut me off while they are turning (frequent cyclists)	1-5	3.25	1.31	92
w_mistk_2	I worry that I will make a mistake while bicycling that could endanger me or someone else (frequent cyclists)	1-5	2.44	1.21	94
w_door_2	I worry that I'll be hit by someone opening a car door (frequent cyclists)	1-5	3.27	1.24	94
w_attn_2	I worry that I'll be hit by a driver who isn't paying attention to the road (frequent cyclists)	1-5	3.41	1.18	95
w_agg_2	I worry that drivers will be intentionally aggressive toward me while bicycling (frequent cyclists)	1-5	2.44	1.25	94
w_close_2	I worry that drivers will drive too close to me while passing (frequent cyclists)	1-5	3.04	1.21	94
w_safety	additive varb of perceived safety among infrequent & potential cyclists	6-24	14.6	5.66	298
w_safety_2	additive varb of perceived safety among frequent cyclists	8-30	18.1	6.19	92
strong_worry	1 if person is strongly/always worried about any potential worry; else, 0	0-1	0.44	0.50	418
num_strongworry	count of number of worries person lists as strong	0-7	1.41	2.08	418
ave_worry	average worry score for all cyclist types (missing values for any aspect render the entire score missing)	1-5	2.41	0.92	382
sw_close	1 if person strongly worried about driver coming too close	0-1	0.20	0.40	463
sw_fast	1 if person strongly worried about driver driving too fast nearby	0-1	0.21	0.41	463
sw_cut	1 if person strongly worried about driver cutting him off while turning	0-1	0.21	0.40	463
sw_mistk	1 if person strongly worried about making mistake	0-1	0.11	0.31	463
sw_door	1 if person strongly worried about someone opening car door in path	0-1	0.14	0.35	463
sw_attn	1 if person strongly worried about driver not paying attention	0-1	0.28	0.45	463

Variable Name	Description	Range	Mean	s.d.	# obs
sw_agg	1 if person strongly worried about driver being too aggressive	0-1	0.12	0.33	463
bar_wfast	0 if worrying about drivers driving fast near you has no or slight influence; 1 if some or strong influence	0-1	0.53	0.50	310
bar_wclose	0 if worrying about drivers driving fast near you has no or slight influence; 1 if some or strong influence	0-1	0.54	0.50	313
bar_wcut	0 if worrying about drivers driving fast near you has no or slight influence; 1 if some or strong influence	0-1	0.50	0.50	312
bar_wdoor	0 if worrying about drivers driving fast near you has no or slight influence; 1 if some or strong influence	0-1	0.39	0.49	314
bar_wattn	0 if worrying about drivers driving fast near you has no or slight influence; 1 if some or strong influence	0-1	0.61	0.49	314
bar_wagg	0 if worrying about drivers driving fast near you has no or slight influence; 1 if some or strong influence	0-1	0.35	0.48	311
bar_wmistk	0 if worrying about drivers driving fast near you has no or slight influence; 1 if some or strong influence	0-1	0.36	0.48	312
wsafety_potcyclist	interaction between wsafety & potential cyclist	0-24	4.45	7.58	454
wsafety_yearcyclist	interaction between wsafety & yearly cyclist	0-24	2.88	6.17	454
wsafety_monthcyclist	interaction between wsafety & monthly cyclist	0-24	2.08	5.48	454
wsafety_weekcyclist	interaction between wsafety & weekly/daily cyclist	0-24	3.60	7.73	454
w_fast_32	combination of worry fast for all groups				
Non-Risk Related Barriers to Bicycling					
bik_uncomf	Bicycling is physically uncomfortable due to local roadway quality.	1-5	1.99	1.15	408
long_dist	My trip distance is too long to bicycle.	1-5	3.23	1.48	410

Variable Name	Description	Range	Mean	s.d.	# obs
no_bl	There are no bicycle lanes or routes near enough for me to ride where I want to go.	1-5	2.27	1.34	409
embar	I would feel embarrassed if I rode my bike other than for exercise.	1-5	1.27	0.78	410
hills	There are too many hills where I live.	1-5	2.44	1.42	411
weather	The weather where I live discourages me from bicycling.	1-5	1.95	0.92	408
bik_imprac	Bicycling is impractical for me because I need to carry things or people when I travel.	1-5	3.20	1.29	412
no_secpk	Lack of secure bicycle parking at my destination.	1-5	2.39	1.34	410
no_bik	I do not own or have access to a bicycle.	1-5	2.07	1.63	409
pers_sfty	I am concerned about my personal safety from crime.	1-5	2.01	1.22	409
barriers	combined varb of all the non-safety barriers	10-50	22.7	6.85	388
bar_nobl	0 if no bike lane is never or only occasionally a barrier; else, 1	0-1	0.35	0.48	409
bar_embar	0 if feeling embarrassed is never or only occasionally a barrier; else, 1	0-1	0.06	0.24	410
bar_hills	0 if hills are never or only occasionally a barrier; else, 1	0-1	0.39	0.49	411
bar_weather	0 if weather is never or only occasionally a barrier; else, 1	0-1	0.22	0.41	408
bar_imprac	0 if the impracticality of bicycling is never or only occasionally a barrier; else, 1	0-1	0.66	0.48	412
bar_secpk	0 if not having secure bike parking is never or only occasionally a barrier; else, 1	0-1	0.37	0.48	410
bar_persfty	0 if personal safety is never or only occasionally a barrier; else, 1	0-1	0.26	0.44	409

Variable Name	Description	Range	Mean	s.d.	# obs
bar_uncomf	0 if feeling uncomfortable because of roadway quality is never or only occasionally a barrier; else, 1	0-1	0.26	0.44	408
bar_dist	0 if long distance is never or only occasionally a barrier; else, 1	0-1	0.62	0.49	410
bar_nobik	0 if not having a bike never, only occasionally, or half the time a barrier; else, 1	0-1	0.25	0.44	409
Where Respondent Bicycles					
ut_wbl	City streets with bicycle lanes, markings, and signage	0-1	0.37	0.48	463
ut_wobl	City streets without bicycle lanes, markings, or signage	0-1	0.36	0.48	463
ut_offst	Off-street paths	0-1	0.23	0.42	463
ut_oth	Other	0-1	0.03	0.18	463
ut_decl	Decline to say	0-1	0.00	0.05	463
rec_wbl	City streets with bicycle lanes, markings, and signage	0-1	0.39	0.49	463
rec_wobl	City streets without bicycle lanes, markings, or signage	0-1	0.37	0.48	463
rec_offst	Off-street paths	0-1	0.44	0.50	463
rec_oth	Other	0-1	0.09	0.28	463
rec_decl	Decline to say	0-1	0.00	0.07	463
Cyclists' Self-Reported Negative Experiences with Drivers					
bsr_pass3_bo	A driver passed you with fewer than 3 feet of space between you and the car.	0-1	0.64	0.48	273
bsr_beat_turn_bo	A driver tried to beat you to a turn and hit or almost hit you.	0-1	0.23	0.42	273
bsr_blkln_bo	A driver blocked a bicycle lane you were using while he/she was waiting for someone or parking.	0-1	0.53	0.50	273
bsr_blkmg_bo	A driver did not let you into his/her lane when you signaled to move over.	0-1	0.25	0.43	273

Variable Name	Description	Range	Mean	s.d.	# obs
bsr_agg_bo	A driver drove aggressively around you.	0-1	0.42	0.49	273
bsr_honk_bo	A driver honked or yelled at you when you had done nothing against the law.	0-1	0.40	0.49	273
bsr_drvmg_bo	A driver merged into a lane and hit or almost hit you.	0-1	0.31	0.46	273
bsr_hit_turn_bo	A driver hit or almost hit you while turning.	0-1	0.41	0.49	273
bsr_oth_bo	Other incident resulting in a near miss	0-1	.08	0.27	273
bsr_door_bo	A driver or passenger opened a car door without looking and hit or almost hit you.	0-1	0.45	0.50	273
bsr_nobik_bo	I have never bicycled on city streets.	0-1	0.06	0.24	273
never_hit_bo	I have never been hit in any of these situations.	0-1	0.59	0.49	273
hit_pass3_bo	A driver passed you with fewer than 3 feet of space between you and the car.	0-1	0.02	0.15	273
hit_beat_turn_bo	A driver tried to beat you to a turn and hit or almost hit you.	0-1	0.03	0.17	273
hit_blkln_bo	A driver blocked a bicycle lane you were using while he/she was waiting for someone or parking.	0-1	0.01	0.12	273
hit_blkmg_bo	A driver did not let you into his/her lane when you signaled to move over.	0-1	0.01	0.09	273
hit_agg_bo	A driver drove aggressively around you.	0-1	0.02	0.13	273
hit_honk_bo	A driver honked or yelled at you when you had done nothing against the law.	0-1	0.02	0.15	273
hit_drvmg_bo	A driver merged into a lane and hit or almost hit you.	0-1	0.04	0.20	273
hit_turn_bo	A driver hit or almost hit you while turning.	0-1	0.08	0.27	273
hit_oth_bo	Other incident resulting in a collision	0-1	0.04	0.21	273
hit_door_bo	A driver or passenger opened a car door without looking and hit or almost hit you.	0-1	0.06	0.24	273

Variable Name	Description	Range	Mean	s.d.	# obs
hit	ever been hit in the instances I asked about? Only asked of those who bike at least once/year	0-1	0.20	0.40	273
nearmiss	ever had a near miss in the instances I asked about? Only asked of those who bike at least once/year	0-1	0.86	0.34	273
ct_hit	number of categories the person has experienced at least one hit (additive of all categories)	0-9	0.33	0.95	273
ct_nearmiss	number of categories the person has experienced at least near miss (additive of all categories)	0-10	3.73	3.05	273
Bicycle Behavior					
bik_dark	Do you ever bicycle after dark?	0-1	0.62	0.49	272
bsr_lts	Use lights at night	1-5	3.78	1.57	263
bsr_reflect	Wear reflective clothing at night	1-5	2.48	1.50	261
bsr_runss	Proceed through a stop sign without yielding to present traffic	1-5	1.53	0.78	269
bsr_runrl	Proceed through a red light in the presence of cross traffic	1-5	1.33	0.74	270
bsr_helmet	Wear a helmet	1-5	4.14	1.39	273
bsr_sw	Bicycle on the sidewalk	1-5	2.10	0.89	269
bsr_ww	Bicycle against the flow of traffic	1-5	1.54	0.76	268
bsr_turnsig	Use hand signals to indicate turning or lane changing movements	1-5	3.38	1.27	271
safecyclist	additive varb from safe cycling behav (use lights, wear reflective clothing, alt_run stop sign, alt_run red light, alt_ride wrong way, helmet, use turnsig) varb, divided by # varb added	1-5	3.91	0.60	249
safecyclist2	additive varb from safe cycling behav (use lights, wear reflective clothing, alt_run stop sign, alt_run red light, alt_ride wrong way, helmet, use turnsig) varb	7-35	27.34	4.22	249

Variable Name	Description	Range	Mean	s.d.	# obs
Opinions about Laws					
req_helmet	Currently, children under age 18 are required to wear bicycle helmets in California. Do you think adult bicyclists should also be required to wear helmets?	0-2	1.41	0.83	462
no_helmet	1=don't think that people should be required to wear helmets	0-1	0.22	0.42	463
dk_helmet	not sure about people being required to wear helmets	0-1	0.15	0.35	463
stop_yld	Would you support a law allowing bicyclists to yield at stop signs when no cross traffic were present?	0-2	1.43	0.87	462
y_stop_yld	agree with law to change stop sign to yield	0-1	0.68	0.47	463
red_stop	Would you support a law allowing bicyclists to proceed through a red light--after stopping completely--when no cross traffic were present?	0-2	1.04	0.98	462
y_red_stop	agree with law to change red light to stop sign	0-1	0.49	0.50	463
y_Idaho	agree with stop as yield and red as stop (missing values for this question were counted as 0, as everyone got this question)	0-1	0.45	0.50	463
contra_flow	Would you support a law allowing bicyclists to travel against the flow of traffic on a one-way street?	0-2	0.95	0.88	37
Knowledge of Traffic Laws					
law_wtraf	Bicyclists are required to bicycle with, not against, traffic	0-1	0.80	0.40	463
law_handsig	Bicyclists are required to use hand signals when turning or merging lanes	0-1	0.81	0.39	463
law_lights	Bicyclists are required to use lights after dark	0-1	0.78	0.41	463
law_none	None of the above	0-1	0.02	0.13	463
law_dk	Don't know	0-1	0.07	0.26	463

Variable Name	Description	Range	Mean	s.d.	# obs
law_2abrst	Bicyclists are allowed to ride side-by-side (two abreast) when the vehicle lane is not wide enough to safely share with a car.	0-2	0.80	0.74	461
y_2abrst	1=bicyclists are allowed to ride two abreast	0-1	0.19	0.39	461
law_trafspd	When the bicyclist is able to travel the normal speed of traffic	0-1	0.07	0.25	463
law_lturn	When the bicyclist is preparing for a left-hand turn	0-1	0.57	0.50	463
law_ovtk	When the bicyclist needs to overtake another, slower vehicle	0-1	0.23	0.42	463
law_debris	When the bicyclist needs to leave the lane to avoid hazardous conditions, such as debris or an open car door	0-1	0.57	0.50	463
law_always	Bicyclists must always ride in the bicycle lane	0-1	0.05	0.23	463
law_never	Bicyclists are never required to ride in a bicycle lane	0-1	0.11	0.32	463
law_bl_dk	Don't know	0-1	0.19	0.39	463
knows_bllaw	interval varb measuring how many segments of the law respondent knew	0-4	1.44	1.26	463
knows_ridinglaw	interval varb measuring how many segments of the law respondent knew	0-3	2.40	0.95	462
drv_bl_turn	When a driver is making a right-hand turn from a street with a bicycle lane, she is required to pull into the bicycle lane before making the turn.	0-2	1.08	0.85	463
drv_blturn_bin	1 = knows driver should pull into bike lane before making right turn; else, 0	0-1	0.40	0.49	463
knows_laws	1=knows laws about driver, bike lanes, and bicycling; else, 0	0-3	1.08	0.75	463
Geographic Questions & Miscellaneous					
long_city	How long have you lived in your current city?	1-3	2.53	0.67	459

Variable Name	Description	Range	Mean	s.d.	# obs
bl_incity	Are there any bicycle lanes or bicycle routes in your city?	0-2	1.80	0.52	463
bl_incity2	1 = yes, 0 = no or don't know	0-1	0.86	0.35	463
clos_bl_home	How close is the nearest bicycle lane or bicycle route to your home?	1-4	1.47	0.82	392
bl_less1mi	1 if bike lane less than 1 mi away from home; else, 0	0-1	0.87	0.34	392
bl_fewblocks	1 if bike lane within a few blocks of home; else, 0	0-1	0.70	0.46	392
city_morbik	Have you ever lived in a city where bicycling was more common than where you live now?	0-1	0.94	0.24	422
bky	1=live in Berkeley (self report)	0-1	0.16	0.37	463
SF	1=live in San Francisco (self report)	0-1	0.16	0.37	463
OAK	1=live in Oakland (self report)	0-1	0.21	0.40	463
AlCo	1=live in Alameda County (self report)	0-1	0.49	0.50	463
CCC	1=live in Contra Costa County (self report)	0-1	0.20	0.40	463
SMC	1=live in San Mateo County (self report)	0-1	0.03	0.17	463
SolC	1=live in Solano County (self report)	0-1	0.06	0.24	463
SCC	1=live in Santa Clara County (self report)	0-1	0.01	0.08	463
YoloCo	1=live in Yolo County (self report)	0-1	0.00	0.05	463
SacC	1=live in Sacramento County (self report)	0-1	0.00	0.07	463
PlacerC	1=live in Placer County (self report)	0-1	0.00	0.05	463
NapaC	1=live in Napa County (self report)	0-1	0.00	0.07	463
MarinC	1=live in Marin County (self report)	0-1	0.02	0.12	463
MontC	1=live in Monterey County (self report)	0-1	0.00	0.05	463
unincorp	1=live in unincorporated area (self report)	0-1	0.01	0.10	463
BOSF	1=live in Berkeley, Oakland, or San Francisco (self report)	0-1	0.52	0.50	463

Variable Name	Description	Range	Mean	s.d.	# obs
learn_drv	In which U.S. state did you learn to drive or get your first U.S. driver's license?	1-59			454
drved_bik	Did your driver's education class cover bicycling?	0-3	0.89	1.01	457
drved_bin	Driver's ed class covered bicycling (1=yes, 0=no/don't remember/no driver's ed)	0-1	0.13	0.34	457
bik_class	Have you ever taken a class specifically on bicycle safety?	0-1	0.12	0.33	454
Experience with Crashes					
ff_crsh_bik	Have you or any of your family members or close friends ever crashed with a motor vehicle while bicycling?	0-2	0.85	0.95	459
ff_crsh_bik2	1 = have friends or family who've crashed with a car while biking; else, 0	0-1	0.38	0.49	459
bik_crsh_inj	Was anyone seriously injured (requiring hospitalization) or killed as a result of the crash?	0-3	1.49	1.49	176
ff_crsh_drv	Have you or any of your family members or close friends ever crashed with a bicyclist while driving a car?	0-2	0.31	0.65	455
ff_crsh_drv2	1 = have friends or family who've crashed with a bike while driving; else, 0	0-1	0.10	0.30	455
drv_crsh_inj	Was anyone seriously injured (requiring hospitalization) or killed as a result of the crash?	0-3	0.87	1.33	46
Demographic Questions					
sex_bin	Sex: female=0, male=1 (no decline to say)	0-1	0.46	0.50	458
age	Which of the following best describes your age range (5-yr increments)?	1-12	4.79	2.59	461
age2	Which of the following best describes your age range (10-yr increments)?	1-7	3.16	1.33	461
children	Do you have any children? (asked of whole sample)	0-1	0.39	0.49	459

Variable Name	Description	Range	Mean	s.d.	# obs
child_16	Of those who indicated that they have children, how many are under age 16?	0-4	0.93	0.96	175
child_sw	Of those who indicated that they have children, do any of bicycle on the street or sidewalk?	0-1	0.53	0.50	175
children_16	How many people (of whole sample) have children under age 16?	0-1	0.22	0.41	457
advocate	Are you a member of or associated with any organizations that advocate for Bay Area bicyclists?	0-1	0.08	0.27	426
black	Black or African American	0-1	0.06	0.24	463
white	White or Caucasian	0-1	0.63	0.48	463
amerin	American Indian or Alaska Native	0-1	0.01	0.11	463
nhpi	Native Hawaiian or Other Pacific Islander	0-1	0.02	0.13	463
asian	Asian	0-1	0.16	0.37	463
hisp	Hispanic or Latino	0-1	0.07	0.26	463
race_decl	Decline to say	0-1	0.04	0.20	463
oth_race	Other	0-1	0.07	0.26	463
race_sum	sum of all races for purpose of knowing who is multi-racial	0-3	1.02	0.33	463
hh_inc	Which of the following best represents your pre-tax household income (i.e., you and your spouse/partner, if applicable)?	1-8	4.54	1.83	406
hh_inc2	HH inc with two highest and two lowest categories collapsed	1-6	3.54	1.66	406
extra	Extra part of the survey (offered to those who ever bike)	0-1	0.60	0.49	382
Comfort Ratings for Roadway Design					
bo_bl_p	Perception of comfort (rated on Likert scale) bicycling on multi-lane street with a striped bike lane and parking.	1-7	4.44	1.84	223
bo_bsbl_p	Perception of comfort (rated on Likert scale) bicycling on multi-lane street with a barrier-separated bike lane and parking.	1-7	6.26	1.36	225

Variable Name	Description	Range	Mean	s.d.	# obs
bo_bl_np	Perception of comfort (rated on Likert scale) bicycling on multi-lane street with a striped bike lane but no parking.	1-7	5.92	1.32	224
bo_bsbl_np	Perception of comfort (rated on Likert scale) bicycling on multi-lane street with a barrier-separated bike lane but no parking.	1-7	6.52	1.14	226
bo_nt_p	Perception of comfort (rated on Likert scale) bicycling on multi-lane street with parking but no bicycle treatment.	1-7	2.75	1.76	224
bo_slm_p	Perception of comfort (rated on Likert scale) bicycling on multi-lane street with shared lane markings (sharrows) and parking.	1-7	3.34	1.84	224
bo_psl_p	Perception of comfort (rated on Likert scale) bicycling on multi-lane street with a painted shared travel lane and parking.	1-7	3.31	1.95	224
bo_pbl_p	Perception of comfort (rated on Likert scale) bicycling on multi-lane street with a painted bike lane and parking.	1-7	5.07	1.76	224
bo_des_score	composite score of all designs as a cyclist	8-56	37.55	8.87	208
bo_no_bsbl	composite score for all non-barrier-separated designs as a cyclist	6-42	24.80	8.05	209
bo_only_bsbl	composite score for only barrier-separated designs as cyclist	2-14	12.78	2.06	225
drv_bl_p	Perception of comfort (rated on Likert scale) driving on multi-lane street with a striped bike lane and parking.	1-7	5.65	1.59	261
drv_bsbl_p	Perception of comfort (rated on Likert scale) driving on multi-lane street with a barrier-separated bike lane and parking.	1-7	6.37	1.24	262
drv_bl_np	Perception of comfort (rated on Likert scale) driving on multi-lane street with a striped bike lane but no parking.	1-7	6.18	1.31	261
drv_bsbl_np	Perception of comfort (rated on Likert scale) driving on multi-lane street with a barrier-separated bike lane but no parking.	1-7	6.44	1.23	261

Variable Name	Description	Range	Mean	s.d.	# obs
drv_nt_p	Perception of comfort (rated on Likert scale) driving on multi-lane street with parking but no bicycle treatment.	1-7	5.19	2.04	263
drv_slm_p	Perception of comfort (rated on Likert scale) driving on multi-lane street with shared lane markings (sharrows) and parking.	1-7	4.75	1.96	259
drv_psl_p	Perception of comfort (rated on Likert scale) driving on multi-lane street with a painted shared travel lane and parking.	1-7	4.28	2.11	262
drv_pbl_p	Perception of comfort (rated on Likert scale) driving on multi-lane street with a painted bike lane and parking.	1-7	5.95	1.43	262
drv_des_score	composite score of all designs as driver (includes all drivers)	8-56	44.74	8.78	250
drv_no_bsbl	composite score for all non-barrier-separated designs as a driver	10-42	31.92	7.93	253
drv_only_bsbl	composite score for only barrier-separated designs as a driver	2-14	12.81	2.09	260
do_des_score	composite score of all designs as driver (does not include drivers who don't also bike)	8-56	45.14	8.67	217
Beliefs about Bicycle Lanes					
bl_space	agreement (Likert scale) with statement “bicycle lanes give cyclists their own space”	1-5	4.26	0.70	261
bl_lturn	agreement (Likert scale) with statement “bicycle lanes make it more difficult for cyclists to turn left”	1-5	2.79	1.04	262
bl_pace	agreement (Likert scale) with statement “bicycle lanes allow cyclists to ride at their own pace”	1-5	3.87	0.82	262
bl_nobel	agreement (Likert scale) with statement “bicycle lanes tell drivers that cyclists don’t belong on non-bicycle routes”	1-5	2.83	1.16	263
bl_door	agreement (Likert scale) with statement “bicycle lanes increase the chance of being hit by a car door”	1-5	2.58	0.95	262

Variable Name	Description	Range	Mean	s.d.	# obs
bl_expect	agreement (Likert scale) with statement “bicycle lanes tell drivers to expect cyclists”	1-5	4.33	0.63	263
bl_close	agreement (Likert scale) with statement “bicycle lanes encourage drivers to drive closer to cyclists”	1-5	2.25	0.87	263
bl_restrict	agreement (Likert scale) with statement “bicycle lanes unnecessarily restrict fast cyclists”	1-5	2.10	0.82	262
bl_predict	agreement (Likert scale) with statement “bicycle lanes make cyclists more predictable on the roadway”	1-5	3.93	0.87	261
GIS and Census Data					
nodes_25	intersection density within 0.25 mi buffer	1-99	25.0	12.6	410
nnodes_25	intersection density within 0.25 mi buffer - but outermost outliers deleted	1-66	24.5	11.3	406
nodes_50	intersection density within 0.5 mi buffer	1-292	94.1	42.8	410
nodes_1	intersection density within 1 mi buffer	4-995	364	167	410
nodes_2	intersection density within 2 mi buffer	9-2741	1356	634	410
walkscore	Walkscore of location	0-100	84.7	22.8	410
leng1_1	length of class 1 bicycle facilities within 1 mi buffer	0-12641	1884	2886	410
leng1_2	length of class 2 bicycle facilities within 1 mi buffer	0-31073	7448	6209	410
leng1_3	length of class 3 bicycle facilities within 1 mi buffer	0-33084	9152	8041	410
leng25_1	length of class 1 bicycle facilities within 0.25 mi buffer	0-2520	111	328	410
leng25_2	length of class 2 bicycle facilities within 0.25 mi buffer	0-4222	579	811	410
leng25_3	length of class 3 bicycle facilities within 0.25 mi buffer	0-4971	737	957	410
leng50_1	length of class 1 bicycle facilities within 0.5 mi buffer	0-6063	483	918	410

Variable Name	Description	Range	Mean	s.d.	# obs
leng50_2	length of class 2 bicycle facilities within 0.5 mi buffer	0-11094	2002	2115	410
leng50_3	length of class 3 bicycle facilities within 0.5 mi buffer	0-13594	2619	2740	410
traillen50	length of class 1 trails within 0.5 mi buffer	0-4022	411	729	410
traillen1	length of class 1 trails within 1 mi buffer	0-12370	1616	2486	410
traillen25	length of class 1 trails within 0.25 mi buffer	0-1832	93.94	259	410
streets50	Total street distance (m) within 0.5 mi buffer	5660-50325	29508	8097	410
streets25	Total street distance (m) within 0.25 mi buffer	1613-15424	7708	2098	410
streets1	Total street distance (m) within 1 mi buffer	13475-174132	111623	33019	410
all25	All collisions within 0.25 mi buffer, 2006-2010	0-454	51.3	57.5	410
all_ped25	All ped collisions within 0.25 mi buffer, 2006-2010	0-178	8.8	15.6	410
all_bike25	All bike collisions within 0.25 mi buffer, 2006-2010	0-76	8.7	12.4	410
fs_bike25	All fatal or severe bike collisions within 0.25 mi buffer, 2006-2010	0-9	0.62	1.26	410
fs_ped25	All fatal or severe ped collisions within 0.25 mi buffer, 2006-2010	0-18	0.98	1.94	410
all50	All collisions within 0.5 mi buffer, 2006-2010	0-1404	197	196	410
all_ped50	All ped collisions within 0.5 mi buffer, 2006-2010	0-502	34.1	55.0	410
all_bike50	All bike collisions within 0.5 mi buffer, 2006-2010	0-273	33.1	45.7	410
fs_bike50	All fatal or severe bike collisions within 0.5 mi buffer, 2006-2010	0-22	2.22	3.75	410
fs_ped50	All fatal or severe ped collisions within 0.5 mi buffer, 2006-2010	0-55	3.77	6.34	410
all1	All collisions within 1 mi buffer, 2006-2010	2-4872	757	717	410

Variable Name	Description	Range	Mean	s.d.	# obs
all_ped1	All ped collisions within 1 mi buffer, 2006-2010	0-1391	132	185	410
all_bike1	All bike collisions within 1 mi buffer, 2006-2010	0-815	127	159	410
fs_bike1	All fatal or severe bike collisions within 1 mi buffer, 2006-2010	0-74	8.21	11.4	410
fs_ped1	All fatal or severe ped collisions within 1 mi buffer, 2006-2010	0-145	14.4	20.0	410
all2	All collisions within 2 mi buffer, 2006-2010	46-9507	2568	2051	410
all_ped2	All ped collisions within 2 mi buffer, 2006-2010	0-2368	423	496	410
all_bike2	All bike collisions within 2 mi buffer, 2006-2010	0-1657	389	397	410
fs_bike2	All fatal or severe bike collisions within 2 mi buffer, 2006-2010	0-128	25.5	27.9	410
fs_ped2	All fatal or severe ped collisions within 2 mi buffer, 2006-2010	0-272	48.7	56.0	410
trvg10l_50	Total travel length (m) with AADT 10k-20k within 0.5 mi buffer	0-9239	2535	2237	410
trvl10_50	Total travel length (m) with AADT less than 10k within 0.5 mi buffer	0-41682	12325	6657	410
trvg20_50	Total travel length (m) with AADT greater than 20k within 0.5 mi buffer	0-10694	1908	2096	410
trvg10l_1	Total travel length (m) with AADT 10k-20k within 1 mi buffer	0-31845	10116	7371	410
trvl10_1	Total travel length (m) with AADT less than 10k within 1 mi buffer	0-39478	7326	6209	410
trvg20_1	Total travel length (m) with AADT greater than 20k within 1 mi buffer	0-115103	45475	23138	410
trvg10l_25	Total travel length (m) with AADT 10k-20k within 0.25 mi buffer	0-3992	675	840	410
trvl10_25	Total travel length (m) with AADT less than 10k within 0.25 mi buffer	0-4538	506	779	410
trvg20_25	Total travel length (m) with AADT greater than 20k within 0.25 mi buffer	0-12976	3312	1953	410
pop2010_25	Total 2010 population within 0.25 mi buffer	6-16372	2373	1972	410

Variable Name	Description	Range	Mean	s.d.	# obs
white_25	# whites only within 0.25 mi buffer	5-8426	1259	1106	410
black_25	# blacks only within 0.25 mi buffer	0-1966	273	341	410
asian_25	# Asians only within 0.25 mi buffer	0-7363	539	737	410
hispan_25	# Hispanics or Latinos within 0.25 mi buffer	1-3102	335	406	410
males_25	# males only within 0.25 mi buffer	3-9146	1165	1019	410
female_25	# females only within 0.25 mi buffer	3-7227	1207	966	410
age_under_5_25	pop under 5 within 0.25 mi buffer	0-390	109	73.0	410
age_5_9_25	pop age 5-9 within 0.25 mi buffer	0-355	88.4	5.25	410
age_10_14_25	pop age 10-14 within 0.25 mi buffer	0-324	79.6	50.8	410
age_15_19_25	pop age 15-19 within 0.25 mi buffer	0-2555	121	206	410
age_20_24_25	pop age 20-24 within 0.25 mi buffer	0-3263	220	376	410
age_25_34_25	pop age 25-34 within 0.25 mi buffer	0-4404	490	542	410
age_35_44_25	pop age 35-44 within 0.25 mi buffer	1-2442	377	344	410
age_45_54_25	pop age 45-54 within 0.25 mi buffer	1-2123	311	245	410
age_55_64_25	pop age 55-64 within 0.25 mi buffer	1-1952	279	226	410
age_65_74_25	pop age 65-74 within 0.25 mi buffer	1-1221	148	129	410
age_75_84_25	pop age 75-84 within 0.25 mi buffer	0-1166	90.4	105	410
age_85up_25	pop age 85+ within 0.25 mi buffer	0-607	46.8	58.2	410
households_25	# HH within 0.25 mi buffer	3-9865	1082	1047	410
ave_hh_size_25	ave HH size within 0.25 mi buffer	0.847-4.57	2.32	0.50	410
hse_units_25	# housing units within 0.25 mi buffer	5-10960	1176	1159	410
vacant_25	# housing units vacant within 0.25 mi buffer	0-1094	92.17	120	410
owner_occ_25	# housing units owner-occupied within 0.25 mi buffer	0-1044	374	214	410
renter_occ_25	# housing units rented within 0.25 mi buffer	1-9270	708	923	410

Variable Name	Description	Range	Mean	s.d.	# obs
hhintotal_25	from 2000 Census-tot hh inc	2-9209	1070	1034	410
tot_hh_nov_25	from 2000 Census-hh no veh	0-7110	246	560	410
ageg64_25	pop age 65+ within 0.25 mi buffer	2-3602	336	342	410
med_hh_inc_25	median HH income within 0.25 mi buffer	23191-182898	76096	28406	410
ageless18_25	pop under age 18 within 0.25 mi buffer	0-1318	339	210	410
jobs_25	# jobs within 0.25 mi buffer	1-11425	970	1575	410
meanhhinc_25	mean HH income within 0.25 mi buffer	29247-229048	97812	36101	410
numwork_tot_25	# people working within 0.25 mi buffer	2-8356	1270	1150	410
numwork_male_25	# males working within 0.25 mi buffer	1-4647	656	614	410
numwork_fem_25	# females working within 0.25 mi buffer	1-3712	613	544	410
numbike_25	# people commuting by bike within 0.25 mi buffer	0-770	59.4	90.9	410
numbike_male_25	# males commuting by bike within 0.25 mi buffer	0-588	37.9	62.1	410
numbike_fem_25	# females commuting by bike within 0.25 mi buffer	0-182	19.8	31.0	410
numauto_tot_25	# people commuting by car within 0.25 mi buffer	1-2489	665	433	410
numauto_male_25	# males commuting by car within 0.25 mi buffer	1-1202	343	226	410
numauto_fem_25	# females commuting by car within 0.25 mi buffer	1-1286	320	217	410
numwalk_tot_25	# people commuting by foot within 0.25 mi buffer	0-3231	123	268	410
numwalk_male_25	# males commuting by foot within 0.25 mi buffer	0-1799	58.3	134	410
numwalk_fem_25	# females commuting by foot within 0.25 mi buffer	0-1432	63.3	139	410
numpublic_tot_25	# people commuting by public transit within 0.25 mi buffer	0-3097	308	450	410

Variable Name	Description	Range	Mean	s.d.	# obs
numpublic_male_25	# males commuting by public transit within 0.25 mi buffer	0-1824	151	229	410
numpublic_fem_25	# females commuting by public transit within 0.25 mi buffer	0-1270	156	227	410
totalpop_25	total population within 0.25 mi buffer	5-14595	2309	1922	410
college_25	# people in college within 0.25 mi buffer	0-4371	229	425	410
gradsch_25	# people in grad school within 0.25 mi buffer	0-806	112	144	410
highsch_25	# people in highschool within 0.25 mi buffer	0-410	74.0	57.5	410
midsch_25	# people in middle school within 0.25 mi buffer	0-279	60.6	45.1	410
elemsch_25	# people in elementary school within 0.25 mi buffer	0-305	71.0	47.5	410
tothh_25	total # HH within 0.25 mi buffer	2-9349	1078	1036	410
tothh0veh_25	total # HH 0 veh within 0.25 mi buffer	0-7106	251	561	410
tothh1veh_25	total # HH 1 veh within 0.25 mi buffer	1-2250	480	465	410
tothh2veh_25	total # HH 2 veh within 0.25 mi buffer	1-723	257	151	410
tothh3veh_25	total # HH 3 veh within 0.25 mi buffer	0-187	61.7	36.5	410
tothh4veh_25	total # HH 4+ veh within 0.25 mi buffer	0-112	23.6	16.5	410
houses_25	total # houses within 0.25 mi buffer	5-10897	1178	1162	410
houses_1940s_25	total # houses built 1940-1949 within 0.25 mi buffer	0-642	105	92.8	410
houses_old1939_25	total # houses built 1939 or earlier within 0.25 mi buffer	0-8323	534	765	410
pct_houses_1950_25	% houses built before 1950	0-0.8445	0.41	0.27	410
pct_tothh0veh_25	% hh sans vehicle within 0.25 mi buffer	0-0.7601	0.14	0.13	410
pct_tothh1veh_25	% hh one vehicle within 0.25 mi buffer	0.0763-0.8143	0.40	0.13	410
pct_tothh2veh_25	% hh two vehicles within 0.25 mi buffer	0.018-0.5768	0.32	0.12	410

Variable Name	Description	Range	Mean	s.d.	# obs
pct_tothh3veh_25	% hh three vehicles within 0.25 mi buffer	0-0.3408	0.10	0.07	410
pct_tothh4veh_25	% hh four+ vehicles within 0.25 mi buffer	0-0.2228	0.04	0.04	410
pct_college_grad_25	% population in college or gradschool within 0.25 mi buffer	0-0.7957	0.12	0.11	410
pct_highsch_25	% population in high school within 0.25 mi buffer	0-0.1113	0.04	0.02	410
pct_midsch_25	% population in middle school within 0.25 mi buffer	0-0.1043	0.04	0.02	410
pct_elemsch_25	% population in elementary school within 0.25 mi buffer	0-0.1055	0.04	0.02	410
pct_enrhs_25	from older Census-% enrolled in hs	0-0.2626	0.11	0.05	410
pct_bike_25	% people commuting by bike within 0.25 mi buffer	0-0.3531	0.03	0.04	410
pct_bikem_25	% males commuting by bike within 0.25 mi buffer	0-0.3723	0.04	0.05	410
pct_bikef_25	% females commuting by bike within 0.25 mi buffer	0-0.3371	0.02	0.03	410
pct_auto_25	% people commuting by car within 0.25 mi buffer	0.1763-0.9583	0.64	0.19	410
pct_autom_25	% males commuting by car within 0.25 mi buffer	0.1704-1	0.64	0.19	410
pct_autof_25	% females commuting by car within 0.25 mi buffer	0.169-1	0.64	0.19	410
pct_walk_25	% people commuting by foot within 0.25 mi buffer	0-0.4572	0.06	0.08	410
pct_walkm_25	% males commuting by foot within 0.25 mi buffer	0-0.3975	0.06	0.07	410
pct_walkf_25	% females commuting by foot within 0.25 mi buffer	0-0.5146	0.07	0.09	410
pct_public_25	% people commuting by public transit within 0.25 mi buffer	0-0.527	0.17	0.10	410
pct_publicm_25	% males commuting by public transit within 0.25 mi buffer	0-0.5046	0.17	0.10	410
pct_publicf_25	% females commuting by public transit within 0.25 mi buffer	0-0.5617	0.18	0.12	410

Variable Name	Description	Range	Mean	s.d.	# obs
pct_less18_25	% population age 18 or younger within 0.25 mi buffer	0-0.3493	0.18	0.07	410
pct_1824_25	% population 18-24 within 0.25 mi buffer	-0.1667-0.7457	0.09	0.10	410
pct_2534_25	% population 25-34 within 0.25 mi buffer	0-0.3879	0.17	0.07	410
pct_3544_25	% population 35-44 within 0.25 mi buffer	0.0065-0.2494	0.15	0.03	410
pct_4554_25	% population 45-54 within 0.25 mi buffer	0.0152-0.2115	0.14	0.03	410
pct_5564_25	% population 55-64 within 0.25 mi buffer	0.0296-0.2466	0.13	0.03	410
pct_6574_25	% population 65-74 within 0.25 mi buffer	0.0089-0.2278	0.07	0.03	410
pct_75ov_25	% population 75+ within 0.25 mi buffer	0-0.6356	0.06	0.04	410
pop2010_50	Total 2010 population within 0.5 mi buffer	25-55127	9106	7250	410
white_50	# whites only within 0.5 mi buffer	21-27057	4768	4079	410
black_50	# blacks only within 0.5 mi buffer	0-5187	1081	1253	410
asian_50	# Asians only within 0.5 mi buffer	0-22012	2067	2501	410
hispan_50	# Hispanics or Latinos within 0.5 mi buffer	2-10876	1315	1535	410
males_50	# males only within 0.5 mi buffer	13-30675	4484	3797	410
female_50	# females only within 0.5 mi buffer	12-24454	4613	3500	410
age_under_5_50	pop under 5 within 0.5 mi buffer	1-1563	413	269	410
age_5_9_50	pop age 5-9 within 0.5 mi buffer	0-1421	338	204	410
age_10_14_50	pop age 10-14 within 0.5 mi buffer	1-1278	306	186	410
age_15_19_50	pop age 15-19 within 0.5 mi buffer	1-5308	450	599	410
age_20_24_50	pop age 20-24 within 0.5 mi buffer	1-8062	806	1125	410
age_25_34_50	pop age 25-34 within 0.5 mi buffer	2-13595	1851	1965	410
age_35_44_50	pop age 35-44 within 0.5 mi buffer	2-7993	1438	1274	410

Variable Name	Description	Range	Mean	s.d.	# obs
age_45_54_50	pop age 45-54 within 0.5 mi buffer	4-7522	1197	928	410
age_55_64_50	pop age 55-64 within 0.5 mi buffer	5-6932	1074	833	410
age_65_74_50	pop age 65-74 within 0.5 mi buffer	4-3958	572	482	410
age_75_84_50	pop age 75-84 within 0.5 mi buffer	1-3255	348	378	410
age_85up_50	pop age 85+ within 0.5 mi buffer	0-1509	173	188	410
households_50	# HH within 0.5 mi buffer	12-31757	4139	3853	410
ave_hh_size_50	ave HH size within 0.5 mi buffer	0.96-4.5267	2.33	0.48	410
hse_units_50	# housing units within 0.5 mi buffer	20-35742	4491	4270	410
vacant_50	# housing units vacant within 0.5 mi buffer	3-3997	340	437	410
owner_occ_50	# housing units owner-occupied within 0.5 mi buffer	0-3897	1434	788	410
renter_occ_50	# housing units rented within 0.5 mi buffer	3-29181	2693	3378	410
hhintotal_50	from 2000 Census-tot hh inc	9-29934	4083	3771	410
tot_hh_nov_50	from 2000 Census-hh no veh	0-21838	946	2034	410
ageg64_50	pop age 65+ within 0.5 mi buffer	8-10059	1310	1228	410
med_hh_inc_50	median HH income within 0.5 mi buffer	23191-182898	76310	26717	410
ageless18_50	pop under age 18 within 0.5 mi buffer	0-5353	1319	775	410
jobs_50	# jobs within 0.5 mi buffer	3-42928	3890	5977	410
meanhhinc_50	mean HH income within 0.5 mi buffer	29247-225873	98517	33755	410
numwork_tot_50	# people working within 0.5 mi buffer	7-26398	4836	4192	410
numwork_male_50	# males working within 0.5 mi buffer	5-15332	2518	2282	410
numwork_fem_50	# females working within 0.5 mi buffer	3-11546	2310	1938	410
numbike_50	# people commuting by bike within 0.5 mi buffer	0-1827	213	305	410

Variable Name	Description	Range	Mean	s.d.	# obs
numbike_male_50	# males commuting by bike within 0.5 mi buffer	0-1258	134	199	410
numbike_fem_50	# females commuting by bike within 0.5 mi buffer	0-563	68.6	101	410
numauto_tot_50	# people commuting by car within 0.5 mi buffer	6-6701	2544	1565	410
numauto_male_50	# males commuting by car within 0.5 mi buffer	3-3488	1317	825	410
numauto_fem_50	# females commuting by car within 0.5 mi buffer	2-3473	1214	760	410
numwalk_tot_50	# people commuting by foot within 0.5 mi buffer	0-8295	453	898	410
numwalk_male_50	# males commuting by foot within 0.5 mi buffer	0-4764	215	461	410
numwalk_fem_50	# females commuting by foot within 0.5 mi buffer	0-4388	223	446	410
numpublic_tot_50	# people commuting by public transit within 0.5 mi buffer	0-9955	1164	1653	410
numpublic_male_50	# males commuting by public transit within 0.5 mi buffer	0-5907	574	869	410
numpublic_fem_50	# females commuting by public transit within 0.5 mi buffer	0-4070	575	801	410
totalpop_50	total population within 0.5 mi buffer	19-48553	8835	6993	410
college_50	# people in college within 0.5 mi buffer	0-10334	840	1276	410
gradsch_50	# people in grad school within 0.5 mi buffer	0-2155	409	480	410
highsch_50	# people in highschool within 0.5 mi buffer	0-1176	287	199	410
midsch_50	# people in middle school within 0.5 mi buffer	0-1011	233	157	410
elemsch_50	# people in elementary school within 0.5 mi buffer	0-1135	265	160	410
tothh_50	total # HH within 0.5 mi buffer	9-29757	4104	3763	410
tothh0veh_50	total # HH 0 veh within 0.5 mi buffer	0-21402	959	2032	410
tothh1veh_50	total # HH 1 veh within 0.5 mi buffer	3-7177	1804	1666	410

Variable Name	Description	Range	Mean	s.d.	# obs
tothh2veh_50	total # HH 2 veh within 0.5 mi buffer	3-2577	977	544	410
tothh3veh_50	total # HH 3 veh within 0.5 mi buffer	1-646	233	124	410
tothh4veh_50	total # HH 4+ veh within 0.5 mi buffer	0-361	86.73	55.83	410
houses_50	total # houses within 0.5 mi buffer	19-35630	4503	4272	410
houses_1940s_50	total # houses built 1940-1949 within 0.5 mi buffer	0-1846	397	327	410
houses_old1939_50	total # houses built 1939 or earlier within 0.5 mi buffer	0-24201	2009	2728	410
pct_houses_1950_50	% houses built before 1950	0-0.8121	0.41	0.26	410
pct_tothh0veh_50	% hh sans vehicle within 0.5 mi buffer	0-0.7889	0.14	0.13	410
pct_tothh1veh_50	% hh one vehicle within 0.5 mi buffer	0.0782-0.0745	0.39	0.12	410
pct_tothh2veh_50	% hh two vehicles within 0.5 mi buffer	0.028-0.5615	0.32	0.12	410
pct_tothh3veh_50	% hh three vehicles within 0.5 mi buffer	0.0037-0.3061	0.10	0.07	410
pct_tothh4veh_50	% hh four+ vehicles within 0.5 mi buffer	0-0.2102	0.04	0.04	410
pct_college_grad_50	% population in college or grad school within 0.5 mi buffer	0-0.7419	0.12	0.10	410
pct_highsch_50	% population in high school within 0.5 mi buffer	0-0.1096	0.04	0.02	410
pct_midsch_50	% population in middle school within 0.5 mi buffer	0-0.1043	0.04	0.02	410
pct_elemsch_50	% population in elementary school within 0.5 mi buffer	0-0.0988	0.04	0.02	410
pct_enrhs_50	% population enrolled in high school within 0.5 mi buffer	0.0011-0.2635	0.11	0.05	410
pct_bike_50	% people commuting by bike within 0.5 mi buffer	0-0.3213	0.03	0.04	410
pct_bikem_50	% males commuting by bike within 0.5 mi buffer	0-0.3474	0.04	0.04	410
pct_bikef_50	% females commuting by bike within 0.5 mi buffer	0-0.294	0.02	0.03	410

Variable Name	Description	Range	Mean	s.d.	# obs
pct_auto_50	% people commuting by car within 0.5 mi buffer	0.1754-0.9454	0.64	0.18	410
pct_autom_50	% males commuting by car within 0.5 mi buffer	0.1687-0.9464	0.64	0.18	410
pct_autof_50	% females commuting by car within 0.5 mi buffer	0.1876-0.9813	0.64	0.19	410
pct_walk_50	% people commuting by foot within 0.5 mi buffer	0-0.3986	0.06	0.07	410
pct_walkm_50	% males commuting by foot within 0.5 mi buffer	0-0.3425	0.06	0.07	410
pct_walkf_50	% females commuting by foot within 0.5 mi buffer	0-0.4499	0.06	0.08	410
pct_public_50	% people commuting by public transit within 0.5 mi buffer	0-0.4635	0.17	0.10	410
pct_publicm_50	% males commuting by public transit within 0.5 mi buffer	0-0.4399	0.16	0.09	410
pct_publicf_50	% females commuting by public transit within 0.5 mi buffer	0-0.5015	0.18	0.11	410
pct_less18_50	% population age 18 or younger within 0.5 mi buffer	0-0.3431	0.18	0.06	410
pct_1824_50	% population 18-24 within 0.5 mi buffer	0.002-0.701	0.09	0.09	410
pct_2534_50	% population 25-34 within 0.5 mi buffer	0.0038-0.3662	0.17	0.07	410
pct_3544_50	% population 35-44 within 0.5 mi buffer	0.0065-0.2305	0.15	0.03	410
pct_4554_50	% population 45-54 within 0.5 mi buffer	0.0174-0.2089	0.14	0.03	410
pct_5564_50	% population 55-64 within 0.5 mi buffer	0.0378-0.2415	0.13	0.03	410
pct_6574_50	% population 65-74 within 0.5 mi buffer	0.0084-0.2299	0.07	0.02	410
pct_75ov_50	% population 75+ within 0.5 mi buffer	0.0014-0.6353	0.06	0.04	410
pop2010_1	Total 2010 population within 1 mi buffer	130-138507	33002	23749	410
white_1	# whites only within 1 mi buffer	112-69942	16983	13839	410

Variable Name	Description	Range	Mean	s.d.	# obs
black_1	# blacks only within 1 mi buffer	3-15738	3953	3993	410
asian_1	# Asians only within 1 mi buffer	2-48872	7551	7077	410
hispan_1	# Hispanics or Latinos within 1 mi buffer	14-26318	4894	4856	410
males_1	# males only within 1 mi buffer	66-72907	16279	12371	410
female_1	# females only within 1 mi buffer	64-65598	16667	11463	410
age_under_5_1	pop under 5 within 1 mi buffer	5-4421	1485	922	410
age_5_9_1	pop age 5-9 within 1 mi buffer	5-3907	1241	676	410
age_10_14_1	pop age 10-14 within 1 mi buffer	6-3643	1123	597	410
age_15_19_1	pop age 15-19 within 1 mi buffer	6-8639	1704	1541	410
age_20_24_1	pop age 20-24 within 1 mi buffer	5-16490	2904	3158	410
age_25_34_1	pop age 25-34 within 1 mi buffer	10-34339	6447	6366	410
age_35_44_1	pop age 35-44 within 1 mi buffer	12-21096	5108	4292	410
age_45_54_1	pop age 45-54 within 1 mi buffer	21-18449	4329	3020	410
age_55_64_1	pop age 55-64 within 1 mi buffer	25-17441	3851	2620	410
age_65_74_1	pop age 65-74 within 1 mi buffer	13-10995	2039	1512	410
age_75_84_1	pop age 75-84 within 1 mi buffer	2-8834	1230	1141	410
age_85up_1	pop age 85+ within 1 mi buffer	1-4161	590.0	574.5	410
households_1	# HH within 1 mi buffer	60-77760	14722	12525	410
ave_hh_size_1	ave HH size within 1 mi buffer	1.0275-4.5308	2.352	0.427	410
hse_units_1	# housing units within 1 mi buffer	99-87618	15984	13860	410
vacant_1	# housing units vacant within 1 mi buffer	15-9866	1180	1382	410
owner_occ_1	# housing units owner-occupied within 1 mi buffer	0-13818	5237	2766	410
renter_occ_1	# housing units rented within 1 mi buffer	16-67909	9400	10598	410

Variable Name	Description	Range	Mean	s.d.	# obs
hhintotal_1	from 2000 Census-tot hh inc	48-73067	14431	12154	410
tot_hh_nov_1	from 2000 Census-hh no veh	0-44640	3309	5861	410
ageg64_1	pop age 65+ within 1 mi buffer	17-28192	4730	3800	410
med_hh_inc_1	median HH income within 1 mi buffer	23191-182898	75822	25005	410
ageless18_1	pop under age 18 within 1 mi buffer	19-15261	4924	2585	410
jobs_1	# jobs within 1 mi buffer	13-198971	17478	28245	410
meanhhinc_1	mean HH income within 1 mi buffer	29247-232719	98205	31639	410
numwork_tot_1	# people working within 1 mi buffer	43-68663	17090	13657	410
numwork_male_1	# males working within 1 mi buffer	25-38334	8947	7528	410
numwork_fem_1	# females working within 1 mi buffer	18-30701	8073	6170	410
numbike_1	# people commuting by bike within 1 mi buffer	0-4225	678	860	410
numbike_male_1	# males commuting by bike within 1 mi buffer	0-2905	413	557	410
numbike_fem_1	# females commuting by bike within 1 mi buffer	0-1277	200	263	410
numauto_tot_1	# people commuting by car within 1 mi buffer	36-20844	9107	5115	410
numauto_male_1	# males commuting by car within 1 mi buffer	20-12181	4734	2780	410
numauto_fem_1	# females commuting by car within 1 mi buffer	15-9970	4289	2363	410
numwalk_tot_1	# people commuting by foot within 1 mi buffer	0-18602	1527	2515	410
numwalk_male_1	# males commuting by foot within 1 mi buffer	0-9819	722.4	1322	410
numwalk_fem_1	# females commuting by foot within 1 mi buffer	0-8772	725.2	1184	410
numpublic_tot_1	# people commuting by public transit within 1 mi buffer	0-25839	3978	5310	410

Variable Name	Description	Range	Mean	s.d.	# obs
numpublic_male-1	# males commuting by public transit within 1 mi buffer	0-14155	1972	2821	410
numpublic_fem_1	# females commuting by public transit within 1 mi buffer	0-11657	1912	2512	410
totalpop_1	total population within 1 mi buffer	109-127575	31777	22670	410
college_1	# people in college within 1 mi buffer	2-19002	3026	3450	410
gradsch_1	# people in grad school within 1 mi buffer	1-6039	1399	1481	410
highsch_1	# people in highschool within 1 mi buffer	2-3156	1051	605	410
midsch_1	# people in middle school within 1 mi buffer	5-2874	858	475	410
elemsch_1	# people in elementary school within 1 mi buffer	3-3138	954	514	410
tothh_1	total # HH within 1 mi buffer	49-73417	14541	12190	410
tothh0veh_1	total # HH 0 veh within 1 mi buffer	0-44837	3374	5904	410
tothh1veh_1	total # HH 1 veh within 1 mi buffer	13-23819	6233	5441	410
tothh2veh_1	total # HH 2 veh within 1 mi buffer	19-8455	3491	1792	410
tothh3veh_1	total # HH 3 veh within 1 mi buffer	3-2309	828	392	410
tothh4veh_1	total # HH 4+ veh within 1 mi buffer	5-1265	311	198	410
houses_1	total # houses within 1 mi buffer	93-85616	15978	13785	410
houses_1940s_1	total # houses built 1940-1949 within 1 mi buffer	0-4844	1409	1046	410
houses_old1939_1	total # houses built 1939 or earlier within 1 mi buffer	0-50302	6996	8391	410
pct_houses_1950_1	% houses built before 1950	0.0014-0.7416	0.41	0.24	410
pct_tothh0veh_1	% hh sans vehicle within 1 mi buffer	0-0.6588	0.15	0.12	410
pct_tothh1veh_1	% hh one vehicle within 1 mi buffer	0.0878-0.6164	0.39	0.10	410

Variable Name	Description	Range	Mean	s.d.	# obs
pct_tothh2veh_1	% hh two vehicles within 1 mi buffer	0.0467-0.5386	0.31	0.11	410
pct_tothh3veh_1	% hh three vehicles within 1 mi buffer	0.0064-0.2919	0.10	0.07	410
pct_tothh4veh_1	% hh four+ vehicles within 1 mi buffer	0.0031-0.2041	0.04	0.04	410
pct_college_grad_1	% population in college or gradschool within 1 mi buffer	0.0275-0.6103	0.12	0.09	410
pct_highsch_1	% population in high school within 1 mi buffer	0.0086-0.1085	0.04	0.02	410
pct_midsch_1	% population in middle school within 1 mi buffer	0.0041-0.0893	0.04	0.02	410
pct_elemsch_1	% population in elementary school within 1 mi buffer	0.0108-0.097	0.04	0.02	410
pct_enrhs_1	% population enrolled in high school within 1 mi buffer	0.023-0.2455	0.11	0.05	410
pct_bike_1	% people commuting by bike within 1 mi buffer	0-0.27303	0.03	0.03	410
pct_bikem_1	% males commuting by bike within 1 mi buffer	0-0.3021	0.03	0.03	410
pct_bikef_1	% females commuting by bike within 1 mi buffer	0-0.2421	0.02	0.02	410
pct_auto_1	% people commuting by car within 1 mi buffer	0.2367-0.9491	0.64	0.18	410
pct_autom_1	% males commuting by car within 1 mi buffer	0.2357-0.9489	0.64	0.18	410
pct_autof_1	% females commuting by car within 1 mi buffer	0.2338-0.9493	0.64	0.18	410
pct_walk_1	% people commuting by foot within 1 mi buffer	0-0.3158	0.06	0.06	410
pct_walkm_1	% males commuting by foot within 1 mi buffer	0-0.3122	0.05	0.06	410
pct_walkf_1	% females commuting by foot within 1 mi buffer	0-0.3532	0.06	0.07	410
pct_public_1	% people commuting by public transit within 1 mi buffer	0-0.4245	0.17	0.09	410
pct_publicm_1	% males commuting by public transit within 1 mi buffer	0-0.4044	0.16	0.09	410

Variable Name	Description	Range	Mean	s.d.	# obs
pct_publicf_1	% females commuting by public transit within 1 mi buffer	0-0.4629	0.17	0.10	410
pct_less18_1	% population age 18 or younger within 1 mi buffer	0.047-0.3445	0.18	0.06	410
pct_1824_1	% population 18-24 within 1 mi buffer	0.0079-0.5716	0.10	0.08	410
pct_2534_1	% population 25-34 within 1 mi buffer	0.0118-0.3265	0.17	0.06	410
pct_3544_1	% population 35-44 within 1 mi buffer	0.0261-0.2213	0.15	0.03	410
pct_4554_1	% population 45-54 within 1 mi buffer	0.0471-0.1975	0.14	0.03	410
pct_5564_1	% population 55-64 within 1 mi buffer	0.0473-0.2411	0.13	0.03	410
pct_6574_1	% population 65-74 within 1 mi buffer	0.0084-0.2029	0.07	0.02	410
pct_75ov_1	% population 75+ within 1 mi buffer	0.0019-0.5357	0.06	0.03	410
fam25	Total # families within 0.25 mi buffer	2-2523	448	309	410
povl50_25	# families with inc < 50% poverty level within 0.25 mi buffer	0-170.6214	15.8	23.4	410
povg75_25	# families with inc > 75% poverty level within 0.25 mi buffer	0-135.8456	9.16	15.2	410
ppovl50_25	% families with inc < 50% poverty level within 0.25 mi buffer	0-0.23	0.04	0.04	383
ppovg75_25	% families with inc > 75% poverty level within 0.25 mi buffer	0-0.144	0.02	0.03	339
fam50	Total # families within 0.5 mi buffer	7-7866	1731	1115	410
povl50_50	# families with inc < 50% poverty level within 0.5 mi buffer	0-468.477	61.0	70.2	410
povg75_50	# families with inc > 75% poverty level within 0.5 mi buffer	0-354.5793	37.5	51.7	410
ppovl50_50	% families with inc < 50% poverty level within 0.5 mi buffer	0-0.229	0.03	0.03	399
ppovg75_50	% families with inc > 75% poverty level within 0.5 mi buffer	0-0.136	0.02	0.02	376

Variable Name	Description	Range	Mean	s.d.	# obs
fam1	Total # families within 1 mi buffer	35-21281	6291	3621	410
povl50_1	# families with inc < 50% poverty level within 1 mi buffer	0-988.4905	232	196	410
povg75_1	# families with inc > 75% poverty level within 1 mi buffer	0-954.9568	146	150	410
ppovl50_1	% families with inc < 50% poverty level within 1 mi buffer	0-0.231	0.03	0.02	405
ppovg75_1	% families with inc > 75% poverty level within 1 mi buffer	0-0.097	0.02	0.02	394
fam2	Total # families within 2 mi buffer	168-53845	20897	11454	410
povl50_2	# families with inc < 50% poverty level within 2 mi buffer	0.8673-2283.966	807	550	410
povg75_2	# families with inc > 75% poverty level within 2 mi buffer	0-1993.497	559	457	410
ppovl50_2	% families with inc < 50% poverty level within 2 mi buffer	0-0.101	0.04	0.02	410
ppovg75_2	% families with inc > 75% poverty level within 2 mi buffer	0-0.071	0.03	0.02	402
land_sq_mi	sq mileage of land in each city (2010 Census)	0.947-97.915	28.8	20.2	455
pop_dens	population per sq mi of land (2010 Census)	296-17179	8050	4847	455
pop_quart	quartiles of population density: 1 = pop_dens < 5000; 2 = pop_dens > 5000 & < 10,000; 3 = pop_dens > 10,000 & < 15,000; 4 = pop_dens > 15,000	1-4	2.176	1.068	455
hous_dens	housing units per sq mi of land (2010 Census)	138-8042	3569	2349	455
ipop_quart_2	dummy variable for 2nd pop_quartile--1st quartile is reference (2nd-least dense)	0-1	0.32	0.47	455
ipop_quart_3	dummy variable for 3rd pop_quartile (2nd-most dense)	0-1	0.18	0.39	455
ipop_quart_4	dummy variable for 4th pop_quartile (most dense)	0-1	0.16	0.37	455

Factor Variables	
f_biksupp	factor containing mor_bik, fund_bik, low_spd
f_bikrt	factor containing alt_bikdesrt, alt_bikoffst
f_red_car	factor containing priority red drunk, agg, spd, dist
f_red_bikeped	factor containing priority red run, ww, jaywalk
f_bikoffst	factor containing bik_desrt, bik_offst, bik_safsw
f_awaredriv	factor containing chk_turn, pass_3, chk_pk
f_netwkbik	factor containing know_bik, ff_bik
f_drivanx	factor containing bik_pres, safer_laws, anx_trail, bik_sdang
f_discbik	factor containing disc_bik
f_morbike	factor containing mor_bik, fund_bik, low_spd, rmv_pkg
f_blbad3	factor containing lturn, nobel, door, close, restrict
f_blgood3	factor containing space, pace, expect, predict
f_biksafe1	factor containing runss, runrl, bikww, biksw
f_biksafe2	factor containing helmet, turnsig
f_biksafe1b	factor containing alt versions of runss, runrl, bikww, biksw
f_biksafe2b	factor containing alt versions of helmet, turnsig
f_evadebik	factor containing any of the evade variables
f_drivsafe1	factor containing comp_stp, ovr_lim, ror
f_drivsafe2	factor containing talk, text
f_drivsafe3	factor containing seatbelt
f_drivagg3	factor containing pass clos, beat turn, block bl, purp agg
f_drivoth3	factor containing honk, block merge, turn hit
f_drivattn3	factor containing door, disal-mg
f_changelaw	factor containing stop_yld, red_stop
f_knowslaws	factor containing knows_bllaw, knows_ridinglaw
f_othlaws	factor containing req_helmet, law_2abrst, drv_bl_turn
f_hitagg	factor for aggressive actions resulting in a collision
f_hitattn	factor for actions resulting in a collision from not paying attention
f_uncomf	factor containing bik_uncomf, pers_sfty, weather, hills, no_secpk, no_bl
f_imprac	factor containing long distance, bicycle impractical
f_wsafety	factor for worries of infrequent and potential cyclists

f_nearmiss1	factor containing half of the near misses
f_nearmiss2	factor containing the other types of near misses
f_wsafety	factor containing related safety variables
f_barsafety	factor containing related safety variables measured as usually or always impediments
f_wsafety2	factor for worries of frequent cyclists
f_sw	factor for strong worries

Table C2. Bi-variate Correlations between Key Variables

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
freq_dr			N*	N***				
drv_daily			N#	N***				
drv_1_3				**				
driv_weekly				N***				
dl			#		n/a			
freq_seebik				**		#		
red_drunk	#							
red_agg	N#	N*		N*			N#	N#
red_spd				N*	N#			
red_dist				N**				
red_run				***				
red_ww		N*		***				
red_jay	N**	N***	N#	***			*	**
chk_turn				***	*	*	#	#
pass_3				***			**	**
chk_pk		#		***	**	***		
awaredriver		#		***	***	***	**	**
stblt								
turn_sig								
comp_stp				#				
ovr_lim		N#		N*		N#		
ror							#	#
talk_cell	N*	N*						
text_cell								

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
safedriver	#	#						
carefuldriver	#		#					
mor_bik	N**	N*	*		*	*	***	***
fund_bik			***		*		***	***
low_spd	*		**					
rmv_pkg			**				*	
bik_desrt	***	***			N***	N***	N***	N***
bik_offst	***	***	#		N***	N***	N***	N***
bik_supp		N**	*		***	**	***	***
neg_funding			N*		N**	N*	N***	N**
neg_morbik	*	*			N*	N**	N***	N***
neg_lowspd	N#		N*					
neg_rmvpkg			N*		N*		N*	
neg_bikdesrt	N***	N***			*	**	**	***
neg_bikoffst	N**	N***	N**		***	***	***	***
disc_bik	***	*		N***			N*	N**
ff_bik			#	***	*	**		
know_bik			*	***	#	*		
netwk_bik	N#		*	***	**	**	#	#
bik_pres	**	*	#					
safer_laws	#	#	#	N**	N*	N*		
anx_trail	***	***	**	N***	N***	N***	N***	N***
bik_safsw	**	***		N***	N***	N***		N#
bik_sdang	*		#	N***	*	*		

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
drv_biksafety	***	***		N***	N***	N***	N**	N**
neut_bikpres								
mk_bikpres								
bik_res	N***	N**	N***	***	*	*	***	***
drv_res	N**	N*	N*		*	*	**	**
wlk_res			N**		#		***	***
bik_com	N***	N***	N***	**	***	***	***	***
drv_com	N*	N***	N*		#		*	**
wlk_com	N*	N***	N***	*	#		***	***
lowval_bikres	***	**	**		N**	N**	N***	N***
evade	*			N***				
bik_ranss				N***				
bik_ranrl				N***				
bik_nlt		#						
bik_nlk				N***	N*	N#	N*	N*
bik_ww			#					
bik_sw				N*				
ct_evade			#	N***				
endang_bik				**				
driver_notadmit				N*				
driv_endang								
door_hit_3								
pass_clos_3								
beat_turn_3			*					

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
block_bl_3				*				
disal_mg_3						#		
honk_3				N***			N#	
mg_hit_3			#					
purp_agg_3	*		#	N**				
turn_hit_3			*	N #				
freq_bik_util	N*	N*		***	*	**	*	*
bik_util_fut				***	**	**	#	#
freq_bik_rec				***	**	**	*	*
bik_rec_fut						N#		
never_bik				***				
bik_freq	N#	N#		***	***	***	**	**
subset								
bik_month				*		*		*
bik_week				***	#		*	#
bik_year				N #				
noncyclist				N***				
never_cyclist								
pot_cyclist				N***	N***	N***	N#	N#
infreq_cyclist								
freq_cyclist				***				
cyclist_type				***				
cyclist_type2	N#			***	***	***	**	**
cyclist_type3	N#				***	***	**	***

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
cyclist_type4								
cyclist_type5								
never_bik_bin				N***				
like_bike								
bik_wk_month					**	**	**	**
w_close				N**	N***	N***	N**	N**
w_cut				N*	N***	N***	N*	N**
w_mistk				N**	N**	N**	N*	N*
w_door					N#	N#		N#
nobal				N**	N*	N*		
w_attn				N #	N***	N***	N#	N*
w_agg				N**	N**	N***	N**	N***
w_fast				N*	N***	N***	N**	N***
w_fast_2					N**	N***		
w_cut_2				**				
w_mistk_2								
w_door_2				***				
w_attn_2					N***	N***	N#	
w_agg_2					N***	N***		
w_close_2				*	N*	N**		N#
w_safety				N**	N***	N***	N**	N***
w_safety_2				*	N**	N***		
strong_worry				N***	N***	N***	N*	N**
num_strongworry					N***	N***	N**	N***

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
ave_worry					N***	N***	N*	N**
sw_close					N***	N***	N*	N*
sw_fast				N*	N***	N***	N**	N***
sw_cut					N***	N***	N*	N**
sw_mistk				N*				
sw_door					N*	N*		
sw_attn					N***	N***	N*	N*
sw_agg				N #	N**	N**		N#
bar_wfast				N*	N***	N***	N**	N***
bar_wclose				N**	N***	N***	N*	N**
bar_wcut					N**	N**	N#	N*
bar_wdoor					N#	N*		
bar_wattn				N*	N***	N***	N#	N#
bar_wagg				N**	N***	N***	N**	N***
bar_wmistk				N**	N**	N**	N*	N*
wsafety_potcyclist				N***	N***	N***	N*	N*
wsafety_yearcyclist				N**				
wsafety_monthcyclist				*				
wsafety_weekcyclist				***				
bik_uncomf	***	***	#	N***	N**	N***	N**	N***
long_dist	#			N***	N***	N***		
no_bl	***	***	***	N*	N***	N***	N*	N**
embar	*	**	*	N***		N#		
hills	***	***	*	N***	N*	N*	N***	N***

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
weather	*	***		N*			N#	N#
bik_imprac	**		*	N***	N*	N*		
no_secpk	**	***	***		N*	N*	N*	N*
no_bik		#		N***	N#	N#	N*	N*
pers_sfty	***	***	***	N***			N*	N*
barriers	***	***	***	N***	N***	N***	N***	N***
bar_nobl	***	***	*	N#	N**	N***	N*	N*
bar_embar	#	**	**	N***	N#	N*		
bar_hills	***	***		N***	N*	N**	N*	N**
bar_weather		***		N***				
bar_imprac	#			N***	N*	N*		
bar_secpk	**	***	**			N#		N#
bar_persfty	***	***	*	N***			N*	N#
bar_uncomf	**	***		N*	N***	N***	N**	N**
bar_dist		#		N***	N***	N**		
bar_nobik								
ut_wbl				***	**	**	#	*
ut_wobl	N*			***	**	**	*	*
ut_offst				***				#
rec_wbl	N**	N**		***	***	***	*	*
rec_wobl	N***	N**		***	***	***	***	***
rec_offst	N*			***	#	#		
bsr_pass3_bo			*	***				
bsr_beat_turn_bo	*		***	***	N#			

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composite safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
bsr_blkln_bo			***	***				
bsr_blkmg_bo	#		***	***				
bsr_agg_bo	***	#	***	***				
bsr_honk_bo	**	#	***	***				
bsr_drvmg_bo		*	***	***				
bsr_hit_turn_bo	**		***	***			*	*
bsr_oth_bo				*				
bsr_door_bo			*	***				
bsr_nobik_bo	**	*		N***				
never_hit_bo	#			N***				
hit_pass3_bo								
hit_beat_turn_bo	#		*					
hit_blkln_bo			**				#	#
hit_blkmg_bo			#					
hit_agg_bo			*					
hit_honk_bo			**					
hit_drvmg_bo		#	*		N**	N**		
hit_turn_bo		#						
hit_oth_bo				*				
hit_door_bo				**		N#		
hit			*	***				
nearmiss			#	***				
ct_hit			**	#	N#	N*		
ct_nearmiss	**		***	***				

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
bik_dark	N**	N***		***				
bsr_lts			#	***			*	#
bsr_reflect		**						
bsr_runss				**				
bsr_runrl		*						
bsr_helmet	#			***				
bsr_sw	**	***		***	N*	N*		
bsr_ww	#	*						
bsr_turnsig		#						
safecyclist				**				
safecyclist2								
req_helmet				N #				
no_helmet	N*					#		
dk_helmet				#				
stop_yld				***				
y_stop_yld				***			*	*
red_stop				***				
y_red_stop				***			*	*
y_Idaho				***			*	*
contra_flow				*				
law_wtraf								
law_handsig								
law_lights								
law_none								

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
law_dk								N#
law_2abrst								
y_2abrst	N*			**				#
law_trafspd								
law_lturn								
law_ovtk				**				
law_debris								
law_always				N***			N*	N**
law_never			N#	***		#		
law_bl_dk	N#			N #			N*	N*
knows_bllaw				*			#	*
knows_ridinglaw								
laws_bikeln								
drv_bl_turn				N *				
drv_blturn_bin				N**				
knows_laws	#	#		N#				
long_city								
bl_incity								
bl_incity2				*				
clos_bl_home	**	***	#	N ***	N*	N*	N*	N*
bl_less1mi		N*		***				
bl_fewblocks	N**	N**	N*	**	**	**	*	**
city_morbik								
bky			N*	***	*	*		

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composite safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
SF	*	***						
OAK			**					
AlCo				***		#		
SFCo	*	***						
CCC	N*	N*		N**				
SMC								
SolC				N**		N#	N*	N*
SCC			n/a					
YoloCo								
SacC				N*				
PlacerC								
NapaC								
MarinC								
MontC								
unincorp								
BOSF				***	**	***		
learn_drv								
drved_bik								
drved_bin				N *				
bik_class				#				
ff_crsh_bik								
ff_crsh_bik2			#	***	*	*		*
bik_crsh_inj								
ff_crsh_drv								

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
ff_crsh_drv2				**				
drv_crsh_inj								
sex								
sex_bin		N**		#	*	**	***	***
age								
age2								
children				N #				
child_16								
child_sw	N*	N**		***			#	*
children_16	N*	N#						
advocate				***				
black				N *				
white	N#	N*		***	#		*	*
amerin								
nhpi								
asian	***	***		N ***			N#	N*
hisp				N #				
race_decl								
oth_race								
race_sum								
race								
hh_inc		N**			#	*	#	*
hh_inc2		N**			*	*	#	*
extra				***	n/a		n/a	

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
bo_bl_p	N***	N**	N***				***	***
bo_bsbl_p							***	*
bo_bl_np	N**	N**	N*	***			***	***
bo_bsbl_np				*			***	**
bo_nt_p	N***	N***	N**	#			***	***
bo_slm_p	N***	N***	N***	**			***	***
bo_psl_p	N***	N**	N#	***			***	***
bo_pbl_p	N**	N*	N***				***	***
bo_des_score	N***	N***	N**	***			***	***
bo_no_bsbl	N***	N***	N***	**			***	***
bo_only_bsbl				*			***	***
drv_bl_p	N**	N*	N#	**	***	***		
drv_bsbl_p				***	***	**		
drv_bl_np		N*		***	***	***		
drv_bsbl_np				***	***	*		
drv_nt_p	N*	N**	N*		***	***		
drv_slm_p	N*	N*	N#	***	***	***		
drv_psl_p	N**	N*		***	***	***		
drv_pbl_p		N*		**	***	***		
drv_des_score	N*	N**		***	***	***		
drv_no_bsbl	N**	N***		***	***	***		
drv_only_bsbl				***	***	**		
do_des_score								
bl_space				#	*	*	**	**

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
bl_lturn	***	#	**		N**	N***	N**	N**
bl_pace								
bl_nobel	***		***	N **	N**	N**	N**	N*
bl_door	**	*	**		N**	N**		N*
bl_expect		#						
bl_close								
bl_restrict	#		#					
bl_predict								
nodes_25		N#						
nnodes_25								
nodes_50								
nodes_1								
nodes_2								
walkscore		#						
leng1_1			N***	*				
leng1_2								
leng1_3								
leng25_1			N*					
leng25_2								
leng25_3								
leng50_1			N**	*				
leng50_2								
leng50_3	#							
traillen50			N*	#				

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
traillen1			N**					
traillen25	N#							
streets50			*	***	#	*		
streets25			**	**	#	*		
streets1			**	***	*	*		
all25			*	#	#	*		
all_ped25			*	#				
all_bike25				**				
fs_bike25			#	**				
fs_ped25		*						
all50			**	**				
all_ped50			*	**				
all_bike50			#	***				
fs_bike50			#	**				
fs_ped50				*				
all1			*	***				
all_ped1			*	**				
all_bike1				***	#	#		
fs_bike1				***				
fs_ped1			*	**				
all2			**	***	*	*	#	*
all_ped2			*	*	*	*	#	#
all_bike2			*	***	**	**	#	*
fs_bike2			*	***	*	**	*	*

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
fs_ped2			*	*	*	*	#	#
trvg10l_50			*					
trvl10_50			*	*		#		
trvg20_50			***					
trvg10l_1			**	*				
trvl10_1			***					
trvg20_1			**	*		#		
trvg10l_25			*					
trvl10_25	#		***					
trvg20_25			*		*	**		
pop2010_25			#	**				
white_25			#	***	#	*		
black_25			**	**				
asian_25	*	*						
hispan_25			#	*				
males_25	#		#	**				
female_25			#	**				
age_under_5_25				***				
age_5_9_25		#		***				
age_10_14_25				***				
age_15_19_25		*					N#	N#
age_20_24_25		*						
age_25_34_25			*	**		#		
age_35_44_25			*	**		#		

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
age_45_54_25		#		***				
age_55_64_25				***		#		
age_65_74_25				**		#		
age_75_84_25				#				
age_85up_25				#				
households_25			*	**		#		
ave_hh_size_25			N*	N*				
hse_units_25			*	**		#		
vacant_25			#	*				
owner_occ_25				***	#	*		#
renter_occ_25			*	*				
hhintotal_25								
tot_hh_nov_25								
ageg64_25				*				
med_hh_inc_25								
ageless18_25				***				
jobs_25			*					
meanhhinc_25			N#					
numwork_tot_25			*	**		#		
numwork_male_25			*	**		#		
numwork_fem_25			*	**	#	*		#
numbike_25				***				
numbike_male_25				***				
numbike_fem_25			#	***				

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
numauto_tot_25			#	*				
numauto_male_25				*				
numauto_fem_25			#	**		*		#
numwalk_tot_25				*				
numwalk_male_25				*				
numwalk_fem_25				#				
numpublic_tot_25			*	*		#		
numpublic_male_25			*	*				
numpublic_fem_25			#	*	#	#		
totalpop_25			#	**				
college_25		*						
gradsch_25			#	*				
highsch_25				***				
midsch_25				*				
elemsch_25				**				
tothh_25			*	**		#		
tothh0veh_25			#	*				
tothh1veh_25			*	*	#	*		
tothh2veh_25				***		#		#
tothh3veh_25				#				
tothh4veh_25		*						
houses_25			*	**		#		
houses_1940s_25				***	*	*		
houses_old1939_25	#		*	***	#	*		#

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
pct_houses_1950_25				***	*	**		
pct_tothh0veh_25			*	**				
pct_tothh1veh_25				*				
pct_tothh2veh_25			N*	N #				
pct_tothh3veh_25			N*	N***				
pct_tothh4veh_25			N*	N***	N#	N#		
pct_college_grad_25								
pct_highsch_25			N*					
pct_midsch_25			N*	N*	N*	N*		
pct_elemsch_25			N**	N #				
pct_enrhs_25								
pct_bike_25				***				
pct_bikem_25				***				
pct_bikef_25				***				
pct_auto_25			N#	N***	N*	N*		
pct_autom_25				N***	N**	N***		
pct_autof_25			N#	N**	N#	N#		
pct_walk_25								
pct_walkm_25					#	#		
pct_walkf_25								
pct_public_25			*	**	*	*		
pct_publicm_25			*	***	*	*		
pct_publicf_25	#	*	*	*	#	#		
pct_less18_25			N**	N #	N*	N*		

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composite safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
pct_1824_25		#						
pct_2534_25			**	#		#		
pct_3544_25			#	*				
pct_4554_25			N*					
pct_5564_25			N#					
pct_6574_25			N*					
pct_75ov_25			N#					
pop2010_50			*	**				
white_50			*	***	#	*		#
black_50			**	**				
asian_50	*	*						
hispan_50			*	*				
males_50		#	*	**				
female_50			*	**		#		
age_under_5_50			*	***				
age_5_9_50		#		***				
age_10_14_50		#		***				
age_15_19_50		**						
age_20_24_50		*						
age_25_34_50			**	**		#		
age_35_44_50			*	**		#		
age_45_54_50			#	***		#		
age_55_64_50				***	#	*		
age_65_74_50				***	#	*		#

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
age_75_84_50	#			*				
age_85up_50				*				#
households_50			*	**	#	*		#
ave_hh_size_50			N*	N**				
hse_units_50			*	**	#	#		#
vacant_50	#		*	*				
owner_occ_50				***	*	**		*
renter_occ_50			*	**				
hhintotal_50								
tot_hh_nov_50								
ageg64_50				**	#	#		#
med_hh_inc_50								
ageless18_50				***				
jobs_50			#					
meanhhinc_50								
numwork_tot_50			*	**	#	*		#
numwork_male_50			*	**		#		
numwork_fem_50			*	**	#	*		#
numbike_50				***				
numbike_male_50				***				
numbike_fem_50			*	***				
numauto_tot_50			*	*		#		#
numauto_male_50			*	*				
numauto_fem_50			*	*		*		*

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composite safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
numwalk_tot_50				#				
numwalk_male_50				*				
numwalk_fem_50				#				
numpublic_tot_50			*	*		#		
numpublic_male_50			*	**				
numpublic_fem_50			#	*		#		#
totalpop_50			*	**		#		
college_50		*						
gradsch_50			#	*	#	#		
highsch_50				***				
midsch_50				*				
elemsch_50				**				
tothh_50			*	**	#	*		#
tothh0veh_50			#	*				
tothh1veh_50			*	**	*	*		#
tothh2veh_50			#	***	#	*		#
tothh3veh_50				#				
tothh4veh_50		*			N*	N#		
houses_50			*	**	#	*		#
houses_1940s_50		*		***	*	*		
houses_old1939_50			*	***	#	*	#	#
pct_houses_1950_50				***	**	**		
pct_tothh0veh_50			*	**				
pct_tothh1veh_50				*				

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
pct_tothh2veh_50			N*	N*	N#	N#		
pct_tothh3veh_50			N*	N***	N#	N#		
pct_tothh4veh_50			N#	N***	N*	N*		
pct_college_grad_50								
pct_highsch_50			N**	N #		N#		
pct_midsch_50			N*	N*	N*	N*		
pct_elemsch_50			N*	N*	N#			
pct_enrhs_50								
pct_bike_50	N#			***				
pct_bikem_50	N#			***				
pct_bikef_50				***				
pct_auto_50				N***	N*	N**		
pct_autom_50				N***	N**	N**		
pct_autof_50				N***	N*	N*		
pct_walk_50								
pct_walkm_50					#	#		
pct_walkf_50								
pct_public_50			*	**	*	*		
pct_publicm_50			*	***	*	*		
pct_publicf_50		#	#	*	#	*		
pct_less18_50			N**	N #	N*	N*		
pct_1824_50		*						
pct_2534_50			**			#		
pct_3544_50			#					

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
pct_4554_50			N#					
pct_5564_50			N*					
pct_6574_50			N*					
pct_75ov_50			N*					
pop2010_1			**	**	#	*		#
white_1			*	**	*	*	#	*
black_1			***	**				#
asian_1	*	**						
hispan_1			**	*				
males_1			**	**	#	#		
female_1			**	***	#	*		#
age_under_5_1			**	**				
age_5_9_1			*	**				
age_10_14_1			#	*				
age_15_19_1		*						
age_20_24_1				*				
age_25_34_1			**	**	#	*		#
age_35_44_1			**	**	#	*		#
age_45_54_1			**	**		*		#
age_55_64_1			*	***	*	*		#
age_65_74_1	#		*	**	*	*		#
age_75_84_1	#	#		#		#		#
age_85up_1	*	#	#	#		#		#
households_1			**	**	*	*		*

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
ave_hh_size_1				N***	N#	N#		
hse_units_1			**	**	*	*	#	*
vacant_1			**	*		#		#
owner_occ_1			*	**	*	*		#
renter_occ_1			**	**	#	*		#
hhintotal_1								
tot_hh_nov_1								
ageg64_1	#		#	**	*	*		#
med_hh_inc_1				N*				
ageless18_1			*	***				
jobs_1			#					
meanhhinc_1				N #				
numwork_tot_1			**	**	#	*		#
numwork_male_1			**	**	#	*		#
numwork_fem_1			**	**	*	*		#
numbike_1			#	***	#	*		
numbike_male_1			*	***	#	#		
numbike_fem_1			*	***	#	*		
numauto_tot_1			**	*		*		#
numauto_male_1			**	#		#		#
numauto_fem_1			***	*		*		#
numwalk_tot_1			#	*				
numwalk_male_1			*	*				
numwalk_fem_1			#	*				

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
numpublic_tot_1			*	*		#		#
numpublic_male-1			*	*		#		
numpublic_fem_1			*	*		#		#
totalpop_1			**	**	#	*		#
college_1		#		#				
gradsch_1				***	*	*		
highsch_1				**				
midsch_1				#				
elemsch_1			*	*				
tothh_1			**	**	*	*	#	*
tothh0veh_1			*	*				
tothh1veh_1			**	**	*	**	#	*
tothh2veh_1			**	***	#	*		#
tothh3veh_1								
tothh4veh_1	#	#		N**	N*	N#		
houses_1			**	**	*	*	#	*
houses_1940s_1		*	#	***	*	*		
houses_old1939_1			**	***	*	*	#	*
pct_houses_1950_1				***	*	**		
pct_tothh0veh_1			*	**	*	*		
pct_tothh1veh_1				**	#	#		#
pct_tothh2veh_1			N*	N**	N*	N*	N#	N*
pct_tothh3veh_1			N*	N***	N*	N*		
pct_tothh4veh_1			N#	N***	N*	N**		

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
pct_college_grad_1								
pct_highsch_1			N**	N**	N#	N*		
pct_midsch_1			N*	N***	N**	N**		
pct_elemsch_1			N*	N**	N*	N*		
pct_enrhs_1								
pct_bike_1	N#			***		#		
pct_bikem_1	N#			***		#		
pct_bikef_1	N#			***				
pct_auto_1				N***	N**	N**		
pct_autom_1			N#	N***	N**	N**		
pct_autof_1				N***	N**	N**		
pct_walk_1				*	#	#		
pct_walkm_1				*	#	#		
pct_walkf_1				*				
pct_public_1			*	**	*	*		
pct_publicm_1			*	**	*	*		
pct_publicf_1			#	*	#	*		
pct_less18_1			N*	N*	N*	N*		
pct_1824_1								
pct_2534_1			***	#	*	*	#	*
pct_3544_1			*					
pct_4554_1				N**	N#	N#		
pct_5564_1								N#
pct_6574_1			N*					

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
pct_75ov_1								
fam25				***				
povl50_25								
povg75_25	*	*		***				
ppovl50_25								
ppovg75_25	*	*						
fam50				***		#		
povl50_50				**				
povg75_50	*	*		**				
ppovl50_50								
ppovg75_50		#						
fam1			*	***	#	*		#
povl50_1			*	***				
povg75_1	#		**	**				
ppovl50_1				**				
ppovg75_1			*					
fam2			**	*	#	*		#
povl50_2			***	***		#		#
povg75_2			***	#				
ppovl50_2			#	**				
ppovg75_2			**					
land_sq_mi	*	#	**					
pop_dens	#	**		*	*	**		
pop_quart		**		**	**	**		

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
hous_dens	#	**		*	*	*		
ipop_quart_2								
ipop_quart_3								
ipop_quart_4								
f_biksupp	N***	N***	N*		***	***	***	***
f_bikrt	*		***					
f_red_car				N*				
f_red_bikeped	N*	N**		***				#
f_awaredriv								
f_bikoffst								
f_awaredriv2								
f_netwkbik2								
f_drivanx								
f_discbik								
f_morbike								
f_travsafe								
f_blbad3								
f_blgood3								
f_biksafe1								
f_biksafe2								
f_biksafe1b								
f_biksafe2b								
f_evadebik								
f_drivsafe1								

Variable Name	bi-var corr to strong_ worry	bi-var corr to composite safety varb –pot & infreq cyclists	bi-var corr to composi te safety varb – freq cyclists	bi-var corr to bike support	bi-var corr to bike des score	bi-var corr to bike des score-no barrier sep	bi-var corr to driver des score	bi-var corr to driv des score-no barrier sep
f_drivsafe2								
f_drivsafe3								
f_drivagg3								
f_drivoth3								
f_drivattn3								
f_changelaw								
f_knowslaws								
f_othlaws								
f_hitagg								
f_hitattn								
f_hitoth								
f_uncomf	***	***	***	N**	N**	N***	N***	N***
f_imprac	#			N***	N**	N**		
f_wsafety								
f_nearmiss1								
f_nearmiss2								
f_wsafety								
f_barsafety								
f_wsafety2								
f_sw								

Significant correlation between variables at the following levels:
= $p \leq 0.10$; * = $p \leq 0.05$; ** = $p \leq 0.01$; *** = $p \leq 0.001$
N indicates negative correlation

Appendix D – Additional Tables and Figures

This appendix contains additional information about the survey respondents and the data presented in this dissertation.

Table D1. Respondents' Agreement or Disagreement with Statements about Bicycling in One's City (N=461)

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Would like to see more cyclists in city	34%	31%	26%	6%	3%
Support using public funding to encourage cycling	30%	34%	18%	13%	6%
Would support a 20 mph speed limit to encourage cycling	10%	16%	20%	35%	19%
Would support removing some car parking along major streets to provide bike lanes	20%	32%	12%	24%	13%
Bicyclists should ride on designated bike routes	22%	20%	17%	29%	13%
Bicyclists should be restricted to off-street paths	6%	10%	19%	33%	32%

Table D2. Percentage of Respondents who Agree or Strongly Agree with Statements about Support for Bicycling, by Bicycling Frequency (N=463)

	Non-cyclists (n=192) %	Occasional Cyclists (n=169) %	Regular Cyclists (n=102) %
Would like to see more cyclists in city, but think bicyclists should be restricted to off-street paths	5	4	6
Would like to see more cyclists in city, but think bicyclists should ride only on designated bike routes	19	23	16
Would like to see more cyclists in city, but do not support public funding to encourage cycling	5	5	3
Would like to see more cyclists in city, but would not support a 20 mph speed limit to encourage cycling	19	31	43
Would like to see more cyclists in city, but would not support removing some car parking along major streets in order to provide bike lanes	3	11	17

Table D3. Percentage of Respondents Usually or Always Affected by Various Barriers to Bicycling (N=411)

	Potential Cyclists		**Occasional Cyclists**		**Regular Cyclists**	
	Never (n=68) %	Less than once/ year (n=73) %	Few times/ year (n=98) %	Several times/ month (n=71) %	Several times/ week (n=75) %	Daily (n=26) %
Fundamental barriers to bicycling for a majority of people						
Trip distance too long to bicycle***	**63**	58	64	45	28	**8**
Bicycling impractical due to need to carry things or people***	**59**	51	64	39	32	**4**
Don’t have regular access to bicycle***	**84**	38	11	4	4	**4**

Probable barriers to bicycling for some people						
Worried that I'll be hit by a driver not paying attention	43	32	33	30	49	54
Worried that drivers will drive too fast near me	40	23	27	22	23	34
Too many hills***	**39**	42	34	24	9	**8**
No secure bicycle parking at destination	36	27	26	15	23	15
Worried that drivers will drive too close to me	34	19	26	26	42	38
Worried that drivers will cut me off while turning	30	21	19	28	44	59
No bicycle lanes or routes where need to travel#	22	24	32	26	12	12
Possible barriers to bicycling for a few people						
Concerns about personal safety from crime*	24	19	19	7	8	8
Worried that I will make a mistake that will endanger me or others	23	12	10	10	23	16
Worried that drivers will be intentionally aggressive toward me	18	13	16	13	23	13
Bicycling uncomfortable due to local roadway quality	18	13	14	8	11	8
Worried that I'll be hit by a car door	16	16	13	13	42	46
Weather discourages bicycling	12	4	4	4	7	12
Feel embarrassed riding bike other than for recreation	9	4	6	1	1	-
I don't have enough balance to bike without falling off	4	5	2	3	n/a	n/a

Significant difference between non- and potential cyclists, occasional cyclists, and regular cyclists at the following levels: # = $p \leq 0.10$; * = $p \leq 0.05$; ** = $p \leq 0.01$; *** = $p \leq 0.001$

Table D4. Percentage of Respondents who Agree or Strongly Agree with Statements about Support for Bicycling, by Bicycling Frequency (N=463)

	Non-cyclists (n=45) %	**Potential cyclists** (n=145) %	**Yearly cyclists** (n=100) %	**Monthly cyclists** (n=71) %	**Weekly cyclists** (n=76) %	**Daily cyclists** (n=26) %
(+) Would like to see more cyclists in city***	38	50	59	83	91	96
(+) Support using public funding to encourage cycling***	40	58	53	69	88	96
(+) Would support removing some car parking along major streets in order to provide bike lanes***	33	42	48	58	70	81
(+/-) Would support a 20 mph speed limit to encourage cycling**	22	17	21	36	37	44
(-) Bicyclists should ride only on designated bike routes***	**53**	**54**	**46**	37	18	15
(-) Bicyclists should be restricted to off-street paths***	**29**	**24**	13	10	5	**8**

Significant differences indicated by the following: ** = $p \leq 0.01$, *** = $p \leq 0.001$

Table D5. Percentage of Respondents Ranking Roadway Designs as at Least Moderately Comfortable as a Driver (N=261)

	Non-cyclist (n=36) %	**Potential cyclist** (n=74) %	**Yearly Cyclist** (n=51) %	**Monthly Cyclist** (n=38) %	**Weekly Cyclist** (n=46) %	**Daily Cyclist** (n=18) %
Barrier-separated space						
Barrier-separated bike lane, no parking	**91**	**86**	**86**	**89**	**91**	**94**
Barrier-separated bike lane next to parking	78	86	82	84	93	89
Marked, separated space						
Striped bike lane, no parking***	72	74	82	92	96	94
Green painted bike lane next to parking#	72	72	82	84	73	83
Striped bike lane next to parking#	54	67	71	82	67	83
Shared space						
No treatment, on-street parking	64	61	59	71	57	56
Shared lane marking next to parking (sharrow)*	39	42	49	59	52	67
Painted shared lane next to parking	**31**	**37**	**41**	**42**	**41**	**56**

Significant differences between groups indicated by the following: # = $p \leq 0.10$, * = $p \leq 0.05$, *** $p \leq 0.001$

Table D6. Percentage of Respondents Ranking Roadway Designs as at Least Moderately Comfortable as a Bicyclist (N=224)

	Potential cyclist (n=73) %	Yearly Cyclist (n=49) %	Monthly Cyclist (n=38) %	Weekly Cyclist (n=47) %	Daily Cyclist (n=18) %
Barrier-separated space					
Barrier-separated bike lane, no parking	**92**	**90**	**87**	**91**	**100**
Barrier-separated bike lane next to parking	81	86	86	87	83
Marked, separated space					
Striped bike lane, no parking*	61	80	79	87	82
Green painted bike lane next to parking*	41	65	68	52	71
Striped bike lane next to parking**	20	47	58	40	50
Shared space					
Shared lane markings (sharrow) next to parking**	11	17	18	23	28
Painted shared lane next to parking*	7	20	19	30	33
No treatment, on-street parking*	**3**	**10**	**13**	**9**	**6**

Significant differences between groups indicated by the following: * = $p \leq 0.05$, ** = $p \leq 0.01$

Table D7. Percentage of Highest Priority Rankings for Local Transportation Issues, by Bicycling Frequency

	Non & Potential cyclists (n=187) %	**Occasional cyclists** (n=164) %	**Regular cyclists** (n=96) %	**Total** (N=447) %
Reduce drunk driving	45	44	39	43
Reduce distracted driving	36	35	39	36
Reduce aggressive driving	22	27	26	25
Reduce speeding	24	20	16	21
Reduce cyclists' red light & stop sign running	21	16	14	17
Reduce cyclists' wrong-way riding	15	10	12	12
Reduce jaywalking by pedestrians	12	12	14	12
	Chi Square not significant			

Table D8. The Extent to which Various Traffic Risks Influence Potential, Yearly, and Monthly Bicyclists' Decision to Ride a Bicycle for any Purpose (n=312)

	Strong Influence	Some Influence	No Influence
Worry that I'll be hit by a driver not paying attention	34%	27%	18%
Worry that drivers will drive too fast near me	28%	25%	26%
Worry that drivers will drive too close to me	26%	29%	23%
Worry that drivers will cut me off while turning	24%	26%	30%
Worry that I'll be hit by a car door	14%	25%	34%
Worry that drivers will be intentionally aggressive toward me	15%	20%	42%
Worry that I will make a mistake that will endanger me or others	13%	22%	44%
I don't have enough balance to bike without falling off	4%	6%	80%

Response options included strong influence/some influence/slight influence/no influence

Appendix E – SWITRS Crash Types and Traffic Violations

As discussed in Chapter Nine, SWITRS data can be sorted by crash type, traffic violation, and California Vehicle Code violation. This chapter contains definitions for these three categories.

Collision Investigation Manual: Type of Collision (California Highway Patrol, 2003)

1. **Head-On**. Two motor vehicles, approaching from opposite directions, make direct contact. For example, the front of one vehicle collides with the front of another. Or prior to impact, one vehicle skids sideways, causing the side of the skidding vehicle to collide with the front of the other.

2. **Sideswipe**. One motor vehicle strikes the side of another with a glancing blow. For example, two vehicles are proceeding in the same direction or from opposite directions, and the side of one vehicle strikes the side of the other. 4-13 HPM 110.5

3. **Rear End**. Two motor vehicles, traveling in the same direction, make direct contact. For example, the front of one vehicle strikes the rear of another vehicle, or Vehicle #1 approaches Vehicle #2 from the rear and skids sideways during a braking action, causing the side of Vehicle #1 to strike the rear of Vehicle #2.

4. **Broadside**. One motor vehicle strikes another vehicle at an angle greater than that of a sideswipe.

5. **Hit Object**. A motor vehicle strikes a fixed object or other object.

6. **Overturned**. A motor vehicle overturns and no prior collision caused the overturning. This would include a motorcyclist losing control, causing the vehicle to lie down on its side. Do not use when the vehicle hits an object and then overturns.

7. **Vehicle/Pedestrian**. A vehicle strikes a pedestrian.

8. **Other**. A collision not covered in the preceding elements. This entry shall be explained in the narrative, such as a vehicle involved with:

(a) A bicycle, train, or animal.

(b) An automobile fire.

(c) Passengers falling or jumping from a vehicle.

(d) A vehicle backing.

(e) A bicycle involved with a pedestrian or another bicycle.

Table E1. California Vehicle Code: Traffic Violations

SWITRS Traffic Violation	Common CA Vehicle Code Violation
Unsafe lane change	Laned roadway
Improper passing	Overtaking on the left Passing with insufficient clearance Passion on the right
Following too closely	
Other hazardous violation	Bicycling while intoxicated Wrong way down one-way street Violation of green arrow or light Driving on sidewalk Permitted movements from bike lanes Driving in bicycle lane Failure to heed regulatory sign Hitting cyclist with car door
Lights	Failure to use required equipment
Unsafe speed	Unsafe speed for conditions (e.g., weather, roadway design, etc.)
Improper turning	Driver crossed bike lane before turning General turning Turn prohibited U-turn in business area U-turn in residential area Improper use of turn signal
Other improper driving	Other improper driving
Auto ROW	Red light violation Intersection right-of-way violation Failure to yield for left turn Stop sign violation Yield sign violation Roadway entry violation
Wrong side of road	Drove left of double lines Drove on wrong side of road Drove on wrong side of divided highway Wrong lane positioning
Traffic signals & signs	Red light violation Stop line violation

Source: California Vehicle Code (California Department of Motor Vehicles, 2013)

Table E2. California Vehicle Code: Code Definitions

CA Vehicle Code Section	CA Vehicle Code Definition
Accidents and Accident Reports	
20001 – Duty to Stop at Scene of Accident	(a) The driver of a vehicle involved in an accident resulting in injury to a person, other than himself or herself, or in the death of a person shall immediately stop the vehicle at the scene of the accident and shall fulfill the requirements of Sections 20003 and 20004. (b) (1) Except as provided in paragraph (2), a person who violates subdivision (a) shall be punished by imprisonment in the state prison, or in a county jail for not more than one year, or by a fine of not less than one thousand dollars ($1,000) nor more than ten thousand dollars ($10,000), or by both that imprisonment and fine . (2) If the accident described in subdivision (a) results in death or permanent, serious injury, a person who violates subdivision (a) shall be punished by imprisonment in the state prison for two, three, or four years, or in a county jail for not less than 90 days nor more than one year, or by a fine of not less than one thousand dollars ($1,000) nor more than ten thousand dollars ($10,000), or by both that imprisonment and fine. However, the court, in the interests of justice and for reasons stated in the record, may reduce or eliminate the minimum imprisonment required by this paragraph. (3) In imposing the minimum fine required by this subdivision, the court shall take into consideration the defendant's ability to pay the fine and, in the interests of justice and for reasons stated in the record, may reduce the amount of that minimum fine to less than the amount otherwise required by this subdivision. (c) A person who flees the scene of the crime after committing a violation of Section 191.5 of, or paragraph (1) of subdivision (c) of Section 192 of the Penal Code, upon conviction of any of those sections, in addition and consecutive to the punishment prescribed, shall be punished by an additional term of imprisonment of five years in the state prison. This additional term shall not be imposed unless the allegation is charged in the accusatory pleading and admitted by the defendant or found to be true by the trier of fact. The court shall not strike a finding that brings a person within the provisions of this subdivision or an allegation made pursuant to this subdivision. (d) As used in this section, "permanent, serious injury" means the loss or permanent impairment of function of a bodily member or organ.
20002 – Permissible Action: Duty Where Property Damaged	(a) The driver of any vehicle involved in an accident resulting only in damage to any property, including vehicles, shall immediately stop the vehicle at the nearest location that will not impede traffic or otherwise jeopardize the safety of other motorists. Moving the vehicle in accordance with this subdivision does not affect the question of fault. The driver shall also immediately do either of the following: (1) Locate and notify the owner or person in charge of that property of the name and address of the driver and owner of the vehicle involved and, upon locating the driver of any other vehicle involved or the owner or person in charge of any damaged property, upon being requested, present his or her driver's license, and vehicle registration, to the other driver, property owner, or person in charge of that property. The information presented shall include the current residence address of the driver and of the registered owner. If the registered owner of an involved vehicle is present at the scene, he or she shall also, upon request, present his or her driver's license information, if available, or other valid identification to the other involved parties. (2) Leave in a conspicuous place on the vehicle or other property damaged a written notice giving the name and address of the driver and of the owner of the vehicle involved and a statement of the circumstances thereof and shall without unnecessary delay notify the police department of the city wherein the collision occurred or, if the collision occurred in unincorporated territory, the local

	headquarters of the Department of the California Highway Patrol. (b) Any person who parks a vehicle which, prior to the vehicle again being driven, becomes a runaway vehicle and is involved in an accident resulting in damage to any property, attended or unattended, shall comply with the requirements of this section relating to notification and reporting and shall, upon conviction thereof, be liable to the penalties of this section for failure to comply with the requirements. (c) Any person failing to comply with all the requirements of this section is guilty of a misdemeanor and, upon conviction thereof, shall be punished by imprisonment in the county jail not exceeding six months, or by a fine not exceeding one thousand dollars ($1,000), or by both that imprisonment and fine.
20003 – Duty Upon Injury or Death	(a) The driver of any vehicle involved in an accident resulting in injury to or death of any person shall also give his or her name, current residence address, the names and current residence addresses of any occupant of the driver's vehicle injured in the accident, the registration number of the vehicle he or she is driving, and the name and current residence address of the owner to the person struck or the driver or occupants of any vehicle collided with, and shall give the information to any traffic or police officer at the scene of the accident. The driver also shall render to any person injured in the accident reasonable assistance, including transporting, or making arrangements for transporting, any injured person to a physician, surgeon, or hospital for medical or surgical treatment if it is apparent that treatment is necessary or if that transportation is requested by any injured person. (b) Any driver or injured occupant of a driver's vehicle subject to the provisions of subdivision (a) shall also, upon being requested, exhibit his or her driver's license, if available, or, in the case of an injured occupant, any other available identification, to the person struck or to the driver or occupants of any vehicle collided with, and to any traffic or police officer at the scene of the accident.
Operation of Bicycles	
21200 – Laws Applicable to Bicycle User: Peace Officer Exemption	(a) A person riding a bicycle or operating a pedicab upon a highway has all the rights and is subject to all the provisions applicable to the driver of a vehicle by this division, including, but not limited to, provisions concerning driving under the influence of alcoholic beverages or drugs, and by Division 10 (commencing with Section 20000), Section 27400, Division 16.7 (commencing with Section 39000), Division 17 (commencing with Section 40000.1), and Division 18 (commencing with Section 42000), except those provisions which by their very nature can have no application. (b) (1) A peace officer, as defined in Chapter 4.5 (commencing with Section 830) of Title 3 of Part 2 of the Penal Code, operating a bicycle during the course of his or her duties is exempt from the requirements of subdivision (a), except as those requirements relate to driving under the influence of alcoholic beverages or drugs, if the bicycle is being operated under any of the following circumstances: (A) In response to an emergency call. (B) While engaged in rescue operations. (C) In the immediate pursuit of an actual or suspected violator of the law. (2) This subdivision does not relieve a peace officer from the duty to operate a bicycle with due regard for the safety of all persons using the highway.

21201 – Equipment Requirements	(a) No person shall operate a bicycle on a roadway unless it is equipped with a brake which will enable the operator to make one braked wheel skid on dry, level, clean pavement. (b) No person shall operate on the highway a bicycle equipped with handlebars so raised that the operator must elevate his hands above the level of his shoulders in order to grasp the normal steering grip area. (c) No person shall operate upon a highway a bicycle that is of a size that prevents the operator from safely stopping the bicycle, supporting it in an upright position with at least one foot on the ground, and restarting it in a safe manner. (d) A bicycle operated during darkness upon a highway, a sidewalk where bicycle operation is not prohibited by the local jurisdiction, or a bikeway, as defined in Section 890.4 of the Streets and Highways Code, shall be equipped with all of the following: (1) A lamp emitting a white light that, while the bicycle is in motion, illuminates the highway, sidewalk, or bikeway in front of the bicyclist and is visible from a distance of 300 feet in front and from the sides of the bicycle. (2) A red reflector on the rear that shall be visible from a distance of 500 feet to the rear when directly in front of lawful upper beams of headlamps on a motor vehicle. (3) A white or yellow reflector on each pedal, shoe, or ankle visible from the front and rear of the bicycle from a distance of 200 feet. (4) A white or yellow reflector on each side forward of the center of the bicycle, and a white or red reflector on each side to the rear of the center of the bicycle, except that bicycles that are equipped with reflectorized tires on the front and the rear need not be equipped with these side reflectors. (e) A lamp or lamp combination, emitting a white light, attached to the operator and visible from a distance of 300 feet in front and from the sides of the bicycle, may be used in lieu of the lamp required by paragraph (1) of subdivision (d).
21202 – Operation on Roadway	(a) Any person operating a bicycle upon a roadway at a speed less than the normal speed of traffic moving in the same direction at that time shall ride as close as practicable to the right-hand curb or edge of the roadway except under any of the following situations: (1) When overtaking and passing another bicycle or vehicle proceeding in the same direction. (2) When preparing for a left turn at an intersection or into a private road or driveway. (3) When reasonably necessary to avoid conditions (including, but not limited to, fixed or moving objects, vehicles, bicycles, pedestrians, animals, surface hazards, or substandard width lanes) that make it unsafe to continue along the right-hand curb or edge, subject to the provisions of Section 21656. For purposes of this section, a "substandard width lane" is a lane that is too narrow for a bicycle and a vehicle to travel safely side by side within the lane. (4) When approaching a place where a right turn is authorized. (b) Any person operating a bicycle upon a roadway of a highway, which highway carries traffic in one direction only and has two or more marked traffic lanes, may ride as near the left-hand curb or edge of that roadway as practicable.
21203 – Hitching Rides	No person riding upon any motorcycle, motorized bicycle, bicycle, coaster, roller skates, sled, or toy vehicle shall attach the same or himself to any streetcar or vehicle on the roadway.

21204 – Riding on Bicycle	(a) A person operating a bicycle upon a highway shall not ride other than upon or astride a permanent and regular seat attached thereto, unless the bicycle was designed by the manufacturer to be ridden without a seat. (b) An operator shall not allow a person riding as a passenger, and a person shall not ride as a passenger, on a bicycle upon a highway other than upon or astride a separate seat attached thereto. If the passenger is four years of age or younger, or weighs 40 pounds or less, the seat shall have adequate provision for retaining the passenger in place and for protecting the passenger from the moving parts of the bicycle.
21208 – Permitted Movements from Bicycle Lanes	(a) Whenever a bicycle lane has been established on a roadway pursuant to Section 21207, any person operating a bicycle upon the roadway at a speed less than the normal speed of traffic moving in the same direction at that time shall ride within the bicycle lane, except that the person may move out of the lane under any of the following situations: (1) When overtaking and passing another bicycle, vehicle, or pedestrian within the lane or about to enter the lane if the overtaking and passing cannot be done safely within the lane. (2) When preparing for a left turn at an intersection or into a private road or driveway. (3) When reasonably necessary to leave the bicycle lane to avoid debris or other hazardous conditions. (4) When approaching a place where a right turn is authorized. (b) No person operating a bicycle shall leave a bicycle lane until the movement can be made with reasonable safety and then only after giving an appropriate signal in the manner provided in Chapter 6 (commencing with Section 22100) in the event that any vehicle may be affected by the movement.
21209 – Motor Vehicles and Motorized Bicycles in Bicycle Lanes	(a) No person shall drive a motor vehicle in a bicycle lane established on a roadway pursuant to Section 21207 except as follows: (1) To park where parking is permitted. (2) To enter or leave the roadway. (3) To prepare for a turn within a distance of 200 feet from the intersection. (b) This section does not prohibit the use of a motorized bicycle in a bicycle lane, pursuant to Section 21207.5, at a speed no greater than is reasonable or prudent, having due regard for visibility, traffic conditions, and the condition of the roadway surface of the bicycle lane, and in a manner which does not endanger the safety of bicyclists.
21211 – Obstruction of Bikeways or Bicycle Paths or Trails	(a) No person may stop, stand, sit, or loiter upon any class I bikeway, as defined in subdivision (a) of Section 890.4 of the Streets and Highways Code, or any other public or private bicycle path or trail, if the stopping, standing, sitting, or loitering impedes or blocks the normal and reasonable movement of any bicyclist. (b) No person may place or park any bicycle, vehicle, or any other object upon any bikeway or bicycle path or trail, as specified in subdivision (a), which impedes or blocks the normal and reasonable movement of any bicyclist unless the placement or parking is necessary for safe operation or is otherwise in compliance with the law. (c) This section does not apply to drivers or owners of utility or public utility vehicles, as provided in Section 22512. (d) This section does not apply to owners or drivers of vehicles who make brief stops while

	engaged in the delivery of newspapers to customers along the person's route. (e) This section does not apply to the driver or owner of a rubbish or garbage truck while actually engaged in the collection of rubbish or garbage within a business or residence district if the front turn signal lamps at each side of the vehicle are being flashed simultaneously and the rear turn signal lamps at each side of the vehicle are being flashed simultaneously. (f) This section does not apply to the driver or owner of a tow vehicle while actually engaged in the towing of a vehicle if the front turn signal lamps at each side of the vehicle are being flashed simultaneously and the rear turn signal lamps at each side of the vehicle are being flashed simultaneously.
Traffic Signs, Signals, and Markings – Erection and Maintenance	
21367 – Traffic Control: Highway Construction	(a) As provided in Section 125 of the Streets and Highways Code and in Section 21100 of this code, respectively, the duly authorized representative of the Department of Transportation or local authorities, with respect to highways under their respective jurisdictions, including, but not limited to, persons contracting to perform construction, maintenance, or repair of a highway, may, with the approval of the department or local authority, as the case may be, and while engaged in the performance of that work, restrict the use of, and regulate the movement of traffic through or around, the affected area whenever the traffic would endanger the safety of workers or the work would interfere with or endanger the movement of traffic through the area. Traffic may be regulated by warning signs, lights, appropriate control devices, or by a person or persons controlling and directing the flow of traffic. (b) It is unlawful to disobey the instructions of a person controlling and directing traffic pursuant to subdivision (a). (c) It is unlawful to fail to comply with the directions of warning signs, lights, or other control devices provided for the regulation of traffic pursuant to subdivision (a).
Offenses Relating to Traffic Devices	
21451 – Circular Green or Green Arrow	(a) A driver facing a circular green signal shall proceed straight through or turn right or left or make a U-turn unless a sign prohibits a U-turn. Any driver, including one turning, shall yield the right-of-way to other traffic and to pedestrians lawfully within the intersection or an adjacent crosswalk. (b) A driver facing a green arrow signal, shown alone or in combination with another indication, shall enter the intersection only to make the movement indicated by that green arrow or any other movement that is permitted by other indications shown at the same time. A driver facing a left green arrow may also make a U-turn unless prohibited by a sign. A driver shall yield the right-of-way to other traffic and to pedestrians lawfully within the intersection or an adjacent crosswalk. (c) A pedestrian facing a circular green signal, unless prohibited by sign or otherwise directed by a pedestrian control signal as provided in Section 21456, may proceed across the roadway within any marked or unmarked crosswalk, but shall yield the right-of-way to vehicles lawfully within the intersection at the time that signal is first shown. (d) A pedestrian facing a green arrow turn signal, unless otherwise directed by a pedestrian control signal as provided in Section 21456, shall not enter the roadway.
21453 – Circular Red or Red Arrow	(a) A driver facing a steady circular red signal alone shall stop at a marked limit line, but if none, before entering the crosswalk on the near side of the intersection or, if none, then before entering the intersection, and shall remain stopped until an indication to proceed is shown, except as

	provided in subdivision (b). (b) Except when a sign is in place prohibiting a turn, a driver, after stopping as required by subdivision (a), facing a steady circular red signal, may turn right, or turn left from a one-way street onto a one-way street. A driver making that turn shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to any vehicle that has approached or is approaching so closely as to constitute an immediate hazard to the driver, and shall continue to yield the right-of-way to that vehicle until the driver can proceed with reasonable safety. (c) A driver facing a steady red arrow signal shall not enter the intersection to make the movement indicated by the arrow and, unless entering the intersection to make a movement permitted by another signal, shall stop at a clearly marked limit line, but if none, before entering the crosswalk on the near side of the intersection, or if none, then before entering the intersection, and shall remain stopped until an indication permitting movement is shown. (d) Unless otherwise directed by a pedestrian control signal as provided in Section 21456, a pedestrian facing a steady circular red or red arrow signal shall not enter the roadway.
21456 – Walk, Wait, or Don't Walk	Whenever a pedestrian control signal showing the words "WALK" or "WAIT" or "DON'T WALK" or other approved symbol is in place, the signal shall indicate as follows: (a) "WALK" or approved "Walking Person" symbol. A pedestrian facing the signal may proceed across the roadway in the direction of the signal, but shall yield the right-of-way to vehicles lawfully within the intersection at the time that signal is first shown. (b) Flashing or steady "DON'T WALK" or "WAIT" or approved "Upraised Hand" symbol. No pedestrian shall start to cross the roadway in the direction of the signal, but any pedestrian who has partially completed crossing shall proceed to a sidewalk or safety zone or otherwise leave the roadway while the "WAIT" or "DON'T WALK" or approved "Upraised Hand" symbol is showing.
21457 – Flashing Signals	Whenever an illuminated flashing red or yellow light is used in a traffic signal or with a traffic sign, it shall require obedience by drivers as follows: (a) Flashing red (stop signal): When a red lens is illuminated with rapid intermittent flashes, a driver shall stop at a clearly marked limit line, but if none, before entering the crosswalk on the near side of the intersection, or if none, then at the point nearest the intersecting roadway where the driver has a view of approaching traffic on the intersecting roadway before entering it, and the driver may proceed subject to the rules applicable after making a stop at a stop sign. (b) Flashing yellow (caution signal): When a yellow lens is illuminated with rapid intermittent flashes, a driver may proceed through the intersection or past the signal only with caution.
21460 – Double Lines	(a) If double parallel solid yellow lines are in place, a person driving a vehicle shall not drive to the left of the lines, except as permitted in this section. (b) If double parallel solid white lines are in place, a person driving a vehicle shall not cross any part of those double solid white lines, except as permitted in this section or Section 21655.8. ((c) If the double parallel lines, one of which is broken, are in place, a person driving a vehicle shall not drive to the left of the lines, except as follows: (1) If the driver is on the side of the roadway in which the broken line is in place, the driver may cross over the double lines or drive to the left of the double lines when overtaking or passing other vehicles. (2) As provided in Section 21460.5 (Two-Way Left Turn Lanes).

	(d) The markings as specified in subdivision (a), (b), or (c) do not prohibit a driver from crossing the marking if (1) turning to the left at an intersection or into or out of a driveway or private road, or (2) making a Uturn under the rules governing that turn, and the markings shall be disregarded when authorized signs have been erected designating offcenter traffic lanes as permitted pursuant to Section 21657. (e) Raised pavement markers may be used to simulate painted lines described in this section if the markers are placed in accordance with standards established by the Department of Transportation.
21461 – Obedience by Driver to Official Traffic Control Devices	(a) It is unlawful for a driver of a vehicle to fail to obey a sign or signal defined as regulatory in the federal Manual on Uniform Traffic Control Devices, or a Department of Transportation approved supplement to that manual of a regulatory nature erected or maintained to enhance traffic safety and operations or to indicate and carry out the provisions of this code or a local traffic ordinance or resolution adopted pursuant to a local traffic ordinance, or to fail to obey a device erected or maintained by lawful authority of a public body or official. (b) Subdivision (a) does not apply to acts constituting violations under Chapter 9 (commencing with Section 22500) of this division or to acts constituting violations of a local traffic ordinance adopted pursuant to Chapter 9 (commencing with Section 22500).
Driving on Right Side	
21650 – Right Side of Roadway	Upon all highways, a vehicle shall be driven upon the right half of the roadway, except as follows: (a) When overtaking and passing another vehicle proceeding in the same direction under the rules governing that movement. (b) When placing a vehicle in a lawful position for, and when the vehicle is lawfully making, a left turn. (c) When the right half of a roadway is closed to traffic under construction or repair. (d) Upon a roadway restricted to one-way traffic. (e) When the roadway is not of sufficient width. (f) When the vehicle is necessarily traveling so slowly as to impede the normal movement of traffic, that portion of the highway adjacent to the right edge of the roadway may be utilized temporarily when in a condition permitting safe operation. (g) This section does not prohibit the operation of bicycles on any shoulder of a highway, on any sidewalk, on any bicycle path within a highway, or along any crosswalk or bicycle path crossing, where the operation is not otherwise prohibited by this code or local ordinance.
21651 – Divided Highways	(a) Whenever a highway has been divided into two or more roadways by means of intermittent barriers or by means of a dividing section of not less than two feet in width, either unpaved or delineated by curbs, double-parallel lines, or other markings on the roadway, it is unlawful to do either of the following: (1) To drive any vehicle over, upon, or across the dividing section. (2) To make any left, semicircular, or U-turn with the vehicle on the divided highway, except through an opening in the barrier designated and intended by public authorities for the use of vehicles or through a plainly marked opening in the dividing section. (b) It is unlawful to drive any vehicle upon a highway, except to the right of an intermittent

	barrier or a dividing section which separates two or more opposing lanes of traffic. Except as otherwise provided in subdivision (c), a violation of this subdivision is a misdemeanor. (c) Any willful violation of subdivision (b) which results in injury to, or death of, a person shall be punished by imprisonment pursuant to subdivision (h) of Section 1170 of the Penal Code, or imprisonment in a county jail for a period of not more than six months.
21652 – Entrance to Public Highway from Service Road	When any service road has been constructed on or along any public highway and the main thoroughfare of the highway has been separated from the service road, it is unlawful for any person to drive any vehicle into the main thoroughfare from the service road or from the main thoroughfare into the service road except through an opening in the dividing curb, section, separation, or line.
21655 – Designated Lanes for Certain Vehicles	(a) Whenever the Department of Transportation or local authorities with respect to highways under their respective jurisdictions determines upon the basis of an engineering and traffic investigation that the designation of a specific lane or lanes for the travel of vehicles required to travel at reduced speeds would facilitate the safe and orderly movement of traffic, the department or local authority may designate a specific lane or lanes for the travel of vehicles which are subject to the provisions of Section 22406 and shall erect signs at reasonable intervals giving notice thereof. (b) Any trailer bus, except as provided in Section 21655.5, and any vehicle subject to the provisions of Section 22406 shall be driven in the lane or lanes designated pursuant to subdivision (a) whenever signs have been erected giving notice of that designation. Except as otherwise provided in this subdivision, when a specific lane or lanes have not been so designated, any of those vehicles shall be driven in the right-hand lane for traffic or as close as practicable to the right edge or curb. If, however, a specific lane or lanes have not been designated on a divided highway having four or more clearly marked lanes for traffic in one direction, any of those vehicles may also be driven in the lane to the immediate left of that right-hand lane, unless otherwise prohibited under this code. When overtaking and passing another vehicle proceeding in the same direction, the driver shall use either the designated lane, the lane to the immediate left of the right-hand lane, or the right-hand lane for traffic as permitted under this code. This subdivision does not apply to a driver who is preparing for a left- or right-hand turn or who is entering into or exiting from a highway or to a driver who must necessarily drive in a lane other than the right-hand lane to continue on his or her intended route.
21656 – Turning Out of Slow-Moving Vehicles	On a two-lane highway where passing is unsafe because of traffic in the opposite direction or other conditions, a slow-moving vehicle, including a passenger vehicle, behind which five or more vehicles are formed in line, shall turn off the roadway at the nearest place designated as a turnout by signs erected by the authority having jurisdiction over the highway, or wherever sufficient area for a safe turnout exists, in order to permit the vehicles following it to proceed. As used in this section a slow-moving vehicle is one which is proceeding at a rate of speed less than the normal flow of traffic at the particular time and place.
21657 – Designated Traffic Direction	The authorities in charge of any highway may designate any highway, roadway, part of a roadway, or specific lanes upon which vehicular traffic shall proceed in one direction at all or such times as shall be indicated by official traffic control devices. When a roadway has been so designated, a vehicle shall be driven only in the direction designated at all or such times as shall be indicated by traffic control devices.
21658 – Laned Roadways	Whenever any roadway has been divided into two or more clearly marked lanes for traffic in one direction, the following rules apply: (a) A vehicle shall be driven as nearly as practical entirely within a single lane and shall not be moved from the lane until such movement can be made with reasonable safety.

	(b) Official signs may be erected directing slow-moving traffic to use a designated lane or allocating specified lanes to traffic moving in the same direction, and drivers of vehicles shall obey the directions of the traffic device.
21663 – Driving on Sidewalk	Except as expressly permitted pursuant to this code, including Sections 21100. 4 and 21114.5, no person shall operate or move a motor vehicle upon a sidewalk except as may be necessary to enter or leave adjacent property.
Additional Driving Rules	
21700 – Obstruction to Driving	No person shall drive a vehicle when it is so loaded, or when there are in the front seat such number of persons as to obstruct the view of the driver to the front or sides of the vehicle or as to interfere with the driver's control over the driving mechanism of the vehicle.
21701 – Interference with Driver or Mechanism	No person shall willfully interfere with the driver of a vehicle or with the mechanism thereof in such manner as to affect the driver's control of the vehicle. The provisions of this section shall not apply to a drivers' license examiner or other employee of the Department of Motor Vehicles when conducting the road or driving test of an applicant for a driver's license nor to a person giving instruction as a part of a course in driver training conducted by a public school, educational institution or a driver training school licensed by the Department of Motor Vehicles.
21703 – Following Too Closely	The driver of a motor vehicle shall not follow another vehicle more closely than is reasonable and prudent, having due regard for the speed of such vehicle and the traffic upon, and the condition of, the roadway.
21717 – Turning Across Bicycle Lane	Whenever it is necessary for the driver of a motor vehicle to cross a bicycle lane that is adjacent to his lane of travel to make a turn, the driver shall drive the motor vehicle into the bicycle lane prior to making the turn and shall make the turn pursuant to Section 22100.
Overtaking and Passing	
21750 – Overtake and Pass to Left	The driver of a vehicle overtaking another vehicle or a bicycle proceeding in the same direction shall pass to the left at a safe distance without interfering with the safe operation of the overtaken vehicle or bicycle, subject to the limitations and exceptions hereinafter stated.
21751 – Passing without Sufficient Clearance	On a two-lane highway, no vehicle shall be driven to the left side of the center of the roadway in overtaking and passing another vehicle proceeding in the same direction unless the left side is clearly visible and free of oncoming traffic for a sufficient distance ahead to permit such overtaking and passing to be completely made without interfering with the safe operation of any vehicle approaching from the opposite direction.
21752 – When Driving on Left Prohibited	No vehicle shall be driven to the left side of the roadway under the following conditions: (a) When approaching or upon the crest of a grade or a curve in the highway where the driver's view is obstructed within such distance as to create a hazard in the event another vehicle might approach from the opposite direction. (b) When the view is obstructed upon approaching within 100 feet of any bridge, viaduct, or

	tunnel. (c) When approaching within 100 feet of or when traversing any railroad grade crossing. (d)When approaching within 100 feet of or when traversing any intersection. This section shall not apply upon a one-way roadway.
21754 – Passing on the Right	The driver of a vehicle may overtake and pass to the right of another vehicle only under the following conditions: (a) When the vehicle overtaken is making or about to make a left turn. (b) Upon a highway within a business or residence district with unobstructed pavement of sufficient width for two or more lines of moving vehicles in the direction of travel. (c) Upon any highway outside of a business or residence district with unobstructed pavement of sufficient width and clearly marked for two or more lines of moving traffic in the direction of travel. (d) Upon a one-way street. (e) Upon a highway divided into two roadways where traffic is restricted to one direction upon each of such roadways. The provisions of this section shall not relieve the driver of a slow moving vehicle from the duty to drive as closely as practicable to the right hand edge of the roadway.
21755 – Passing on Right Safely	(a) The driver of a vehicle may overtake and pass another vehicle upon the right only under conditions permitting that movement in safety. In no event shall that movement be made by driving off the paved or main traveled portion of the roadway. (b) This section does not prohibit the use of a bicycle in a bicycle lane or on a shoulder.
Right-of-Way	
21800 – Intersections	(a) The driver of a vehicle approaching an intersection shall yield the right-of-way to any vehicle which has entered the intersection from a different highway. (b) (1) When two vehicles enter an intersection from different highways at the same time, the driver of the vehicle on the left shall yield the right-of-way to the vehicle on his or her immediate right, except that the driver of any vehicle on a terminating highway shall yield the right-of-way to any vehicle on the intersecting continuing highway. (2) For the purposes of this section, “terminating highway” means a highway which intersects, but does not continue beyond the intersection, with another highway which does continue beyond the intersection. (c) When two vehicles enter an intersection from different highways at the same time and the intersection is controlled from all directions by stop signs, the driver of the vehicle on the left shall yield the right-of-way to the vehicle on his or her immediate right. (d) (1) The driver of any vehicle approaching an intersection which has official traffic control signals that are inoperative shall stop at the intersection, and may proceed with caution when it is safe to do so. 2) When two vehicles enter an intersection from different highways at the same time, and the

	official traffic control signals for the intersection are inoperative, the driver of the vehicle on the left shall yield the right-of-way to the vehicle on his or her immediate right, except that the driver of any vehicle on a terminating highway shall yield the right-of-way to any vehicle on the intersecting continuing highway. (e) This section does not apply to any of the following: (1) Any intersection controlled by an official traffic control signal or yield right-of-way sign. (2) Any intersection controlled by stop signs from less than all directions. (3) When vehicles are approaching each other from opposite directions and the driver of one of the vehicles intends to make, or is making, a left turn.
21801 – Left-Turn or U-Turn	(a) The driver of a vehicle intending to turn to the left or to complete a U-turn upon a highway, or to turn left into public or private property, or an alley, shall yield the right-of-way to all vehicles approaching from the opposite direction which are close enough to constitute a hazard at any time during the turning movement, and shall continue to yield the right-of-way to the approaching vehicles until the left turn or U-turn can be made with reasonable safety. (b) A driver having yielded as prescribed in subdivision (a), and having given a signal when and as required by this code, may turn left or complete a U-turn, and the drivers of vehicles approaching the intersection or the entrance to the property or alley from the opposite direction shall yield the right-of-way to the turning vehicle.
21802 – Stop Signs: Intersections	(a) The driver of any vehicle approaching a stop sign at the entrance to, or within, an intersection shall stop as required by Section 22450. The driver shall then yield the right-of-way to any vehicles which have approached from another highway, or which are approaching so closely as to constitute an immediate hazard, and shall continue to yield the right-of-way to those vehicles until he or she can proceed with reasonable safety. (b) A driver having yielded as prescribed in subdivision (a) may proceed to enter the intersection, and the drivers of all other approaching vehicles shall yield the right-of-way to the vehicle entering or crossing the intersection. (c) This section does not apply where stop signs are erected upon all approaches to an intersection.
21803 – Yield Signs: Intersections	(a) The driver of any vehicle approaching any intersection which is controlled by a yield right-of-way sign shall, upon arriving at the sign, yield the right-of-way to any vehicles which have entered the intersection, or which are approaching on the intersecting highway close enough to constitute an immediate hazard, and shall continue to yield the right-of-way to those vehicles until he or she can proceed with reasonable safety. (b) A driver having yielded as prescribed in subdivision (a) may proceed to enter the intersection, and the drivers of all other approaching vehicles shall yield the right-of-way to the vehicle entering or crossing the intersection.
21804 – Entry Onto Highway	(a) The driver of any vehicle about to enter or cross a highway from any public or private property, or from an alley, shall yield the right-of-way to all traffic, as defined in Section 620, approaching on the highway close enough to constitute an immediate hazard, and shall continue to yield the right-of-way to that traffic until he or she can proceed with reasonable safety. (b) A driver having yielded as prescribed in subdivision (a) may proceed to enter or cross the highway, and the drivers of all other vehicles approaching on the highway shall yield the right of-way to the vehicle entering or crossing the intersection.

21806 – Authorized Emergency Vehicles	Upon the immediate approach of an authorized emergency vehicle which is sounding a siren and which has at least one lighted lamp exhibiting red light that is visible, under normal atmospheric conditions, from a distance of 1,000 feet to the front of the vehicle, the surrounding traffic shall, except as otherwise directed by a traffic officer, do the following: (a) (1) Except as required under paragraph (2), the driver of every other vehicle shall yield the right-of-way and shall immediately drive to the right-hand edge or curb of the highway, clear of any intersection, and thereupon shall stop and remain stopped until the authorized emergency vehicle has passed. (2) A person driving a vehicle in an exclusive or preferential use lane shall exit that lane immediately upon determining that the exit can be accomplished with reasonable safety. (b) The operator of every street car shall immediately stop the street car, clear of any intersection, and remain stopped until the authorized emergency vehicle has passed. (c) All pedestrians upon the highway shall proceed to the nearest curb or place of safety and remain there until the authorized emergency vehicle has passed.
Pedestrians' Rights and Duties	
21950 – Right-of-Way at Crosswalks	(a) The driver of a vehicle shall yield the right-of-way to a pedestrian crossing the roadway within any marked crosswalk or within any unmarked crosswalk at an intersection, except as otherwise provided in this chapter. (b) This section does not relieve a pedestrian from the duty of using due care for his or her safety. No pedestrian may suddenly leave a curb or other place of safety and walk or run into the path of a vehicle that is so close as to constitute an immediate hazard. No pedestrian may unnecessarily stop or delay traffic while in a marked or unmarked crosswalk. (c) The driver of a vehicle approaching a pedestrian within any marked or unmarked crosswalk shall exercise all due care and shall reduce the speed of the vehicle or take any other action relating to the operation of the vehicle as necessary to safeguard the safety of the pedestrian. (d) Subdivision (b) does not relieve a driver of a vehicle from the duty of exercising due care for the safety of any pedestrian within any marked crosswalk or within any unmarked crosswalk at an intersection.
21951 – Vehicles Stopped for Pedestrians	Whenever any vehicle has stopped at a marked crosswalk or at any unmarked crosswalk at an intersection to permit a pedestrian to cross the roadway the driver of any other vehicle approaching from the rear shall not overtake and pass the stopped vehicle.
21954 – Pedestrians Outside Crosswalks	(a) Every pedestrian upon a roadway at any point other than within a marked crosswalk or within an unmarked crosswalk at an intersection shall yield the right-of-way to all vehicles upon the roadway so near as to constitute an immediate hazard. (b) The provisions of this section shall not relieve the driver of a vehicle from the duty to exercise due care for the safety of any pedestrian upon a roadway.
21955 – Crossing Between Controlled Intersections	Between adjacent intersections controlled by traffic control signal devices or by police officers, pedestrians shall not cross the roadway at any place except in a crosswalk.
21956 – Pedestrian on Roadway	(a) No pedestrian may walk upon any roadway outside of a business or residence district otherwise than close to his or her left-hand edge of the roadway.

	(b) A pedestrian may walk close to his or her right-hand edge of the roadway if a crosswalk or other means of safely crossing the roadway is not available or if existing traffic or other conditions would compromise the safety of a pedestrian attempting to cross the road.
Turning, Stopping, and Turning Signals	
22100 – Turning Upon a Highway	Except as provided in Section 22100.5 or 22101, the driver of any vehicle intending to turn upon a highway shall do so as follows: (a) Right Turns. Both the approach for a right-hand turn and a right-hand turn shall be made as close as practicable to the right-hand curb or edge of the roadway except: (1) Upon a highway having three marked lanes for traffic moving in one direction that terminates at an intersecting highway accommodating traffic in both directions, the driver of a vehicle in the middle lane may turn right into any lane lawfully available to traffic moving in that direction upon the roadway being entered. (2) If a right-hand turn is made from a one-way highway at an intersection, a driver shall approach the turn as provided in this subdivision and shall complete the turn in any lane lawfully available to traffic moving in that direction upon the roadway being entered. (3) Upon a highway having an additional lane or lanes marked for a right turn by appropriate signs or markings, the driver of a vehicle may turn right from any lane designated and marked for that turning movement. (b) Left Turns. The approach for a left turn shall be made as close as practicable to the left-hand edge of the extreme left-hand lane or portion of the roadway lawfully available to traffic moving in the direction of travel of the vehicle and, when turning at an intersection, the left turn shall not be made before entering the intersection. After entering the intersection, the left turn shall be made so as to leave the intersection in a lane lawfully available to traffic moving in that direction upon the roadway being entered, except that upon a highway having three marked lanes for traffic moving in one direction that terminates at an intersecting highway accommodating traffic in both directions, the driver of a vehicle in the middle lane may turn left into any lane lawfully available to traffic moving in that direction upon the roadway being entered.
22101 – Regulation of Turns at Intersection	(No definition listed)
22102 – U-turn in Business District	No person in a business district shall make a U-turn, except at an intersection, or on a divided highway where an opening has been provided in accordance with Section 21651. This turning movement shall be made as close as practicable to the extreme left-hand edge of the lanes moving in the driver's direction of travel immediately prior to the initiation of the turning movement, when more than one lane in the direction of travel is present.
22103 – U-turn in Residence District	No person in a residence district shall make a U-turn when any other vehicle is approaching from either direction within 200 feet, except at an intersection when the approaching vehicle is controlled by an official traffic control device.
22105 – Unobstructed View Necessary for U-Turn	No person shall make a U-turn upon any highway where the driver of such vehicle does not have an unobstructed view for 200 feet in both directions along the highway and of any traffic thereon.

22106 – Starting Parked Vehicles or Backing	No person shall start a vehicle stopped, standing, or parked on a highway, nor shall any person back a vehicle on a highway until such movement can be made with reasonable safety.
22107 – Turning Movements and Required Signals	No person shall turn a vehicle from a direct course or move right or left upon a roadway until such movement can be made with reasonable safety and then only after the giving of an appropriate signal in the manner provided in this chapter in the event any other vehicle may be affected by the movement.
22108 – Duration of Signal	Any signal of intention to turn right or left shall be given continuously during the last 100 feet traveled by the vehicle before turning.
22109 – Signal When Stopping	No person shall stop or suddenly decrease the speed of a vehicle on a highway without first giving an appropriate signal in the manner provided in this chapter to the driver of any vehicle immediately to the rear when there is opportunity to give the signal.
Speed Laws	
22348 – Excessive Speed and Designated Lane Use	(a) Notwithstanding subdivision (b) of Section 22351, a person shall not drive a vehicle upon a highway with a speed limit established pursuant to Section 22349 or 22356 at a speed greater than that speed limit. (b) A person who drives a vehicle upon a highway at a speed greater than 100 miles per hour is guilty of an infraction punishable, as follows: (1) Upon a first conviction of a violation of this subdivision, by a fine of not to exceed five hundred dollars ($500). The court may also suspend the privilege of the person to operate a motor vehicle for a period not to exceed 30 days pursuant to Section 13200.5. (2) Upon a conviction under this subdivision of an offense that occurred within three years of a prior offense resulting in a conviction of an offense under this subdivision, by a fine of not to exceed seven hundred fifty dollars ($750). The person’s privilege to operate a motor vehicle shall be suspended by the Department of Motor Vehicles pursuant to subdivision (a) of Section 13355. (3) Upon a conviction under this subdivision of an offense that occurred within five years of two or more prior offenses resulting in convictions of offenses under this subdivision, by a fine of not to exceed one thousand dollars ($1,000). The person’s privilege to operate a motor vehicle shall be suspended by the Department of Motor Vehicles pursuant to subdivision (b) of Section 13355. (c) A vehicle subject to Section 22406 shall be driven in a lane designated pursuant to Section 21655, or if a lane has not been so designated, in the right-hand lane for traffic or as close as practicable to the right-hand edge or curb. When overtaking and passing another vehicle proceeding in the same direction, the driver shall use either the designated lane, the lane to the immediate left of the right-hand lane, or the right-hand lane for traffic as permitted under this code. If, however, specific lane or lanes have not been designated on a divided highway having four or more clearly marked lanes for traffic in one direction, a vehicle may also be driven in the lane to the immediate left of the right-hand lane, unless otherwise prohibited under this code. This subdivision does not apply to a driver who is preparing for a left- or right-hand turn or who is in the process of entering into or exiting from a highway or to a driver who is required necessarily to drive in a lane other than the right-hand lane to continue on his or her intended route.

22350 – Basic Speed Law	No person shall drive a vehicle upon a highway at a speed greater than is reasonable or prudent having due regard for weather, visibility, the traffic on, and the surface and width of, the highway, and in no event at a speed which endangers the safety of persons or property.
22400 – Minimum Speed Law	(a) No person shall drive upon a highway at such a slow speed as to impede or block the normal and reasonable movement of traffic, unless the reduced speed is necessary for safe operation, because of a grade, or in compliance with law. No person shall bring a vehicle to a complete stop upon a highway so as to impede or block the normal and reasonable movement of traffic unless the stop is necessary for safe operation or in compliance with law. (b) Whenever the Department of Transportation determines on the basis of an engineering and traffic survey that slow speeds on any part of a state highway consistently impede the normal and reasonable movement of traffic, the department may determine and declare a minimum speed limit below which no person shall drive a vehicle, except when necessary for safe operation or in compliance with law, when appropriate signs giving notice thereof are erected along the part of the highway for which a minimum speed limit is established. Subdivision (b) of this section shall apply only to vehicles subject to registration.
Special Stops Required	
22450 – Stop Requirements	(a) The driver of any vehicle approaching a stop sign at the entrance to, or within, an intersection shall stop at a limit line, if marked, otherwise before entering the crosswalk on the near side of the intersection. If there is no limit line or crosswalk, the driver shall stop at the entrance to the intersecting roadway . (b) The driver of a vehicle approaching a stop sign at a railroad grade crossing shall stop at a limit line, if marked, otherwise before crossing the first track or entrance to the railroad grade crossing. (c) Notwithstanding any other provision of law, a local authority may adopt rules and regulations by ordinance or resolution providing for the placement of a stop sign at any location on a highway under its jurisdiction where the stop sign would enhance traffic safety.
Stopping, Standing, or Parking	
22516 – Locked Vehicle	No person shall leave standing a locked vehicle in which there is any person who cannot readily escape therefrom.
22517 – Opening and Closing Doors	No person shall open the door of a vehicle on the side available to moving traffic unless it is reasonably safe to do so and can be done without interfering with the movement of such traffic, nor shall any person leave a door open upon the side of a vehicle available to moving traffic for a period of time longer than necessary to load or unload passengers.
22526 – Entering Intersection, Rail Crossing, or Marked Crosswalk	(a) Notwithstanding any official traffic control signal indication to proceed, a driver of a vehicle shall not enter an intersection or marked crosswalk unless there is sufficient space on the other side of the intersection or marked crosswalk to accommodate the vehicle driven without

	obstructing the through passage of vehicles from either side. (b) A driver of a vehicle which is making a turn at an intersection who is facing a steady circular yellow or yellow arrow signal shall not enter the intersection or marked crosswalk unless there is sufficient space on the other side of the intersection or marked crosswalk to accommodate the vehicle driven without obstructing the through passage of vehicles from either side. (c) A driver of a vehicle shall not enter a railroad or rail transit crossing, notwithstanding any official traffic control device or signal indication to proceed, unless there is sufficient undercarriage clearance to cross the intersection without obstructing the through passage of a railway vehicle, including, but not limited to, a train, trolley, or city transit vehicle. (d) A driver of a vehicle shall not enter a railroad or rail transit crossing, notwithstanding any official traffic control device or signal indication to proceed, unless there is sufficient space on the other side of the railroad or rail transit crossing to accommodate the vehicle driven and any railway vehicle, including, but not limited to, a train, trolley, or city transit vehicle. (e) A local authority may post appropriate signs at the entrance to intersections indicating the prohibition in subdivisions (a), (b), and (c). (f) A violation of this section is not a violation of a law relating to the safe operation of vehicles and is the following: (1) A stopping violation when a notice to appear has been issued by a peace officer described in Section 830.1, 830.2, or 830.33 of the Penal Code. (2) A parking violation when a notice of parking violation is issued by a person, other than a peace officer described in paragraph (1), who is authorized to enforce parking statutes and regulations. (g) This section shall be known and may be cited as the Anti-Gridlock Act of 1987.
Driving Offenses	
23104 – Reckless Driving: Bodily Injury	(a) Except as provided in subdivision (b), whenever reckless driving of a vehicle proximately causes bodily injury to a person other than the driver, the person driving the vehicle shall, upon conviction thereof, be punished by imprisonment in the county jail for not less than 30 days nor more than six months or by a fine of not less than two hundred twenty dollars ($220) nor more than one thousand dollars ($1,000), or by both the fine and imprisonment. (b) A person convicted of reckless driving that proximately causes great bodily injury, as defined in Section 12022.7 of the Penal Code, to a person other than the driver, who previously has been convicted of a violation of Section 23103, 23104, 23105, 23109, 23109.1, 23152, or 23153, shall be punished by imprisonment pursuant to subdivision (h) of Section 1170 of the Penal Code, by imprisonment in the county jail for not less than 30 days nor more than six months or by a fine of not less than two hundred twenty dollars ($220) nor more than one thousand dollars ($1,000) or by both the fine and imprisonment.
23114 – Spilling Loads on Highways	(a) Except as provided in Subpart I (commencing with Section 393.100) of Title 49 of the Code of Federal Regulations related to hay and straw, a vehicle shall not be driven or moved on any highway unless the vehicle is so constructed, covered, or loaded as to prevent any of its contents or load other than clear water or feathers from live birds from dropping, sifting, leaking, blowing, spilling, or otherwise escaping from the vehicle. (b) (1) Aggregate material shall only be carried in the cargo area of a vehicle. The cargo area shall not contain any holes, cracks, or openings through which that material may escape, regardless of the degree to which the vehicle is loaded, except as provided in paragraph (2).

	(2) Every vehicle used to transport aggregate materials, regardless of the degree to which the vehicle is loaded, shall be equipped with all of the following: (A) Properly functioning seals on any openings used to empty the load, including, but not limited to, bottom dump release gates and tailgates. (B) Splash flaps behind every tire, or set of tires, regardless of the position on the truck, truck tractor, or trailer. (C) Center flaps at a location to the rear of each bottom dump release gate as to trucks or trailers equipped with bottom dump release gates. The center flap may be positioned directly behind the bottom dump release gate and in front of the rear axle of the vehicle, or it may be positioned to the rear of the rear axle in line with the splash flaps required behind the tires. The width of the center flap may extend not more than one inch from one sidewall to the opposite sidewall of the inside tires and shall extend to within five inches of the pavement surface, and may be not less than 24 inches from the bottom edge to the top edge of that center flap. (D) Fenders starting at the splash flap with the leading edge of the fenders extending forward at least six inches beyond the center of the axle that cover the tops of tires not already covered by the truck, truck tractor, or trailer body. (E) Complete enclosures on all vertical sides of the cargo area, including, but not limited to, tailgates. (F) Shed boards designed to prevent aggregate materials from being deposited on the vehicle body during top loading. (c) Vehicles comprised of full rigid enclosures are exempt only from subparagraphs (C) and (F) of paragraph (2) of subdivision (b). (d) For purposes of this section, "aggregate material" means rock fragments, pebbles, sand, dirt, gravel, cobbles, crushed base, asphalt, and other similar materials. (e) (1) In addition to subdivisions (a) and (b), a vehicle may not transport any aggregate material upon a highway unless the material is covered. (2) Vehicles transporting loads composed entirely of asphalt material are exempt only from the provisions of this section requiring that loads be covered. (3) Vehicles transporting loads composed entirely of petroleum coke material are not required to cover their loads if they are loaded using safety procedures, specialized equipment, and a chemical surfactant designed to prevent materials from blowing, spilling, or otherwise escaping from the vehicle. (4) Vehicles transporting loads of aggregate materials are not required to cover their loads if the load, where it contacts the sides, front, and back of the cargo container area, remains six inches from the upper edge of the container area, and if the load does not extend, at its peak, above any part of the upper edge of the cargo container area. (5) The requirements of this subdivision shall become operative on September 1, 1990. (f) A person who provides a location for vehicles to be loaded with an aggregate material or other material shall provide a location for vehicle operators to comply with this section before entering a highway. (1) A person is exempt from the requirements of this subdivision if the location that he or she provides for vehicles to be loaded with the materials described in this subdivision has 100 yards or less between the scale houses where the trucks carrying aggregate material are weighed and the point of egress to a public road. (2) A driver of a vehicle loaded with aggregate material leaving locations exempted from the

	requirements of this subdivision is authorized to operate on public roads only until that driver is able to safely cover the load at a site near the location's point of egress to the public road. Except as provided under paragraph (4) of subdivision (e), an uncovered vehicle described in this paragraph may not operate more than 200 yards from the point of egress to the public road.
Offenses Involving Alcohol or Drugs	
23152 – Driving Under Influence of Alcohol or Drugs	(a) It is unlawful for any person who is under the influence of any alcoholic beverage or drug, or under the combined influence of any alcoholic beverage and drug, to drive a vehicle. (b) It is unlawful for any person who has 0.08 percent or more, by weight, of alcohol in his or her blood to drive a vehicle. For purposes of this article and Section 34501.16, percent, by weight, of alcohol in a person's blood is based upon grams of alcohol per 100 milliliters of blood or grams of alcohol per 210 liters of breath. In any prosecution under this subdivision, it is a rebuttable presumption that the person had 0.08 percent or more, by weight, of alcohol in his or her blood at the time of driving the vehicle if the person had 0.08 percent or more, by weight, of alcohol in his or her blood at the time of the performance of a chemical test within three hours after the driving. (c) It is unlawful for any person who is addicted to the use of any drug to drive a vehicle. This subdivision shall not apply to a person who is participating in a narcotic treatment program approved pursuant to Article 3 (commencing with Section 11875) of Chapter 1 of Part 3 of Division 10.5 of the Health and Safety Code. (d) It is unlawful for any person who has 0.04 percent or more, by weight, of alcohol in his or her blood to drive a commercial motor vehicle, as defined in Section 15210. In any prosecution under this subdivision, it is a rebuttable presumption that the person had 0.04 percent or more, by weight, of alcohol in his or her blood at the time of driving the vehicle if the person had 0.04 percent or more, by weight, of alcohol in his or her blood at the time of the performance of a chemical test within three hours after the driving.
23153 - Driving Under Influence of Alcohol or Drugs Causing Injury	(a) It is unlawful for any person, while under the influence of any alcoholic beverage or drug, or under the combined influence of any alcoholic beverage and drug, to drive a vehicle and concurrently do any act forbidden by law, or neglect any duty imposed by law in driving the vehicle, which act or neglect proximately causes bodily injury to any person other than the driver. (b) It is unlawful for any person, while having 0.08 percent or more, by weight, of alcohol in his or her blood to drive a vehicle and concurrently do any act forbidden by law, or neglect any duty imposed by law in driving the vehicle, which act or neglect proximately causes bodily injury to any person other than the driver. In any prosecution under this subdivision, it is a rebuttable presumption that the person had 0.08 percent or more, by weight, of alcohol in his or her blood at the time of driving the vehicle if the person had 0.08 percent or more, by weight, of alcohol in his or her blood at the time of the performance of a chemical test within three hours after driving. (c) In proving the person neglected any duty imposed by law in driving the vehicle, it is not necessary to prove that any specific section of this code was violated. (d) It is unlawful for any person, while having 0.04 percent or more, by weight, of alcohol in his or her blood to drive a commercial motor vehicle, as defined in Section 15210, and concurrently do any act forbidden by law or neglect any duty imposed by law in driving the vehicle, which act or neglect proximately causes bodily injury to any person other than the driver.

	In any prosecution under this subdivision, it is a rebuttable presumption that the person had 0.04 percent or more, by weight, of alcohol in his or her blood at the time of driving the vehicle if the person had 0.04 percent or more, by weight, of alcohol in his or her blood at the time of performance of a chemical test within three hours after driving.
Lighting Equipment	
24250 – Lighting During Darkness	During darkness, a vehicle shall be equipped with lighted lighting equipment as required for the vehicle by this chapter.

Source: California Vehicle Code (California Department of Motor Vehicles, 2013)