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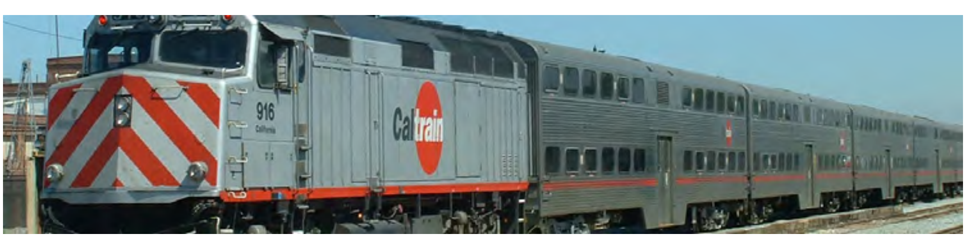
Bikesharing and Bicycle Safety

MTI Report 12-54



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REPORT 12-54

BIKESHARING AND BICYCLE SAFETY

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16. Abstract

The growth of bikesharing in the United States has had a transformative impact on urban transportation. Major cities have established large bikesharing systems, including Boston, Chicago, Denver, Minneapolis-Saint Paul, New York City, Salt Lake City, the San Francisco Bay Area, Seattle, Washington DC, and others. These systems began operating as early as 2010, and no fatalities have occurred within the US as of this writing. However, three have happened in North America—two in Canada and one in Mexico. Bikesharing has some qualities that appear inherently unsafe for bicyclists. Most prominently, helmet usage is documented to be quite low in most regions. In addition, bikesharing is also used by people who bicycle less frequently, and by tourists, who are often less familiar with the local terrain. In this study, researchers take a closer look at bikesharing safety from qualitative and quantitative perspectives. Through a series of four focus groups, they discussed bikesharing usage and safety with bikesharing members and nonmembers in the Bay Area. They further engaged experts nationwide from a variety of fields to evaluate their opinions and perspectives on bikesharing and safety. Finally, researchers conducted an analysis of bicycle and bikesharing activity data, as well as bicycle and bikesharing collisions to evaluate injury rates associated with bikesharing when compared with benchmarks of personal bicycling. The data analysis found that collision and injury rates for bikesharing are lower than previously computed rates for personal bicycling. Experts and focus group participants independently pointed to bikesharing rider behavior and bikesharing bicycle design as possible factors. In particular, bikesharing bicycles are generally designed in ways that promote stability and limited speeds, which mitigate the conditions that contribute to collisions. Data analysis also explored whether there was evidence of a "safety in numbers benefit" that resulted from bikesharing activity. However, no significant impact from bikesharing activity on broader bicycle collisions could be found within the regions in which they operate. Discussion and recommendations are presented in the conclusion.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Public bikesharing systems have recently proliferated across cities within the United States, Canada, and Mexico. The result has been an augmentation of the mobility options available to residents of cities both large and small. People within these cities are bicycling more, often in substitution of other modes such as walking, bus, rail, and automobile. While the impacts of bikesharing on modal shift are a subject of active study, it is clear that bikesharing is increasing the presence of bicycles on the urban streets of North America. Many of the bicycles deployed in bikesharing systems are equipped with lights and are brightly marked, increasing their visibility at night. The presence of bikesharing—and its resulting expansion of bicycle travel—may have impacts on the broader safety of urban bicycling. The safety of this new form of bicycling is also important for planning considerations. The increased presence of bicycles and the prominence that comes with public bikesharing should bring an elevated visibility and awareness of bicyclists on the street. At the same time, bikesharing also increases bicyclist exposure to motor vehicles, often without protective equipment. This study explores the topic of bikesharing safety using qualitative and quantitative approaches. The study conducted four focus groups with bikesharing and non-bikesharing members in the San Francisco Bay Area and completed eleven expert interviews with stakeholders. It also engaged in concurrent multi-year data analysis of bikesharing and bicycle collision data within three US metropolitan areas.

The focus groups were designed to explore the perspectives and perceptions of bikesharing safety among members of a local bikesharing system, called Bay Area Bike Share (BABS), as well as among persons that were primarily car drivers within the BABS operating region. *The focus groups found that people generally considered bicycling with bikesharing bikes to be safer than with regular bikes. The bicycle design was one of the primary reasons bikesharing was thought to be safer.* Bikesharing bicycles are bigger, slower, and sturdier than many personal bicycles and thus are not ridden as aggressively. *Members of the focus groups noted that people riding bikesharing bicycles appeared to do so more cautiously.* This was noted in conjunction with the widely observed fact that helmet usage is clearly lower for bikesharing bicycles.

Eleven expert interviews were conducted with a diverse array of practitioners in the field, including government officials, industry representatives, and emergency responders. The array of experts considered bikesharing to have a number of plausible safety benefits. The reasons the experts considered bikesharing safer than personal bicycling were very similar to those observed in the focus groups. *Many cited the bicycle design as one of the key reasons that bikesharing appears to have a good safety record despite the acknowledged lack of helmet use. Overall, the experts interviewed considered bikesharing to be relatively safe, and they collectively considered infrastructure improvements and promotion of helmet use as key strategies for improving bicycle safety in the region.*

This study conducted an analysis of bicycle safety using data quantifying urban bicycle activity, overall bicycle collisions, bikesharing activity, and bikesharing collisions. *The analysis established that within bikesharing regions, bicycle collisions were generally rising, but that this rise was very likely due to rising urban bicycle activity overall.* The correlation between growth in bicycle collisions and the estimated population commuting by bicycle was found to be rather high in the studied regions. The analysis proceeded to use bikesharing activity data and collision data to compute key safety metrics to a high degree of precision. *The results found that the bikesharing systems evaluated in this study appeared to have a lower nonfatal injury rate than prevailing US and Canadian benchmark estimates. This result may indicate that certain factors, such as the bicycle design or bikesharing user behavior, could be reducing the likelihood of a collision event.*

The processing of origin-destination information within bikesharing activity data permitted an informed estimation of distances traveled by bikesharing bicycles. Estimating distances traveled is very difficult to do for the general bicycling population, since information on the number of bicycling trips and miles traveled is generally not available to great precision or at regular time intervals. These computations, coupled with bikesharing collision data, provide new metrics for bicycle safety that can be tracked over time. The authors present initial calculations of these metrics within this report and compare them with metrics for the broader bicycle population of a metropolitan region.

Overall, the results of the study suggest that *bikesharing safety is at levels similar to or better than bicycling safety of the general population*. It is important to acknowledge that bikesharing users have suffered injuries, some very serious and incapacitating. But at present no fatalities have occurred in the United States. Three fatalities have occurred in North America—two in Canada and one in Mexico. *The authors explored whether bikesharing may add to overall bicycle safety through a safety-in-numbers effect, but the empirical evidence of this impact was not convincingly evident in the population and activity data evaluated in this study.* Future study of bikesharing and bikesharing safety should focus on bicycle design, better promotion of helmet use, and improvements of infrastructure that can enhance the safety environment for bikesharing and bicycling more broadly.

I. INTRODUCTION

Bikesharing systems provide shared bicycles for use by the general public. Often, bikesharing systems consist of a network of docking stations that position bicycles throughout a metropolitan region for public access. However, bikesharing systems have also evolved into dockless models, which permit bicycles to be dropped off in more flexible regions or zones. Generally, most bikesharing systems permit one-way trips by allowing bicycles to be checked out of one docking station and then returned to another in the system. Many bikesharing systems offer instant access in that they can be accessed by people that are both members of the system and by non-members. Members pay a fee for monthly or annual access. Those paying for set terms often receive some reduced cost for per-trip use, which can include 30 minutes of free riding time. Non-members avoid paying the upfront fee, but they often pay a higher marginal cost per trip.

Bikesharing has grown rapidly across North America over the last half-decade. The first modern information technology based (“IT-based”) bikesharing system in North America was established in Tulsa, Oklahoma in 2007. The system was small, sponsored by a health-care provider, and it served a multi-use path in the city. This system, called Tulsa Townies, is still in operation today. In 2009, “IT-based” bikesharing was elevated and expanded with the establishment of the BIXI bikesharing system in Montreal. From then on, a succession of major cities launched their own branded versions of bikesharing. Through this rapid growth, bikesharing has had a transformative impact on the transportation landscape within cities throughout North America. Recent research funded by the Mineta Transportation Institute (MTI) has documented the industry growth and developed extensive knowledge of bikesharing impacts on travel patterns (Shaheen et al., 2014). The most recent MTI study surveyed the members of five bikesharing systems including BIXI Montreal, BIXI Toronto, Nice Ride Minnesota, GreenBike SLC of Salt Lake City, and EcoBici of Mexico City. Spanning three countries and conducted in three languages, the survey probed the impacts of bikesharing on travel behavior, vehicle ownership, and economic impacts. The survey asked questions about perceptions of the system, personal usage, and changes in travel patterns resulting from bikesharing, as well as demographics and locational attributes. Across all five surveys, the results showed that people were bicycling more and driving less because of bikesharing (Shaheen et al., 2014). These results provided more depth to findings from an earlier report that presented insights on the newly expanding bikesharing industry, in which a survey of four cities revealed reductions in driving, increases in bicycling, and mixed impacts on walking and public transit (Shaheen et al., 2012).

A number of public benefits stem from the documented increase in bicycle use resulting from bikesharing. These include a reduction in emissions from forgone driving and an increase in exercise through the use of an active transportation mode. But bikesharing also exposes more people to the well-documented safety hazards of bicycling. Moreover, survey researchers (Shaheen et al., 2014) asked about helmet usage while bikesharing and found it to be very limited. Low levels of helmet use were attributed partly to the spontaneous nature of bikesharing trips, which are often unplanned. Respondents also reported that the awkwardness of carrying helmets and lack of helmet ownership were two other factors limiting helmet use (Shaheen et al., 2014). Bikesharing systems in North America have experienced three fatalities through the end of 2015. The first occurred in Toronto, another in Montreal, and the third in Mexico City (Kauri, 2013; Monroy, 2014; Sioui, 2014).

According to a report by Williams (2014), bicyclists experienced 722 deaths in 2012 just in the US. Williams notes that bicyclist deaths have been increasing in the US in recent years, up 16% since 2010 following a long decline from 1975 to 2010. Notably, however, current deaths are at levels well below the annual averages of previous decades, which Williams calculated to average 933 in the late 1970s, 889 in the 1980s, and 792 in the 1990s, and 696 from 2000 to 2012. The number of deaths in 2010 (621) was in fact the lowest ever recorded in the Fatality Analysis Reporting System (FARS) database (Williams, 2014). This is notable because bicyclist exposure has been increasing with its growing modal share.

These dynamics have raised questions about the impacts that bikesharing might have on public safety (Davis, 2013). Much has been written about cycling safety and the improvement of bicycling safety, and a large portion of the research and implementation of safety improvements is viewed from the perspective of improving bicyclist safety. However, less is known with respect to whether or not bikesharing has safety dynamics that are different from bicycling in general and whether or not those dynamics yield an improvement or reduction in overall safety.

The effects of bikesharing on bicycle safety could be positive, negative, or neutral. By expanding the modal share of bicycling, bikesharing increases the number of people on bicycles who are exposed to road hazards. This could have the long-run effect of worsening key bicycle safety statistics, including injury collisions and fatalities. Bikesharing increases these risks because there are: 1) more bicyclists on the road overall; 2) potentially less-experienced bicyclists among them, possibly riding in unfamiliar terrain (e.g., tourists); and 3) a bicycling population that is, on balance, less prone to helmet use. At the same time, having a larger number of people bicycling has several effects that, in theory, could improve safety. People using a bikesharing bicycle may be more careful with it, given that it is unfamiliar, and perhaps because they would be charged for damages caused to the bicycle (e.g., programs typically require a deposit). The bicycle design, as found in this study, appears to have a safety-inducing effect on how people ride. Additionally, the increase in bicyclists on the road as a result of bikesharing could raise the profile and awareness of bicycling among motorists, potentially causing motorists to be more careful in areas where bicycles are expected. Further, bicyclists may be more inclined to follow traffic laws more precisely when in the presence of many other bicyclists. These dynamics and the roles that they play in the context of safety and bikesharing are poorly understood.

This latter dynamic is sometimes referred to as the “safety-in-numbers” phenomenon (Tin Tin et al., 2011). The concept has received a fair amount of attention in recent years. The principal is simple: if there are more bicyclists, drivers are more aware of bikes on the road and take extra caution in their presence. Jacobsen (2003) published some data showing that there is some evidence to this effect. However, he found that the effect requires a critical mass of bicyclists and a commensurate reduction in automobile exposure. For example, bicyclists in Amsterdam are safer both because their numbers permit drivers to be more aware of them but also because of the smaller motor vehicle presence. This effect could increase the safety of individual bicyclists in the US, where there is a significant presence of bicyclists, especially in college towns. But, in cities with significant sprawl, bicyclists would still have to navigate streets where there are fewer bicyclists present and where the “safety in numbers” effect may be more difficult to achieve.

The challenges facing bicycle safety are abundantly evident in the aggregate statistics. According to Beck et al. (2007), "relative to passenger vehicle occupants, motorcyclists, bicyclists, and pedestrians are 58.3, 2.3, and 1.5 times respectively, more likely to be fatally injured on a given trip." It should be noted that the relative risk of dying depends on the specific environment. But overall, these numbers show that on average (on a per-trip basis), a bicyclist is twice as likely to die than is a passenger vehicle occupant. Because bicycle and walking trips are much shorter than average passenger-vehicle trips, the relative risk of cycling and walking on a per-mile basis is even higher.

This study seeks to shed light on the impacts that bikesharing may have on safety through several exploratory methods. First, the research team conducted four focus groups within the San Francisco Bay Area with members of BABS and with people identified as non-bicyclists (but as drivers) within the region. Second, the researchers interviewed eleven key experts in several industry sectors related to bicycle and bikesharing safety. This included officials in the federal and local government, representatives within the bikesharing industry, and members of the law enforcement community. Third, researchers conducted an analysis of bicycle-involved collision data, bicycle activity, bikesharing activity, and bikesharing collision data. This analysis draws inferences about bikesharing safety metrics and explores the role that bikesharing may (or may not) play in contributing to other cyclist safety. Finally, the report concludes with a summary of findings and recommendations.

In the following sections, the authors provide a literature review of previous work in bikesharing safety. This literature is a subset of a much larger body of work discussing the entire bicycle safety field. The authors focus on the literature found to be most directly relevant to bikesharing. They then proceed to discuss the methodological approaches and results of the research efforts outlined above.

II. PREVIOUS RESEARCH IN BICYCLE SAFETY AND BIKESHARING

GENERAL STUDIES OF BICYCLE SAFETY

A number of studies have been done to determine the factors that play into bicycling safety. Schimek (2014) evaluated a number of factors including age, riding patterns, and safety precautions that have been taken by bicyclists to determine their relationship to collisions in the US. For this study, injury data were collected from six sources including: 1) the National Electronic Injury Surveillance System (NEISS) for annual injuries involving bicycles from 2009 to 2011; 2) the General Estimates System (GES) for files on police-reported motor vehicle crashes with bicycles for 2010 to 2011; 3) the Fatality Analysis Reporting System (FARS) for census data on collisions leading to fatalities from 2010 to 2011; 4) the North Carolina Bicycle Crash Database; 5) the National Household Travel Survey (NHTS) of 2009; and 6) the National Survey of Bicyclists and Pedestrian Attitudes and Behavior, which was an over-the-phone survey conducted by the National Highway Traffic Safety Administration (NHTSA) in 2002 and 2012. The data were used to cross-tabulate injuries with age, gender, frequency and duration of use, location of crash, injury severity, lighting conditions, and alcohol and other drug use. While circumstance data were not available for 87% of the crashes analyzed, some patterns were determined. For example, 42% of reported crashes happened when bicyclists were traveling against traffic, 33% when they were bicycling on sidewalks, and 20% in non-daylight conditions (Schimek, 2014).

Williams (2014), as mentioned earlier, prepared a study for the Governors Highway Safety Administration analyzing fatality information gathered through the FARS and the Insurance Institute of Highway Safety. Collision data were compiled through the GES and police reported crashes from NHTSA. Beyond finding that bicyclist deaths had increased 16% from 2010 to 2012, Williams noted that from 1975 to 2012 the fraction of all fatal collisions within the subgroups aged 20 or older increased from 21% to 84%, and that those involving males increased from 82% to 88%. Within urban areas, he found an increase in fatal collisions, from 50% in 1975 to 69% of all fatal collisions in 2012 (Williams, 2014). Williams notes that there is mixed evidence of increasing bicycle use in the US. In particular, a report by the US Census suggests that commute modal share has risen by about 50% between the 2000 Census and the 2008 to 2012 ACS measurements. However, the overall modal share in the US remains low at 0.6% of travel (McKenzie, 2014).

Gawade et al., (2014) conducted a Florida-based study that examined the patterns of persistently high pedestrian fatality rates based on bicyclist and driver behaviors. Florida has had pedestrian fatality rates per 100,000 people that are almost twice as high as the US average for 2008 (2.64 vs. 1.45), 2009 (2.50 vs. 1.34), 2010 (2.58 vs. 1.39), and 2011 (2.57 vs. 1.42) (Gawade et al., 2014). Four hot zones were determined by a separate Federal Highway Administration (FHWA) analysis, which included six counties within Florida (Gawade et al., 2014). The paper conducted the Cramer's V test to find the relationship between one of the variables and the crashes within the problematic locations. To look at how multiple variables affect the crashes within the hot zones, different Multinomial Logistic Regression Models were created to establish how the variables vary with the crash and fatality rates. While the paper focused primarily on pedestrian safety, some findings pertained to bicyclists. It was found that bicyclists “jaywalk” less than pedestrians, yet they also respect pedestrian traffic signals less. Furthermore, it was also found that mobile phone use—by pedestrians, bicyclists, and drivers alike—has led to an increasing number of crashes (Gawade et al., 2014).

Tin Tin et al. (2013) followed 2,590 adult bicyclists to determine the factors in their lives that led to collisions. The participants of the Taupo Bicycle Study were recruited in 2006 and were followed for an average of 4.6 years through four national databases. The participants, who lived in Auckland, New Zealand, were compared with the others based on criterion characteristics, crash outcomes, and their opinions on the environmental impacts of bicycling. To analyze the relationship among the variables, Cox Regression Models were used to look at the repeated events with multivariate adjustments. The study concluded that 53% of crashes that occurred were related to cycling off-road, in the dark, or in groups residing in urban areas (Tin Tin et al., 2013).

Marshall and Garrik (2011) conducted a study that found that bicycle friendly cities were safer for all road users. The study looked at 24 cities within California and classified them into four categories: 1) highest-bicycling safer cities, 2) medium-bicycling safer cities, 3) low-bicycling safer cities, and 4) less safe cities. For these cities, journey-to-work data and socioeconomic data were retrieved from the 2000 US Census and joined with street network measures, street characteristics, traffic flow information, and crash data from the last 11 years, yielding 230,000 data points to use. These data points were geocoded into GIS to look at geographic patterns within the 24 cities. In terms of general bicycling, the study found that, although the absolute number of collisions is greater in cities with more bikers, the relative safety and the severity of the collisions are more important metrics. They found that cities with more bicyclists tend to have fewer accidents per a road-user exposure metric developed. Also, the collisions tend to be less severe in cities that have more bicyclists (Marshall and Garrik, 2011).

Research has also reviewed the specific impact of bikesharing on user safety and health. Ballús-Armet et al. (2013) looked at two existing bikesharing programs to determine the effect they have had on the local communities’ health: Capital Bikeshare (Washington DC) and Nice Ride Minnesota (Minneapolis). With crash data, plots were created with the crashes at the nearest intersections for periods before and after bikesharing implementation and the development of bikesharing infrastructure. They found that after bikesharing was implemented in Washington DC, the crashes per commuter increased. Yet they found the opposite happened in Minneapolis (Ballús-Armet et al., 2013).

Previous research has evaluated the health effects of the London bikeshare system (Woodcock et al., 2014). The paper considered the health benefits of the system compared with a hypothetical scenario in which the system did not exist for people ages 14 and over. The health impacts considered were physical activity, exposure to pollution, and road traffic injuries. The primary metric was disability-adjusted life years (DALYs), which is the sum of lost years due to premature mortality. DALYs are “based on one year impacts of disease and injury” (Woodcock et al., 2014). The analysis was done with a transport and health impact-modeling tool. It looked at multiple hypothetical scenarios to determine the generalizability of the findings. Operational data were provided by the Transport for London for July 30, 2010 to March 31, 2012. There were 12 months of data that included origin-destination and user demographic information for the trips. Other demographic information was retrieved from two surveys conducted by the Transport for London in 2011 (n=3,686). Surveys were cross-checked with the operational data for representativeness. Physical activity was analyzed for different gender and age groups using the metabolic equivalent of tasks (MET) values in hours per week. Air pollution exposure was measured for PM 2.5, and routing was modeled using a software program. Injuries were calculated based on the data provided by the Transport for London's database, which contains police injury reports. Researchers also looked at police reports for people severely injured or killed while cycling in the bikesharing zone from 2005 to 2011 to determine the increased risk associated with an average-duration trip. Deadly collisions between women and heavy goods vehicles were twice as common as similar collisions for men. Overall, they found that bikesharing in London changed male users' DALYs by -72 for men and -15 for women (Woodcock et al., 2014). Because DALYs are the sum of "years lost due to premature mortality," a reduction in DALYs is a net health benefit.

Graves et al. (2014) examined the effect of bikesharing on head injuries. The study considered 10 cities—five with and five without bikesharing—and the head injuries reported at their trauma centers. The percent of head injuries compared with the total number of injuries registered in trauma centers were observed before and after bikesharing was implemented. Sensitivity analyses were performed with a Poisson regression with robust standard variances to assess the variability to risk ratios and age. In total, the number of total injuries per month decreased in bikesharing cities (63.0 to 45.4) compared with non-bikesharing cities (77.6 to 79.4). However, the ratio of head injuries increased in bikesharing cities: 42.3% to 50.1% versus 38.2% to 35.9% (Graves et al., 2014). The patient-level data were not available to know whether or not the injured individual was using bikesharing.

Williams (2014) noted that bicyclist deaths composed 2% of nationwide traffic-related deaths. According to data compiled by the Pedestrian and Bicycle Information Center, bicycle trips account for 0.9% of all trips, which is a magnitude smaller than the 2% of traffic-related deaths. Williams conducted a survey in ten states regarding bicycle safety. All ten confirmed that bicyclist safety is being given considerable attention, despite its small contribution to overall motor vehicle-related fatalities. The matter is further complicated by the reasons for cycling. The Pedestrian and Bicycle Information Center (2012) reported that 61% of bicycling in 2012 was undertaken for the purpose of recreation and health. These types of trips may take place in different places from where shared bike users may be found.

Previous studies of safety have also employed the Haddon Matrix, which is a conceptual framework for injury prevention. The Haddon Matrix breaks down an event into pre-crash (before), crash (present), and post-crash (future) phases and itemizes those phases by causes that relate to components associated with drivers, passengers, pedestrians, bicyclist, motorcyclists, vehicles, highways, police, and other factors (Haddon, 1999). The matrix is effectively extendable to include any number of factors deemed relevant within the three phases, including environmental or other exogenous factors. The structure of the matrix is replicated into two copies. One is used to categorize causal factors to a crash, and the other is used to categorize countermeasures within the same phase and same component. The matrices can be used to identify key points that can be highly effective in reducing crashes. With respect to bikesharing, safety benefits would predominantly arise from the pre-crash phase of the Haddon Matrix. In theory at least, behavior, practices, and infrastructure surrounding bikesharing have some effects in avoiding the crash altogether. The reduced use of helmets in bikesharing does suggest that this would be a key area of focus for addressing issues in the crash phase of the Haddon Matrix. Empirically, however, one can surmise that whatever (if any) beneficial safety effect bikesharing may have, it is not derived from increased helmet use or any post-crash action.

While bicycling is effectively a zero-emission mode, not all researchers agree that it is a cost-effective solution for emission mitigation. Grant et al. (2008) concluded that bicycle and pedestrian projects generally have modest emission reduction effects. They studied the changes in reduction of several pollutants and calculated the cost effectiveness of each project. For example, they found it cost $453,217 to reduce emissions by one ton of CO by building the bike path. By comparison, it cost only $2,030 to reduce emissions by one ton of CO by improving traffic flow through freeway traffic management, and it cost between $621 and $115,766 per ton of CO by providing public transit service upgrades. One of the weaknesses of bicycling as a means of emission reductions was its propensity to reduce emissions for shorter trips. They wrote: “Bicycle and pedestrian trips generally have modest effects on emissions” and “Bicycle and pedestrian trips may be more effective when designed to enhance access to transit, so that longer trips lengths may be reduced.”

THE ROLE OF INFRASTRUCTURE ON BICYCLE SAFETY

Previous research has also assessed the role that infrastructure plays on bikesharing safety. Mekuria (2014) created a bicycle connectivity and safety model. He looked at infrastructure geometry and flow data to determine streets with high levels of traffic stress (LTS). The majority of the street network data and demographic data were provided by the Urban Planning Department of the San Jose State University. The City of San Jose Transportation Department provided data on bicycling infrastructure—such as bike lanes, paths, and trails. LTS is criteria based on Dutch bike riding experience, and a threshold is determined to identify what links in the network are causing it to be disconnected. It was found that, even though certain streets were not high-stress links by themselves, the junctions with high-stress links negatively affected the bicyclist environment.

The Michigan Department of Transportation put together a report on optimizing pedestrian and bicyclist safety and vehicle mobility. The report examined roadway improvements summarized by the FHWA and emerging design innovations compiled by the National Association of City Transportation Officials (NACTO) (LaPlante et al., 2012). Furthermore, crash analysis was done on data from the Michigan Department of Transportation from 2005 to 2010 (LaPlante et al., 2012). They looked at age, gender, actions prior to crash, and alcohol consumption. The report found that roundabouts decrease intersection bicyclist crashes by 35%. They also found that 20% of fatal bicycle crashes happened on roadways posted for 25 mph to 30 mph (40 km/h to 48 km/h) and in between 3:00 to 6:00 p.m. (LaPlante et al., 2012).

Chen et al. (2012) evaluated the safety effects of bicycle lanes in New York. Police-reported crashes were used to compare streets before and after bike lane installation. The study used the generalized estimating methodology on different roadway segments. Installation of bicycle lanes did not lead to an increase in crashes, despite the probable increase in the number of bicyclists. The most likely explanations for the lack of increase in crashes were reduced vehicular speeds and fewer conflicts between vehicles and bicyclists after installation of these lanes (Chen et al., 2012).

SAFETY IN NUMBERS HYPOTHESIS

A few studies have examined the safety-in-numbers hypothesis directly. Marshall and Garrik (2011) have reported that cities with higher bicycling were safer for all road users. Findings suggest that these cities have lower overall speeds because of the high density of bicyclists. As a result, they become more bike friendly. Jacobsen (2003), as reported earlier, backs up the concept of safety in numbers. Five sets of data—three population levels and two time series—were used to establish the relationship between the amount of walking and bicycling and the collisions involving motorists. The paper models the increase in absolute injuries and the decrease in risk by using a power curve. According to his model, the number of injuries should increase with a roughly 0.4 power increase in bicyclist interaction. Meanwhile, the risk decreases by a -0.6 power. He notes that collisions are largely based on motorist behavior, which is affected by the number of people on the road (Jacobsen, 2003). Others have questioned the safety in numbers hypothesis. Bhatia and Wier (2011) question whether or not a non-linear (and non-exponential) relationship between increased walking/bicycling and collisions really indicates a safety effect caused by increased volumes of pedestrian/bike traffic. They considered the inference of safety in numbers to be unsubstantiated. Olivier et al. (2013) also examined the issue with a broader statistical analysis of criticisms of helmet laws. They used New South Wales hospitalization data from 2001 to 2010, and they found no safety in numbers effect.

SAFETY ISSUES RELATED TO INDIVIDUAL SHARED BIKE USERS

Several cycle operator characteristics can influence the likelihood of being involved in a crash. Crashes can occur on roads and streets as well as off-road. Operator characteristics include age, gender, and race/ethnicity. Other related factors include the frequency of riding (related to proficiency of riding a bike) and the purpose (recreation, health, personal business, social, commuting to work, and commuting to school). Although the latter factors are not strictly operator characteristics, they do influence safety. A study in Boston produced bicycle collision data (percent collisions and injuries in various age groups, as well as the percentage of the Boston population in each age group) in various age groups from 2009 to 2012 (City of Boston, 2013). The collision data and the injury data, as a percentage of the total collision and injuries, were almost identical, suggesting that movements in collisions overall could be a reasonable proxy for movements in injuries. Among the many facts uncovered, the report showed that the ratio of the percentage of injuries to the percentage of population was much higher in the 16 to 25 and 25 to 34 age groups than in the other age groups. Naturally, this is a function of exposure and is likely related to the higher incidence of cycling in those age groups. Buck et al. (2012) studied the demographics of area cyclists and users of Capital Bikeshare in Washington DC.

Their report collected valuable and difficult-to-obtain data on demographics of short-term bikesharing users. The comparative distributions of age as reported by Buck et al. (2012) are reproduced in Table 1.

Table 1. Age Groups of Area and Shared Bike Users in Washington DC

Age Group	Area Cyclists (% of Total)	Short-Term CaBi Users (% of Total)	Annual CaBi Users (% of Total)
16 to 24	5	17	12
25 to 34	24	43	55
35 to 44	31	17	20
45 to 54	23	16	10
55+	17	7	5

Source: Reproduced from Buck et al. (2012).

The first observation that can be made is that the area cyclists, broken down by age groups, appear to follow a different distribution from the distribution of US cycling trips by age group. Of short-term Capital Bikeshare users, 55% used it for tourism, which is a very different use compared with regular cyclists. Tourists are subject to many different factors, such as lack of direction and added caution due to their limited knowledge of a specific area. According to the Pedestrian and Bicycle Information Center (2012), only 33% of cycling is for recreation. Buck et al. (2012) found that only 6% of short-term CaBi users wore helmets, while 37% of annual users wore helmets. By comparison, 72% of cyclists in Boston wore a helmet, and only 48% of Emergency Medical Services incidents recorded in Boston wore helmets (City of Boston, 2013). Shaheen et al. (2014) found much the same trend in low-level helmet use. A large percentage of bikesharing users reported never wearing a helmet including: 74% in Mexico City, 54% in Montreal, 46% in Toronto, and 42% in Minneapolis-Saint Paul. Salt Lake City was an exception. Although it was the smallest of all systems studied, it reported only 15% of respondents never wearing a helmet (Shaheen et al., 2014). These statistics indicate relatively low helmet usage among bikesharing riders, which have been confirmed by several other studies (Fischer et al., 2012). It would follow that the average shared-bike user would be more prone to head and brain injuries in the event of a collision. Some have debated the effectiveness of helmets in protecting against bicyclist injury (Matyzszczyk, 2012); however, the consensus among public health researchers conducting case-control studies is that helmets do reduce the risk for head injuries (particularly severe injuries) in the event of a collision (Amoros et al., 2012).

Bikesharing does result in modal substitution from private bikes to shared bikes. Buck et al. (2012) found that both short-term users and annual members of the service reported that most of the shared bike trips substituted for either public transport trips or walk trips. Of the trips that were replaced by short-term users, 35% were public transport trips and 53% were walking trips. The corresponding percentages for annual members were 45% and 31%, respectively. The authors commented that the differences between short-term and annual members could be explained in part by the fact that the majority of short-term users were tourists, and they may not have had access to a personal automobile or a bicycle in Washington DC. Shaheen et al. (2012 and 2014) found similar substitution patterns in their survey of annual members. Bikesharing members reduced public transit use in Montreal, Toronto, Mexico City, and Washington DC, but members interestingly increased rail use in Minneapolis-Saint Paul, and those in Salt Lake City increased both rail and bus use. They concluded that the modal shift dynamics of bikesharing could be more complementary to public transit in smaller cities than in large cities. These substitution dynamics are relevant in the context of safety, given that exposure on a bicycle poses a higher risk compared with exposure on public transit.

SUMMARY

While studies on bikesharing safety are limited, there is evidence to suggest that bicycle equipment (including helmets) and infrastructure have an impact on bicycle safety, and therefore by extension, bikesharing safety. In addition, previous research has found that bikesharing presents an overall health benefit when measured in the form of net change in DALYs. However, there is mixed evidence on the issue of safety in numbers. It is unclear whether or not an increase in the number of cyclists (by itself) reduces crash rates (perhaps due to increased awareness and visibility of cyclists) or increases crash rates due to greater risk exposure. Bikesharing systems increase the number of cyclists on the road, and due to documented reduced helmet use, expose them to greater risk of injury in the event of a collision. Questions remain in the literature with respect to the overall collision rate of bikesharing users relative to bikesharing risk in general.

In sections that follow, the authors describe the methodological approach for advancing understanding of bikesharing and safety through the application of expert interviews, focus groups, and data analysis. Results emerging from this diverse set of investigations are expected to shed light on the safety challenges of bikesharing and how those challenges may be best mitigated. The authors further use data to explore trends in bicycle collision in bikesharing environments and report safety metrics that can be tracked over time.

III. METHODOLOGY

This study evaluated the interaction with bikesharing and bicycle safety using three different methodological approaches. The study first implemented focus groups with members of BABS and with drivers/non-bicyclists within the San Francisco Bay Area. Following the implementation of these focus groups, the study engaged in interviews of industry and governmental experts on bicycle safety and policy. Third, the study implemented a longitudinal data analysis of bicycle collisions and bikesharing activity in three metropolitan areas: 1) Washington DC, 2) Minneapolis-St. Paul, and 3) the San Francisco Bay Area. All three implemented bikesharing systems based on the same technology. This data analysis explored how trends and distributions of bicycle collisions evolved within cities that implemented bicycle sharing. Through the analysis, the authors note some limitations. There do exist limitations inherent in bicycling data because bicycling trips overall are estimated and not known precisely. Bikesharing is in fact exceptional in this regard by providing precise information on the quantity and distribution of trips. Further, data collection did not cover all bikesharing systems in the USA, and thus there are natural limitations made from inferences on a subset of operators. Nonetheless, these limitations do not prevent the authors from exploring the subject in detail and providing insights that can be further evaluated in subsequent study. In the subsections that follow, this report describes in more detail the applied methodologies.

FOCUS GROUPS

Four focus groups were conducted in Summer 2014 to gain insight regarding the impact of bikesharing on safety from the perspective of both bicyclists and drivers. Two of the focus groups were in San Jose, California: one with members of Bay Area Bike Share (BABS) and one with non-members to gain driver perspectives. Two more were conducted in San Francisco, California, which were also separated into BABS members and non-member drivers. BABS's multi-centric system design encompasses different urban environments, with San Francisco having a lower but denser population than San Jose.

All focus groups were guided by protocols designed to gain perspective on the subject of bicycle safety and how bikesharing might influence safety. The study design sought the opinions of those directly exposed to bikesharing through its use and the perspective of drivers exposed to bicyclists on the road. The bikesharing member and driver protocols were varied to capture participants' relative perspectives.

The full protocols for both groups in San Francisco are found in Appendix A. The protocols for the San Jose focus groups were similar, but they were customized for that city. For the BABS member focus groups, the discussion centered on:

- Experience with bicycling and BABS,
- Experience with the BABS and safety, and
- Improving bicycle safety.

For the driver and non-bicyclist focus groups, the discussion centered on:

- Experience with bicycling,
- Experience with bicyclists from the perspective of a driver,
- Experience with BABS, and
- Improving bicycle safety.

These topics were discussed in detail within the four focus groups across the two cities.

EXPERT INTERVIEWS

The purpose of the expert interviews was to obtain additional information on the safety risks associated with bikesharing, perceived and actual causes of collisions, existing and proposed solutions to address bikesharing safety concerns, and to better understand the role of liability and the policy process for evaluating and adopting bicycles and more specifically bikesharing safety initiatives. Interviewees included a bikesharing operator, policymakers, government agency personnel, non-profit personnel, and emergency service personnel. The experts interviewed had experience in a wide range of disciplines including: 1) public policy development; 2) roadway design; 3) bicycle and pedestrian infrastructure; 4) behavioral research and research psychology with experience studying the human aspect of cycling; 5) professional affiliations that encourage safe infrastructure design; 6) transportation planning; 7) emergency response; and 8) bikesharing operations both from the prospective of a system owner and a system operator. The content of the expert interviews reflected the personal views of the interviewees and does not necessarily represent the views or policy positions of their agencies.

COLLISION AND BIKESHARING DATA ANALYSIS

Researchers acquired a variety of data sources to empirically evaluate bicycle safety in the metropolitan areas where bikesharing has been operating including: Washington DC, Minneapolis-St. Paul, and the San Francisco Bay Area. These datasets covered the regions where Capital Bikeshare and Nice Ride Minnesota operate, which are among two of the nation’s longest-running bikesharing systems. In addition, the more recently established BABS was included in the study to explore insights that might emerge from early-stage system implementation. The analysis included data from the US Census, bicycle-involved collision data from each of the US states, collision data from each of the bikesharing operators, as well as bikesharing activity and station location data from each system. These data sources were combined in various ways to generate insights about the relative safety levels of bikesharing in these regions and the influence (or lack thereof) that the presence of bikesharing has on broader bicycle safety.

IV. FOCUS GROUP RESULTS

Four focus groups were conducted in Summer 2014 to gain insight regarding the impact of bikesharing on safety from the perspective of both bicyclists and drivers. Two of the focus groups were conducted with members of BABS and two focus groups were conducted with non-member drivers.

BAY AREA BIKESHARING MEMBER FOCUS GROUPS

Two focus groups were conducted in August 2014. The first group in San Francisco had nine participants. It was composed of five men and four women. The second one was held in San Jose and had seven participants; it was composed of one woman and six men.

Each focus group lasted approximately one and one-half hours and covered numerous topics pertaining to BABS member experiences with cycling, bikesharing, and automobile and pedestrian safety. The focus groups probed participant cycling and walking experiences interacting with automobiles.

Experience with Cycling and Bay Area Bike Share

Of the sixteen participants, one from each group used BABS daily, while two from San Francisco and four from San Jose used BABS almost daily. One individual from San Francisco used BABS on a weekly basis, and all remaining individuals used BABS less regularly.

Four of seven participants from San Francisco who have personal bicycles used the BABS bikes more frequently than they did their personal bicycles. Six of the participants from San Jose owned personal bikes, and four of them use BABS more frequently. Overall, most users in both focus groups used bikesharing more for commuting and short, unplanned trips, whereas personal bikes were reserved for recreational uses and errands outside of the BABS service area and trip duration range.

Participants in both focus groups stated that they used privately-owned bicycles generally for:

- Trips outside the range of the BABS service area,
- Trips involving hills—especially mentioned by San Francisco participants, and
- Recreational trips in parks or on mountains.

Further:

- Eight of the nine participants from San Francisco said that BABS increased how often they ride. Six of the seven participants from San Jose also said that BABS increased their bicycle ridership to varying degrees. Focus group participants said they typically increased their bicycle ridership because BABS made it easier to commute with public transportation, i.e., it bridged the first-last mile gap.

- BABS was used to replace short trips that would either have been done by walking or taking a bus.

Bay Area Bike Share System Impact on Biking

Some focus group participants said the launch of BABS during Summer 2013 changed how they perceived cycling as a mode in the San Francisco Bay Area. Six participants from the San Francisco focus group said they believed there had been a noticeable increase in cycling since the launch of BABS. Four participants from the San Jose focus group said they observed an increase in local cycling; however, only two thought this was a direct consequence of BABS. One participant said BABS changed his community's perception of cycling as a viable transportation mode.

Experience with the Bay Area Bike Share System and Safety

Most focus group participants felt that BABS riders were slower and tended to comply with traffic safety laws. Participants in both focus groups said they thought that compliance with rules resulted from the bicycle size (e.g., bulkiness and large frame), which limited speeds and risky maneuvers. Participants from San Francisco pointed out that BABS users tended to be commuting residents, while San Jose participants added that BABS bicyclists tended to be look more aware and be more cautious as they rode.

There was a general agreement between both BABS member groups that safety when riding depended on the presence or absence of bicycle infrastructure.

A majority of participants from San Francisco and San Jose felt safer riding with other cyclists. Participants from both focus groups felt safer from collisions with cars because drivers would go slower and were more cautious with big groups. Participants in both focus groups said group riding increased the likelihood of collisions between bicycles—especially if people were riding side by side, talking, or trying to pass each other. One member pointed out that groups created a “herd mentality” in which members toward the back of the pack simply followed members in front and often became less aware of traffic hazards, i.e., under the assumption that other group members were looking out on his/her behalf. Participants from San Francisco also emphasized that increased safety associated with riding groups depended on “cluster etiquette,” including avoiding passing each other and riding at a speed dictated by the group.

The focus groups also examined the types of cyclist behaviors that were most harmful to road users. All participants agreed the most common cyclist behaviors most harmful to roadway users were:

- Lack of predictability;
- Not following traffic laws (e.g., running red lights and ignoring stop signs); and
- Aggressive riding (e.g., speeding and swerving).

Both groups said that BABS users were less likely to engage in these harmful behaviors in part because the bicycle design made it harder to be reckless.

Overall Experience with the Bay Area Bike Share System

Compared with their personal bikes, five of the seven participants from San Francisco and four of six from San Jose who owned a bike felt safer on BABS bikes. The most commonly mentioned reasons were:

- BABS bikes are more visible to cars and other bicyclists;
- BABS bikes are sturdier, and;
- BABS bikes have wider tires, which makes the equipment more stable (e.g., stability over potholes, train tracks, etc.).

All participants were against mandatory helmet laws, including users who said they frequently wore helmets. Participants viewed helmet usage as a personal responsibility and choice. Additionally, participants believed compulsory helmet laws would eliminate non-planned trips—which numbered more than planned trips among all participants.

The majority of participants said that having helmets available at the stations would increase helmet usage. The participants had mixed views about maintaining sanitized helmets at the stations. Five participants from San Francisco and two from San Jose said they would wear a sanitized helmet. Four participants from San Francisco and two from San Jose would not wear a sanitized helmet. The remaining participants from San Jose indicated they might wear sanitized helmets depending on cost, sanitization, and fit.

Improving Bicycle Safety

The final section of the focus group was an open discussion on ways to improve bicyclist safety. The broader theme was divided into five questions that addressed the roles of drivers, bicyclists, local government, law enforcement agencies, and BABS. Table 2 contains the questions, the proposed solutions, and the top choices with the weighted number of votes each received (e.g., 3 points for 1st choice, 2 for 2nd choice, and 1 for 3rd choice).

Table 2. Bay Area Bike Share Member Focus Group Voting Results

Proposed Solutions	Top Choices
How can bicyclists improve their safety around drivers?	
a. Bright lights/ Reflective clothing b. Helmets c. Predictability: following rules, signaling d. Eye contact e. Louder bells/ horns	1. Predictability: following rules, signaling (37) 2. Bright lights/ Reflective clothing (24) 3. Eye contact (19)

Proposed Solutions	Top Choices
How can drivers improve bicyclist safety?	
a. Patience b. Predictability c. Avoid distractions d. Looking, awareness, vigilance e. Follow rules: speed and signaling f. Try biking/ have empathy	1. Looking, awareness, vigilance (32) 2. Avoid distractions (17) 3. Follow rules: speeding and signaling (17)
How can local governments improve bicyclist safety?	
a. Bike infrastructure: bike lanes, facilities, signs, "buffer" lanes, etc. b. Education: in schools, at DMV, through ads c. Mandating helmets d. Law enforcement for drivers and bicyclists e. Road maintenance f. Insurance g. Have bike-specific rules	1. Bike infrastructure: bike lanes, facilities, signs, "buffer" lanes, etc. (46) 2. Law enforcement for drivers and bicyclists (14) 3. Road maintenance (13)
How can law enforcement agencies improve bicyclist safety?	
a. Learn laws themselves b. Enforcement c. Education d. Bike cops e. More tolerance f. Stringent enforcement on cars	1. Stringent enforcement on cars (28) 2. Bike cops (20) 3. Learn laws themselves (16)
How can Bay Area Bike Share improve bicyclist safety?	
a. Education: videos on kiosk about bike safety b. Surveillance c. Collaboration between BABS and other advocate groups d. "Watch out!" info graphics about road dangers e. Helmets (sanitary) f. Connection to other transit authorities with safety tutorial g. Expansion	1. Expansion (25) 2. Collaboration between BABS and other advocate groups (23) 3. Helmets (sanitary) (18)

Improving Bicycle Safety

The focus groups concluded by asking participants if they thought the number of collisions would increase or decrease if the number of cyclists increased. Eight participants from San Francisco thought the road would become safer for bicycles and collisions would decrease. The primary reasons mentioned were:

- Increasing the number of bicyclists would take cars off the road, making it safer for bicyclists;
- Cars would be forced to go slower because there are more bicycles on the road; and

- Cities would be forced to improve bicycle infrastructure.

Six participants from San Jose believed overall collisions would increase due to additional riders, but that the rate of collisions would go down, making it statistically safer for individuals. One of the participants believed the increase in collisions would be a short-term problem leading to long-term benefits as road sharing becomes more commonplace.

Conclusion/Summary: BABS Member Bay Area Bike Share Focus Groups

The focus groups emphasized how the members perceived cycling safety and how BABS affected safety. Throughout the focus groups, participants noted problems with overall bike safety and BABS-specific safety. They later made suggestions for improvement.

Overall safety issues were usually the result of two factors: 1) the bicyclist was not following rules—whether he or she did not know them or chose not to follow them—or 2) the infrastructure did not adequately support bicyclists. The first case included examples, such as running red lights, ignoring stop signs, riding opposite to traffic, and riding on the sidewalk. Infrastructure was usually a problem when cyclists were placed in danger while sharing the road with vehicles, buses, and trollies. The BABS focus group participants thought the limitations of the BABS bikes was the primary way in which BABS riders' safety differed from other bicyclists. Because the bikes cannot achieve high speeds, BABS bicyclists were forced to be more conservative in their riding.

DRIVER AND NON-BABS MEMBER FOCUS GROUPS

Two focus groups were conducted with persons that were not members of BABS. They were called "drivers" for the purposes of these focus groups to gain perspective from non-bicyclist road users. Both focus groups were held in July 2014. The first focus group was in San Jose, with five women and four men. The second was held in San Francisco, with six women and four men.

Driving Experience with Bicyclists in General

Participants in both focus groups indicated a number of problematic cyclist behaviors including:

- Running red lights and stop signs;
- Road sharing;
- Cycling on the sidewalk or road when dedicated bicycle infrastructure (e.g., bike lanes) were in close proximity;
- Lane splitting and weaving through cars;
- Cycling opposite to traffic flow; and
- Constantly switching between curb and road riding.

San Jose focus group participants said the most challenging aspects of sharing the road with bicyclists were:

- Night cycling without lights or reflective gear;
- Groups with different skill sets and cycling styles;
- Cyclists that do not signal or comply with traffic laws; and
- Unpredictability (e.g., weaving or making non-signaled turns).

San Francisco participants identified the following difficulties sharing the road with bicyclists:

- Driving near bicyclists who ride side-by-side in the bike lane;
- Driving near distracted bicyclists (e.g., mobile phone usage); and
- Unpredictability (e.g., weaving or making non-signaled turns).

Both groups stressed that unpredictability was what made driving near bicyclists most challenging. As pedestrians, the San Jose and San Francisco groups had similar opinions on what was unsafe behavior:

- Bicyclist unpredictability;
- Bicyclists who run red lights and stop signs and run into crossing pedestrians; and
- Cycling on sidewalks.

Experience with Bay Area Bike Share

When asked about BABS, all but one participant had heard about it. Individuals from both groups had a variety of experiences with BABS bicyclists. Five participants from San Jose who had seen the BABS cyclists thought that, although the riders looked pleased with the system, they often seemed less aware of their surroundings and of cycling rules. Participants also said BABS bicyclists were very rarely seen wearing helmets. In contrast, four out of the seven San Francisco participants who had seen BABS bicyclists thought that they are more law abiding because they were either tourists from bike-friendly cities or unfamiliar with San Francisco and concerned with breaking laws in an unfamiliar place. The remaining three of the seven believed that most BABS users did not know how to ride or did not understand bicycle traffic laws. Many participants from the San Francisco focus group highlighted numerous distractions in an urban environment that increased risks to cyclists unaccustomed to the area. One participant noted that many of the BABS users they encountered were wearing suits and presumably lived or worked in the area.

There was consensus between both focus groups that BABS had not led to a noticeable increase in the number of bicyclists since it was implemented. Participants from San Jose agreed that, since Summer 2013, there has been a general increase in the number of cyclists in the local area. However, they attribute the increase to bike infrastructure improvements in the City of San Jose, not to BABS. Similarly, participants from San Francisco agreed that there was no perceivable increase in bicyclists in the city. Most agreed with a participant's statement that BABS was just "a drop in the bucket." Nonetheless, six individuals from San Francisco believed the existence of BABS showed the San Francisco Bay Area was taking cycling more seriously as a transportation mode. One participant noted the value of BABS in helping to solve the first/last-mile problem with public transportation.

The last section of the focus group was an open discussion on ways to improve bicyclist safety. The broader theme was divided into five questions that addressed the roles of drivers, bicyclists, local governments, law enforcement agencies, and BABS. Table 3 contains the questions, the proposed solutions, and the top choices with the weighted number of votes each received (weighted in the same way defined above).

Table 3. Driver Focus Group Voting Results

Proposed Solutions	Top Choices
How can bicyclists improve their safety around drivers?	
a. Bright lights/ Reflective clothing b. Helmets c. Predictability: following rules, signaling d. Eye contact e. Louder bells/ horns	1. Predictability: following rules, signaling (45) 2. Bright lights/ Reflective clothing (39) 3. Eye contact (14)
How can drivers improve bicyclist safety?	
a. Patience b. Predictability c. Avoid distractions d. Looking, awareness, vigilance e. Follow rules	1. Looking, awareness, vigilance (37) 2. Avoid distractions (36) 3. Follow rules (19)
How can local governments improve bicyclist safety?	
a. Bike infrastructure: bike lanes, facilities, signs, "buffer" lanes, etc. b. Education: in schools, at DMV, through ads c. Mandating helmets d. Law enforcement for drivers and bicyclists e. Road maintenance f. Insurance	1. Bike infrastructure: bike lanes, facilities, signs, "buffer" lanes, etc. (39) 2. Law enforcement for drivers and bicyclists (38) 3. Road maintenance (15)
How can law enforcement agencies improve bicyclist safety?	
a. Learn laws themselves b. Enforcement c. Education d. Bike cops e. More tolerance f. Stringent enforcement on cars	1. Learn laws themselves (28) 2. Enforcement (28) 3. Education (24)

Proposed Solutions	Top Choices
How can Bay Area Bike Share improve bicyclist safety?	
a. Education: videos on kiosk about bike safety b. Surveillance c. Collaboration between BABS and other advocate groups d. “Watch out!” info graphics about road dangers e. Helmets (sanitary) f. Connection to other transit authorities with safety tutorial g. Expansion	1. Education: videos on kiosk about bike safety (16) 2. Collaboration between BABS and other advocate groups (13) 3. Helmets (sanitary) (11)

The focus groups seemed to provide some anecdotal evidence that riding in groups was generally more comfortable and engendered a feeling of safety. This does not mean that cycling would be safer in groups, but that it felt safer. However, the focus groups also raised many of the standard complaints that bicyclists and drivers have about each other (e.g., not following rules, speeding, not signaling, etc.). These longstanding complaints are unlikely to dissipate with bikesharing, but they may diminish with improved infrastructure that separates and segregates rights-of-way among the modes.

V. EXPERT INTERVIEW RESULTS

To better understand industry perspectives on the interaction between bikesharing and safety, the study extended the qualitative analysis of bikesharing safety through a series of expert interviews. In November 2014, researchers conducted eleven expert interviews representing nine organizations. Interviewees represented the following agencies:

- Arlington County Fire Department
- Association of Pedestrian and Bicycle Professionals (APBP)
- Federal Highway Administration (FHWA)
- National Center for Bicycling and Walking (NCBW)
- National Highway Traffic Safety Administration (NHTSA)
- Nice Ride Minnesota
- City of Oakland
- San Francisco Bay Area Air Quality Management District (BAAQMD)
- San Francisco Municipal Transportation Agency (SFMTA).

GENERAL PERCEPTIONS OF BIKESHARING SAFETY

The initial stage of the expert interviews featured questions that examined existing knowledge and perceptions about bikesharing safety. Experts were asked four key questions:

- Do you believe that public bikesharing is safer, less safe, or equally as safe to private cycling?
- Do you think that bikesharing users act differently than other bicyclists? If so, in what ways do you think they behave differently?
- Overall, do you think that the implementation of bikesharing causes (or will cause) an overall increase or decrease in bicycle accidents?
- Do you think bikesharing makes cycling more or less safer for other cyclists?

Despite the varying backgrounds of the experts interviewed, the responses to these questions were generally consistent. Although bikesharing users typically have a much lower rate of helmet usage, public bikesharing was perceived to be safer than private cycling for a number of reasons. However, the experts’ reasoning for why they believed public bikesharing was safer than private cycling varied considerably.

One relatively common point experts made about bikesharing was that bicycle design may influence how people ride. Figure 1 shows design features of a BABS bicycle, which is similar to the design deployed in large cities, such as New York, Washington, Boston, and Minnesota. Figure 2 shows safety reminders on the handle bars of a Columbus, Ohio-based bike share bicycle.

Figure 1. Common Safety Features of Public Bikesharing Bicycles

Courtesy: Bay Area Bike Share.

Figure 2. Handlebar Safety Reminders

Courtesy: CoGo Bike Share.

Bicycle design was frequently cited as a key reason public bikesharing was perceived to be safer than private cycling. *This is because public bikesharing bicycles tend to be heavier with wider tires. Public bikesharing equipment is generally painted bright colors, and users ride slower than their road bike counterparts because of the added weight from larger and heavier frames and because they are often engineered with fewer gears, which limits speeds. Both of these factors contribute to slower riding. Many bikesharing bicycles have lights, often LED lights that illuminate with a pedal-powered motor.* Typically, these lights continue illumination for a period of time after motion has stopped, providing light if a rider stops, parks the bike, or docks the bike. Bikesharing bikes commonly have reflectors on the bikes and pedals, bells to alert pedestrians, and various safety instructions on the bicycle, bikesharing kiosk, and provider’s website. Additionally, road bikes tend to encourage faster use because the rider typically sits above the height of the handlebar and leans forward. This contrasts with most bikesharing bicycles, on which the seat is positioned below the handlebar, promoting a less aerodynamic upright position for riding. In other words, differences in bicycle design tend to encourage a slower, more conservative riding behavior among bikesharing users. See Figure 3 for an illustration of a public bikesharing bike and a road bicycle.

Figure 3. Bikeshare Bike and Road Bike Compared

Sources:
Left: http://www.downtownseattle.com/blog/wp-content/uploads/2014/07/bike_with_P_alaska.jpg
Right: http://velocult.com/bikes/david-tesch-road-bike/

In addition to bicycle design, *a number of experts said bikesharing station location was critical to system safety. Because most public bikesharing kiosks are located in dense urban environments with lower roadway speeds and higher levels of pedestrian activity, motorists are more readily looking out for pedestrians and bicyclists.* In the words of one emergency services supervisor and licensed paramedic: “I have not seen a bikesharing wreck. I asked my colleagues. We cannot recall a [bikesharing] accident. It has always been personally owned bicycles. It is our opinion that we believe bikesharing is safer.”

Additionally, these experts believed that when accidents did occur, they were less severe because of the lower roadway speeds in these urban areas. Finally, *a few experts said that bikesharing tended to attract people who may be new riders to cycling or infrequent riders. These experts said that users who were less experienced were more apt to be cautious, defensive riders and be risk-averse.* However, other experts countered that casual bikesharing users may also be less familiar with local routes and traffic patterns, which could be a contributing cause to bikesharing collisions. Figure 4 shows some the common risks identified by experts associated with public bikesharing and private cycling.

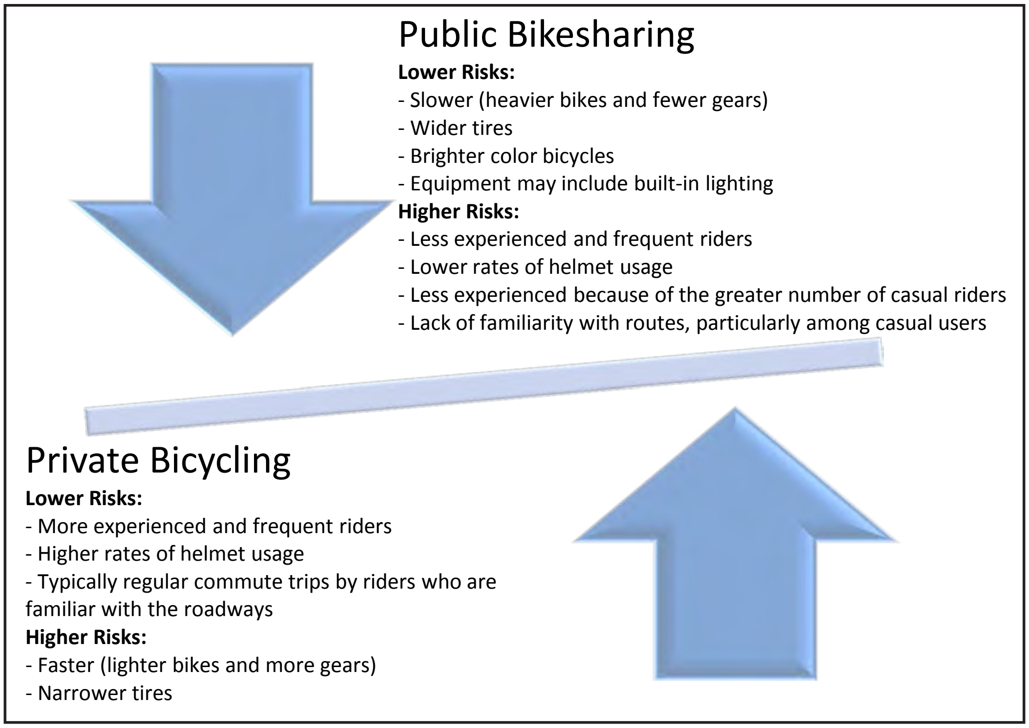

Figure 4. Is Public Bikesharing or Private Cycling Safer: A Comparison of Risk Factors

Defining a typical bikesharing user is difficult. As one operator pointed out, they have users who are experienced riders (some even own their own bicycles but choose to use bikesharing for commuting) and other users who have never ridden a bike and choose to learn on bikesharing. However, generally the experts believed bikesharing users behaved differently than private cyclists. Most experts believed that bikesharing users behaved safer on public bikesharing. *The exception was one expert who believed that the pricing structure of public bikesharing had an adverse impact on bikesharing safety. Specifically, this expert stated that he believed providing 30 minutes of free usage encouraged hazardous behavior by users who felt rushed to return their bicycle before the conclusion of the complimentary 30-minute period.* This expert believed that bikesharing users could be inclined to engage in unsafe behaviors (such as running a red light or stop sign, failing to yield the right-of-way, and practicing similar behaviors) to try to save a few minutes and return the bicycle before the expiration of the free usage period. He felt bikesharing users were particularly prone to this type of behavior if they were nearing the conclusion of the complimentary ride period. Other experts believed bikesharing users were not unsafe in this respect because they have a credit card on file, and users are more concerned about the costs associated with damaging a rented bicycle versus damaging a personally owned bike.

While some experts believed casual users were more error prone because of less familiarity cycling with traffic, they believed this inexperience was compensated for by greater attention, defensive cycling, and motorists who were more forgiving of bikesharing riders. Most experts believed that bikesharing riders are less likely to wear helmets and more likely to ride on sidewalks when trails and bike lanes are unavailable. Most experts believed that the safest bicyclist on the road was an experienced bikesharing rider who wears a helmet.

Figure 5. Safety in Numbers

Source: http://sf.streetsblog.org/wp-content/uploads/2011/03/DSC_6549-1.jpg

Every expert said they believed bikesharing enhances safety for all cyclists. They attributed this to "safety in numbers"—an overall increase in the number of cyclists helps change the road culture, raises awareness and visibility of cyclists sharing the road with other users, and creates more demand for cycling infrastructure. Figure 5 shows an example of multiple cyclists closely riding in a bicycle lane as an example of safety in numbers. *Many of these experts also believed that bikesharing makes streets safer for pedestrians by increasing visibility and awareness of all non-motorized roadway and intersection users. Finally, experts also referenced two types of "network effects." The first involved the high concentration of kiosks and bikesharing users in small geographic areas that contributes to heightened visibility and awareness of all cyclists in these areas. The other "network effect" pertained to education and outreach.* Specifically, the experts said that by getting novice users into bikesharing, these users spread the word of cycling among other non-cycling users, which helps to raise awareness among drivers and non-cyclists. Finally, a number of bikesharing programs have supported general bicycle safety, education, outreach, and free and reduced-cost helmets.

Helmet usage consistently ranks lower among bikesharing users. Although helmet machines remain technically feasible, the experts indicated significant operational challenges with helmet vending (e.g., ensuring vending machines were sufficiently stocked with a variety of sizes and properly cleaning helmets after use). In Seattle, where helmet use is required by law, Pronto Cycle Share has addressed this issue by placing boxes of helmets adjacent to kiosks for users access, as shown in Figure 6.

Figure 6. Helmet Kiosk for the Pronto Cycle Share System in Seattle

Source: Susan Shaheen.

Of all the experts interviewed, only one stated that helmet usage should be mandatory for bikesharing users. They said the health impacts of riding a bicycle outweighed the risks associated with a collision or head injury. The first responder who was interviewed discussed first-hand knowledge of head injuries that could have been prevented by wearing a helmet and was the only expert to highly recommend mandatory helmet laws for all bicycle riders. Numerous bikesharing programs have a free or reduced-cost helmet program for new members. Nice Ride Minnesota has a free helmet program, offering free helmets to any bicycle user. According to Nice Ride Minnesota, most people seen with their helmets are private cyclists rather than bikesharing users.

CAUSES OF INCIDENTS

Experts were also asked to identify common causes of bikesharing crashes. All of the experts stated that collisions do not simply occur. *The vast majority attributed bikesharing (and more broadly bicycle) collisions to a chain of errors. The term "error chain" is a concept that originated in aviation safety referring to the many contributing factors that stem from human-factor related errors causing a collision.* Most of the experts interviewed indicated that the primary purpose of infrastructure design is to modify user behavior to help prevent errors that contribute to collisions.

Experts differed on who they thought was at fault in the majority of bikesharing crashes. Most stated that the fault depended on the circumstances of each crash. A few experts said the cyclist was generally at fault for not sharing the road or insisting on the right-of-way. Other experts said motor vehicles were more often at fault for collisions.

The experts said the leading causes of bikesharing crashes were the same for public bikesharing and private cycling. Infrastructure ranked as the leading cause of crashes when only the cyclist was involved. Experts believed potholes and poorly maintained roadways and trails were the most common causes of crashes involving only the cyclist and said these types of collisions are the least likely to be reported because a cyclist rarely files a report if it is only a single-party collision. *Other leading causes of crashes involving only the cyclist included: alcohol use, distraction or inattention, risky behavior (such as speeding), and weather (specifically wet roadway surfaces).*

Distraction and inattention ranked as the leading factor for crashes when another roadway user was involved. Experts expressed concern about pedestrians, cyclists, and motorists being distracted by mobile phones and headphones. Failure to yield by at least one of the parties involved in the crash ranked as the second-leading cause. The experts attributed this to an overall lack of adequate understanding of traffic laws and who has the right-of-way in many situations on both the part of drivers and cyclists, contributing to a significant number of accidents.

Table 4. Reasons Cyclists Felt Threatened for Personal Safety

Reason	Percent of Respondents
Motorists	83%
Uneven walkways or roadway surfaces	43%
Dogs or other animals	12%
The potential for crime	12%
Uncooperative/ inattentive drivers	7%
Lack of room to ride	5%
Too much bicycle/ pedestrian traffic	4%

Source: Schroeder and Wilbur (2013).

The 2012 National Survey of Bicyclist and Pedestrian Attitudes and Behavior report conducted by NHTSA found that the six most frequent sources of bicycle injuries were: 1) a vehicular accident (29%), 2) falling (17%), 3) roadway/walkway in poor condition or disrepair (13%), 4) rider error or not paying attention (13%), 5) crashed or collision (7%), and 6) a dog ran out after the cyclist (4%). The NHTSA 2012 national survey of bicyclist and pedestrian attitudes and behavior found that one in eight cyclists who had ridden in the past 30 days reported that they felt threatened during some point on their ride.

RISK RELATED TO CRASHES

All but one of the experts indicated that they thought the majority of crashes involved just the cyclist. These experts estimated between 60% and 67% of bicycle crashes involved only the cyclist, compared with an estimated 33% to 40% of bicycle crashes involving another roadway user. Departing from the other experts, the first responder estimated that 25% of bicycle crashes involved only the cyclist, compared with 75% of crashes that involved another roadway user. However, it should be noted that first responders are rarely dispatched to collisions involving only the cyclist (e.g., the cyclist hits a pothole and is injured falling off the bicycle). All experts stated they thought the percentage of crashes involving only the cyclist versus involving another roadway user was the same for private cyclists as for public bikesharing riders.

With one exception, all the experts interviewed said they thought bikesharing crashes were less severe than other cycling crashes because of the heavier, bulkier, and slower bikesharing equipment, even when accounting for lower helmet use. The first responder interviewed said that although bikesharing crashes may be less frequent because of the heavier and slower equipment, bikesharing crashes may be more severe if a head injury is involved because of the relatively low rates of helmet usage among bikesharing users.

There was no consensus on whether or not infrequent bikesharing users (i.e., who ride once a month or less) are more or less prone to have an accident. A number of experts stated that infrequent use raised the risk of these riders because they are less experienced riding with other roadway users, even if they may be more risk adverse. However, these experts also indicated that infrequent users were more likely to use grade-separated bicycle facilities (such as trails), reducing their risk of a roadway accident. Other experts said that increased exposure by regular riders or overestimating their cycling abilities could make regular users more prone to have an accident. The bikesharing operator interviewed said that he did not think there was much of a difference because infrequent bikesharing use did not necessarily translate to infrequent bicycle use. Among Nice Ride Minnesota's annual membership, approximately 60% to 70% have access to a non-bikesharing bicycle. These users selected bikesharing for a variety of reasons including: 1) the need to make a one-way trip on a bicycle; 2) not having to worry about security, maintenance, or parking; and 3) wear and tear on their private bicycles.

IMPACTS OF INFRASTRUCTURE AND PUBLIC POLICY

All of the experts said that lower roadway speeds were critical for improving bikesharing, and more broadly, bicycle safety. All the experts said the maximum roadway speed for motorists should be between 20-30 mph (32-48 km/h) on a roadway with adjacent bicycle lanes.

The experts believed that bike facilities are magnets for bicycle riders, although there was disagreement as to whether or not bikesharing users were more or less likely to use protected routes. Some experts believed that casual bikesharing riders were less likely to be aware of protected routes compared with regular cyclists. Other experts said that bikesharing riders, particularly infrequent riders, may be more likely to take advantage of bicycle infrastructure such as bike lanes and trails because they are less experienced riders. All experts agreed on the importance of station placement (curb placement or on-street) as one of the most important factors impacting whether or not a bikesharing user rides on sidewalks. It was widely believed that users who check out a bike from a curb kiosk were more likely to complete their journey riding on the sidewalk. Figure 7 shows an example of a curbside bikesharing kiosk and an example of an on-street bikesharing station.

Figure 7. Citi Bike Sidewalk and On-street Kiosks

Source: Photos by Lincoln Anderson (left) and Emma Weissmann (right).

Generally, the experts believed that bikesharing users should be restricted by age because of the importance of understanding traffic laws. While all the experts stated that it was permissible to allow children to ride on sidewalks, the experts disagreed on when to permit adult bicycle riders and bikesharing users to ride on sidewalks. *All experts believed that grade-separated bicycle trails were preferable.* A few experts, including the first responder, believed that riding on the sidewalk was safer because of the greater severity of collisions between a cyclist and a motorist versus the severity of collisions between a cyclist and a pedestrian. Many experts wanted to encourage all cyclists to ride on the street, but they were also open to cyclists riding on sidewalks as long as the cyclist was not in an urban business district, the sidewalks were sufficiently wide, and the cyclist was riding at a relatively slow speed.

The experts collectively stated that riding on the sidewalk was perceived safer by cyclists, as motor vehicles were perceived to be the greatest hazard. However, numerous experts identified multiple overlooked risks associated with riding on sidewalks that may be more dangerous than riding on the street. The two most common overlooked risks were vehicles entering and exiting driveways and the prevalence of street fixtures that create cyclist obstacles. Figure 8 shows some examples of cycling hazards, such as street furniture and driveways.

Figure 8. Hazards of Sidewalk Cycling

Source: Photos from NYDOT (left) and John S. Allen (right).

Experts believed that bicycle infrastructure, such as bike lanes and separated bikeways, were most likely to prevent "dooring" and overtaking crashes (by creating a buffer between cyclists and motorists), collisions with pedestrians, rear-end collisions (where the motorist rear-ends a cyclist), and some collisions involving turning movements at intersections. However, the experts universally stated that intersections are the most dangerous location for riders—where cyclists, pedestrians, and motorists assemble and must de-conflict their movements. This suggests that improving intersection safety and design may be the single most important infrastructure improvement that can enhance bicycle and bikesharing safety.

Experts said the same policies that reduce the frequency and severity of private cycling accidents would also reduce the frequency and severity of bikesharing collisions. Key strategies identified included:

1. Greater enforcement (of speeds, traffic laws, and rights-of-ways);

2. Reduced roadway speeds;

3. Better collection and analysis of collision data;

4. Comprehensive education and training for all roadway users (drivers and cyclists); and

5. Greater helmet usage.

Some of the safety initiatives undertaken by the experts and their respective agencies included: 1) BIKESAFE cycle tracks, "Road Diet" information guide, and design guidance from federal agencies; 2) design guidance in partnership with other professional associations, such as the Institute of Transportation Engineers and the National Association of City Transportation Officials (NACTO); 3) comprehensive bicycle and pedestrian outreach, including guided tours; and 4) free and reduced-cost helmets. A number of experts representing operators and funding agencies said they partnered with bicycle coalitions to provide guided rides, education, and outreach. These programs were available to bikesharing users, private cyclists, and motorists. They believed helping everyone to be safer on the roadway makes all cyclists safer, including bikesharing users.

In this study, experts were asked to provide strategies to make bikesharing safer. Key strategies identified include:

1. Data Collection and Management:

    a. Revise the National Household Travel Survey (NHTS) to collect trip information from bikesharing and other emerging modes to better understand how these modes impact a household's daily travel patterns.

    b. Revise the Fatality Analysis Report System (FARS) to track whether or not bicycle crashes are on bikesharing or privately owned equipment.

2. System Design:

    a. Paint bikesharing bicycles a highly visible color to make them more noticeable in urban environments.

    b. Continually monitor safety and implement spot improvements to address safety issues that arise after stations are installed.

    c. Use infographics on bicycles, kiosks, websites, and outreach materials to continually raise safety awareness.

VI. ANALYSIS OF ACTIVITY AND COLLISION DATA

Bikesharing provides researchers and the public with an exceptional window into bicycle activity. Bikesharing activity data provide precise counts of bicycle trips, while the additional processing of origin and destination data can provide good estimates of distances traveled by users of these systems. Outside of bikesharing, these simple bicycle-use metrics (e.g., describing the number of trips, distances traveled, or spatial distribution of such trips) have never been known with such precision at the city scale. These insights, coupled with traditional data sources tracking bicycle activity, can yield new insights on the interaction of bikesharing with the broader safety challenges of cycling.

The areas of analysis were defined by the regions of operation of the three bikesharing systems and jurisdictional boundaries. The analysis of Capital Bikeshare was focused on the highly urbanized District of Columbia, which was the predominant area of operation for this system through 2013. Nice Ride Minnesota operates in the cities of Minneapolis and St. Paul. These cities, which are within Hennepin and Ramsey Counties, exhibit less-dense public transit and street networks, but they are still highly urbanized. The outer regions of the counties are more suburban and rural in nature. Finally, BABS operated in the most dispersed of designs, covering a rail corridor (Caltrain) spanning the counties of San Francisco, San Mateo, and Santa Clara, the latter of which includes the major city of San Jose. The cities, particularly San Francisco, exhibit urban environments much like Washington DC, whereas the nodes in the cities along the Caltrain corridor are less dense. These are still urban, with dense street networks, but population and employment densities are lower than what is found in the downtowns of San Francisco, Minneapolis-St. Paul, and Washington DC.

TRENDS IN BICYCLE ACTIVITY

Traditional data sources show that bicycle use has been increasing fairly rapidly in some major cities across the country since at least 2005. The most continuous and spatially comprehensive measurement of bicycle use in the United States is produced by the US Census American Community Survey (ACS), which annually estimates journey-to-work data within all metropolitan areas, as well as in most other Census-tracked jurisdictions. Journey-to-work data are tracked along a number of dimensions including place of work, time of departure, travel time, and travel mode. By evaluating the trend of bicycle commuting taken year-to-year, a clear picture of increasing bicycle use is evident in the US. However, this increase is more pronounced in cities than in the entire US population. Figure 9 shows the rising modal share of bicycle commuting within the three cities of focus in this study. San Francisco, Washington DC, and Minneapolis have long been among the large American cities with the highest bicycle modal share. A few other cities, such as Seattle and Portland, also have high mode shares. The continued rise of bicycle modal share does suggest that an increase in bicycle commuting was underway before the presence of bikesharing in these cities.

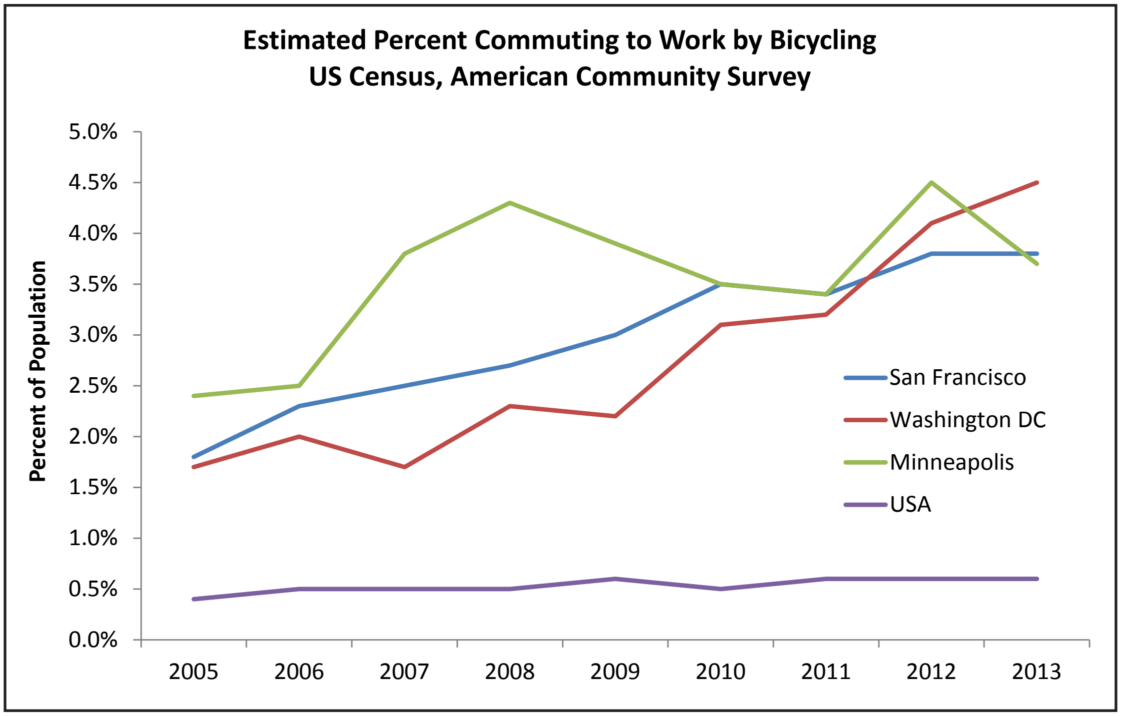

Figure 9. Modal Share of Bicycle for Commuting within Key Cities

Figure 9 shows the difference in the percentage of population commuting by bicycle in the three evaluated cities versus the broader US. Although the national share of bicycle commuting is rising, this is broadly driven by the trends within some urban areas. While these modal shares were at comparable levels in 2013, these cities do not have comparable populations, suggesting that there is a further spread on the estimated size of the bicycle-to-work population based on the size of the working populations over age 16. Figure 10 accounts for population size and growth in the assessment of cycling activity and shows that San Francisco consistently has been among the three cities with the largest cycling population, while Washington DC surpassed Minneapolis in recent years due to both modal share growth and a larger overall population. The trend in the US population is indicated on the right-hand scale (secondary y-axis) to keep the movements in trend visible across the different scales. The estimated increase in the US population commuting appears more pronounced in Figure 10, as the modest rise in the percentage of people commuting is coupled with an overall population that is increasing at a healthy rate. While the percentage of bicycle commuters as a percentage of overall commuting remains relatively low, the estimates presented in Figure 10 indicate that the population commuting by bicycle in the US has increased by 60% from 2005 to 2013.

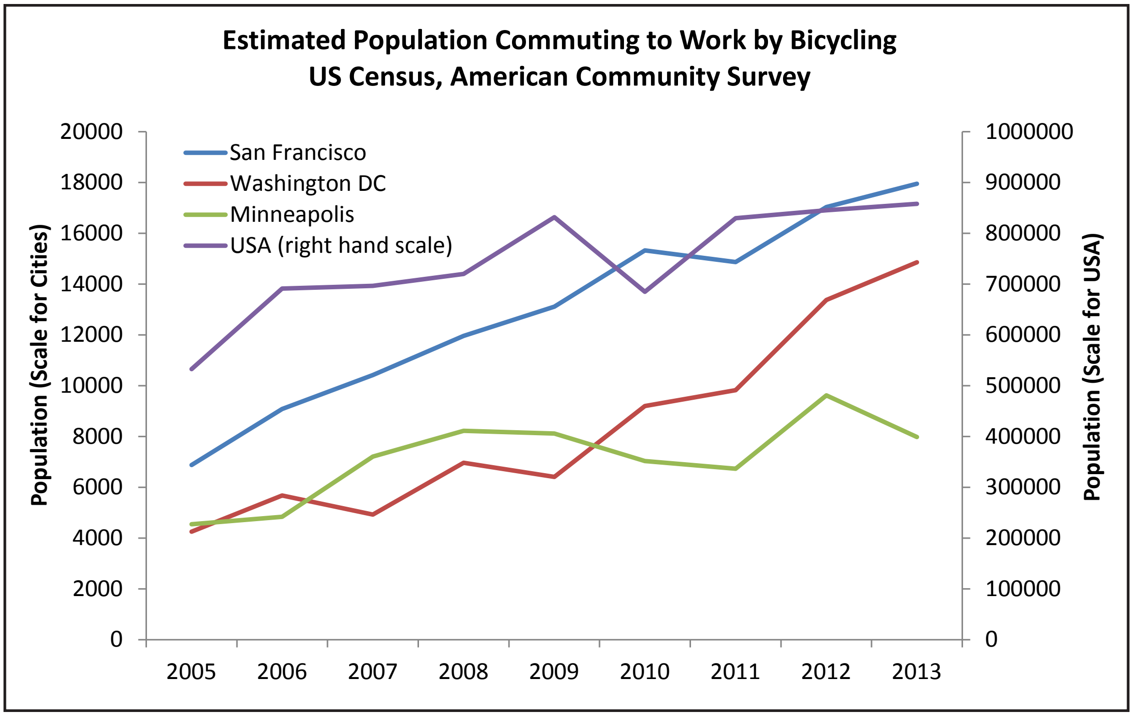

Figure 10. Estimated Population Commuting to Work by Cycling

BIKESHARING ACTIVITY

Accurately estimating the total number of bicycle trips in a large metropolitan region is difficult. While the US Census is considered to be among the best resources for tracking changes in bicycle activity, its focus on the commute imposes some limits. Bikesharing activity in the three cities is similarly varied. The cities have had different start dates and different trajectories of growth within the intervening years.

Capital Bikeshare in Washington DC was among the earliest modern bikesharing systems, and its activity data through 2013 is plotted in Figure 11. The plot separates the activity of registered subscribers and casual users and also shows the total. Registered users are those who have paid for some annual or monthly term, and they receive 30 minutes of free use followed by a charge by the minute. Casual users comprise those who have not signed up for any term and pay for each use based on the time expended. Casual users are often people trying out the system and/or tourists in town who have no need for long-term use. Figure 11 shows that Capital Bikeshare activity seasonally peaks in the fall, and tends to reach an annual low in the winter. The system use has exhibited an upward trend and hit peak maximum usage in September 2013, with over 285,000 trips (the system would go on to exceed this peak in subsequent years). Through the end of 2013, the system registered cumulatively 5,991,390 trips since inception.

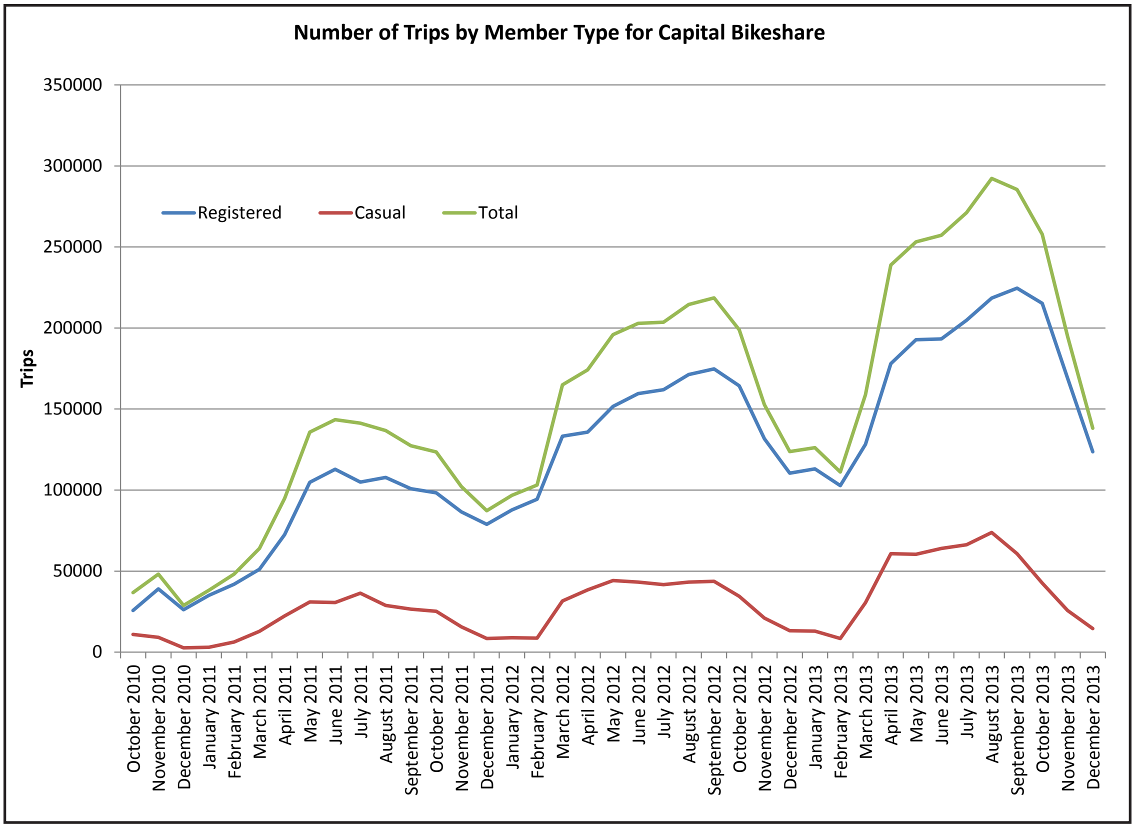

Figure 11. Bikesharing Activity for Capital Bikeshare (Fall 2010 to December 2013)

Nice Ride Minnesota is another one of the earliest established (2011) bikesharing systems in the US. Operating within the Twin Cities metropolitan region, it is a seasonal system, closing down in November and reopening in April. Like Capital Bikeshare, Nice Ride Minnesota has seen increasing ridership among casual riders and subscribers every year through 2013. Casual users play a proportionally greater role in Nice Ride Minnesota versus Capital Bikeshare, as is evident by the closer correspondence of subscribers and casual users. Figure 12 shows the trend in trip activity from inception through 2013.

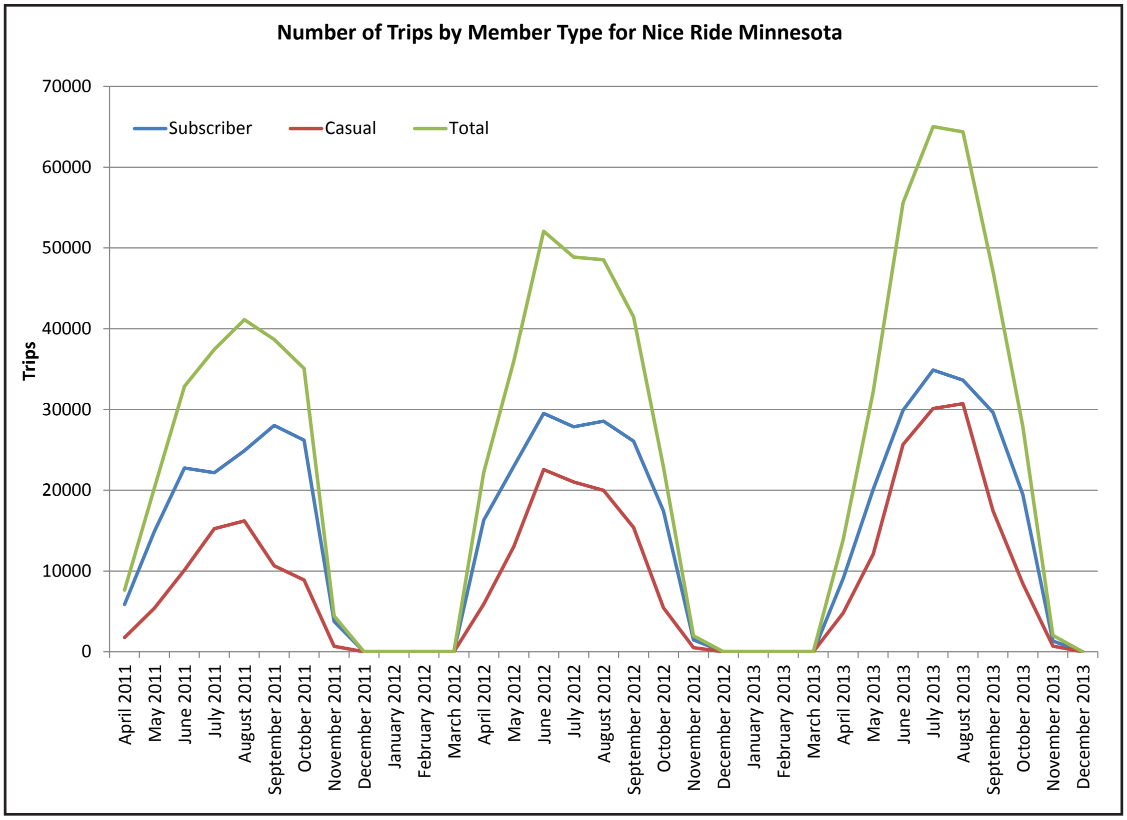

Figure 12. Bikesharing Activity for Nice Ride Minnesota (inception Spring 2011 to December 2013)

BABS is among the newest bikesharing systems in the country. Founded in 2013, the system was the first of its kind to be designed around the rail corridor, Caltrain, from San Francisco to San Jose. Unlike most other bikesharing systems that were initiated within a contiguous urban core, BABS was simultaneously established in downtown San Francisco, downtown San Jose, and in clusters around Caltrain rail terminals between the two cities. Figure 13 shows the latest available data for activity with BABS, spanning about one year of operation from its inception in August 2013.

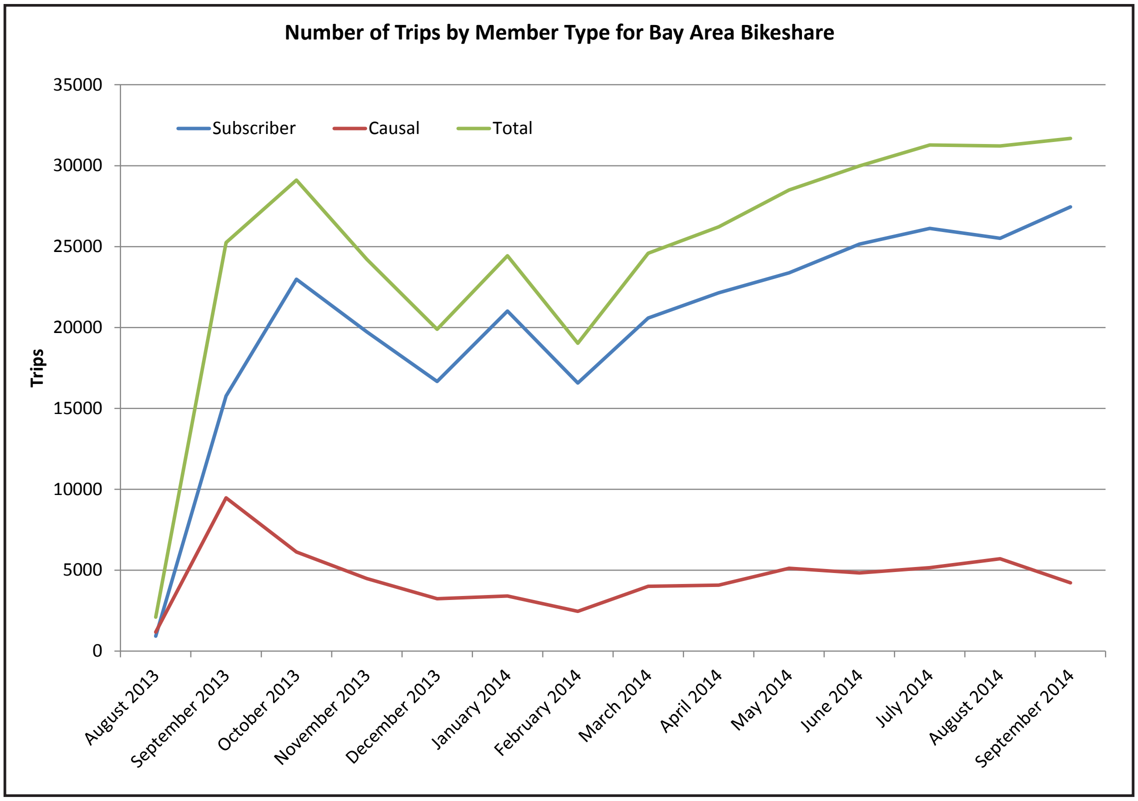

Figure 13. Bikesharing Activity for Bay Area Bike Share (inception Fall 2013 to September 2014)

BICYCLE COLLISION DATA

Understanding bicycle and bikesharing safety requires appropriate data to characterize the risk of cycling to the general public. The authors obtained collision databases for Washington DC, Minneapolis-St. Paul, and the San Francisco Bay Area to evaluate the trends and characteristics of bicycle-involved collisions within and around the regions in which the three bikesharing systems operated. Data were obtained from Washington DC's District Department of Transportation (DDOT), the Minnesota Department of Public Safety (MN DPS), and the California Highway Patrol's Statewide Integrated Traffic Records System (SWITRS) from 2006 to 2013. This information was used to examine more closely the bicycle-involved collisions that occurred over time spanning before and after the establishment of bikesharing systems (DDOT, 2014; MN DPS, 2014; CHP, 2014). In addition, the three bikesharing systems in this study also supplied data characterizing known/reported collisions with bicycles from their systems. Data from these sources are compared and characterized against what is known about activity of general bicycle use and, more specifically, bikesharing.

The format, content, and structure differ across each database. At the most basic level, counts of bicycle-involved collisions show that they have been changing within the regions of all three bikesharing systems. However, beyond these counts, the data sources contain information on the location of each incident, the vehicles involved, the persons involved, as well as the number of injuries and fatalities. For this analysis, the authors focus on the collision counts for incidents involving a bicycle.

All the collision datasets are subject to some degree of underreporting of incidents. For example, California's SWITRS processes fatal and injury collisions in the state that occur on all public roads, including those not within the California Highway Patrol's jurisdiction. It also includes "property damage only" (PDO) collisions that are reported. However, not all PDO collisions are reported by all agencies that report to SWITRS, and not all PDO reports are complete. This means that PDO collisions are not comprehensive in this database. Furthermore, SWITRS does not include information on collisions that take place on private property (CHP, 2014).

The Washington DC data come from the District Department of Transportation's Traffic Accident Reporting and Analysis System. These data are limited to reported collisions, but they include reported injury and non-injury collisions, as well as fatality collisions. Only bicycle-involved collisions were provided for Washington DC (DDOT, 2014).

The Minnesota Crash Records Database data are comprehensive, including vehicle and bicycle-involved collisions, but they are subject to the same limitations of underreporting of minor incidents. The Minnesota data include crashes for which there is no injury, but they usually (although not always) require an officer present to report the crash (MN DPS, 2014).

These reporting limitations are common to collision databases and present some natural drawbacks. The true count of incidents is not known, and data within the database constitute a lower bound of the number of actual incidents. In part, this is simply a reality of bicycle collision data. Collisions will happen that are not substantial enough to warrant a report, but data on collisions with more substantial injuries/fatalities and attended to by a police officer are included within these databases. These are the collisions most paramount to the safety evaluation.

Figure 14 shows the trend in bicycle-involved collision counts within the regions that operate bikesharing systems. They include Washington DC, Hennepin and Ramsey Counties in Minnesota (containing Minneapolis-St. Paul), and San Francisco, San Mateo, and Santa Clara Counties.

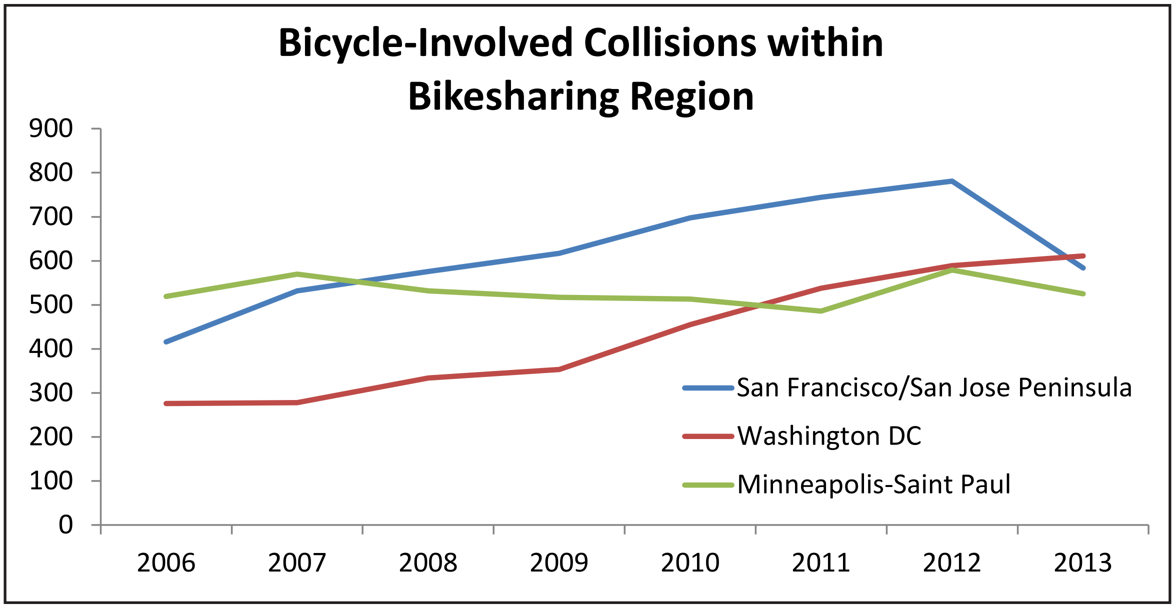

Figure 14. Bicycle Collisions within Bikesharing Regions

The trends in Figure 14 tell somewhat different stories for the different regions. In both Washington DC and the San Francisco Peninsula area (comprising only the Bay Area counties in which there is bikesharing), the trend in collisions is generally upward. Minneapolis-St. Paul appears primarily flat overall, but it ticked up and down from 2011 to 2013. The relative change in bicycle-involved collisions becomes more apparent when the first values within each time series are normalized to one, and all subsequent values vary relative to the first year.

This transformation is shown in Figure 15 in three separate plots. Within each plot, the 2006 measure of the cycling commuting population (that shown within Figure 10) is divided by itself (normalized to 1), and the subsequent measures of the population vary relative to this first value. Each plot shows the normalized trend for: 1) the estimated bicycle commuting population, 2) bicycle-involved collisions, and 3) the overall population of workers over the age of 16.

These comparisons tell an important story within these regions. The growth rates of the bicycle commuting population and bicycle collisions increase at very similar rates. The correlation of these data in Washington DC and in the San Francisco Peninsula area reveals a strong relationship between the growth in collisions and the cycling population. For Washington DC, the correlation coefficient between the two normalized series is 0.96, and for the San Francisco Peninsula area, the correlation coefficient is 0.75. This lower value is entirely driven by the final dip observed in the collisions in 2013. The correlation coefficient for years 2006 to 2012 (excluding the 2013 observation) is 0.97. The Minneapolis-St. Paul series also show a correlation, but while the cycling commuting population grew, the overall number of collisions remained relatively flat. The two series have a correlation coefficient of 0.52, indicating a weaker association. Both collisions and population exhibit a modest decline from 2008 to 2011 before rising and falling again, but at different magnitudes.

Also notable is the relative growth of the population overall in the three study areas. Each of these areas experienced population growth during the study period, but this growth is very small in comparison with the estimated growth of bicycle commuters (indicating a genuine mode shift to the bicycle). In all three cities, the population of bicycle commuters increased by at least 50% from 2006 to 2013, whereas over the same period, the Washington DC working population grew by 16%, the SF/SJ Peninsula grew by 12%, and Minneapolis-St. Paul grew by 7%, although growth from 2008 onwards is relatively flat.

Figure 15 also shows that Washington DC exhibited the largest relative growth in bicycle activity (in population and collisions), followed by the San Francisco Peninsula region, then Minneapolis-St. Paul. Figure 15 shows the striking correlation between one of the best available year-to-year estimates of bicycle use and collisions.

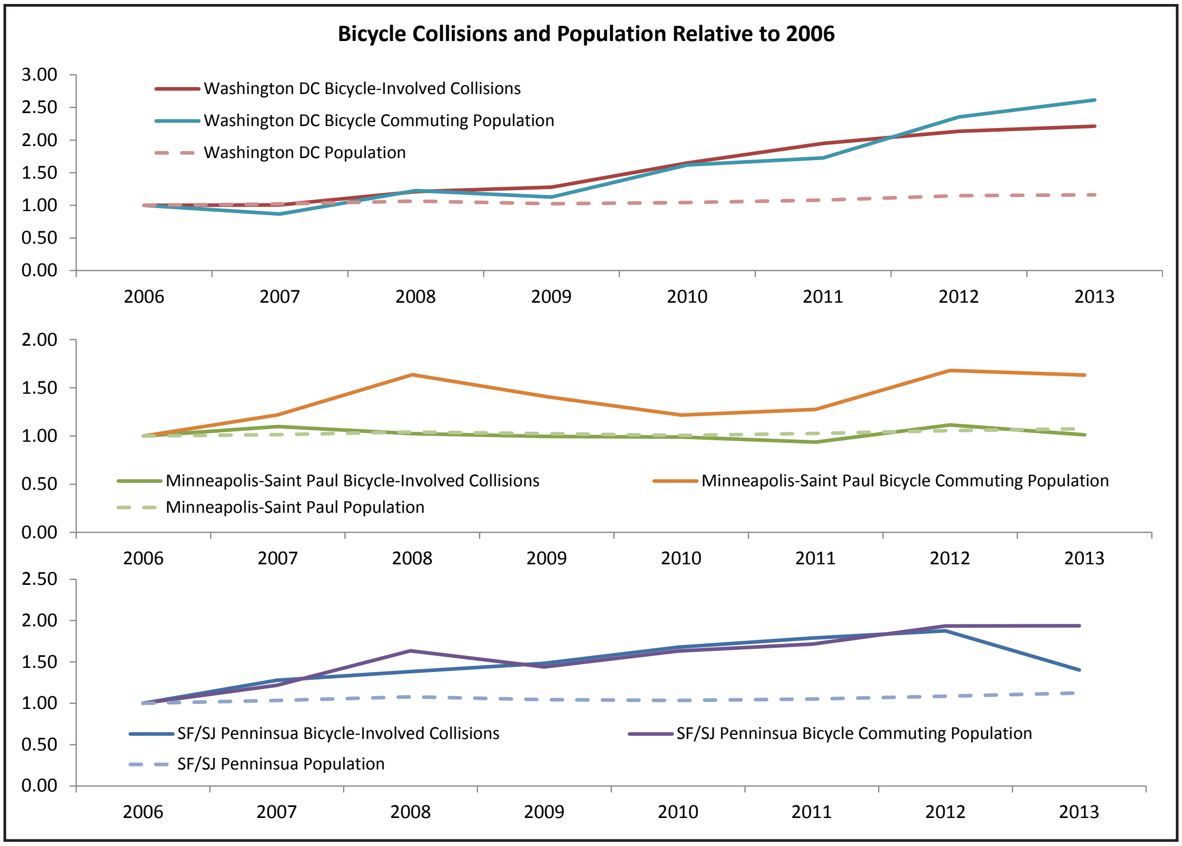

Figure 15. Bicycle Collisions and Population Relative to 2006

The trends in Figure 15 provide an early glimpse into exploration of the safety-in-numbers phenomenon. It suggests that this effect may be somewhat limited in at least of two these regions. The high linear correlation between the rise in bicycle commuters and collisions provides an early suggestion that a rise in bicycle activity may have led to a proportional rise in collisions during this period in at least two of the three case study areas. The exception appears to be Minneapolis-St. Paul, where data show a similar rise in bicycle commuting, a modest rise in the population, and an almost flat trend with respect to collisions. While none of this proves or refutes the safety-in-numbers effect, it at least shows that Minneapolis-St. Paul has experienced an increase in bicycle modal share without a commensurate rise in collisions.

The bicycle collision data, with some considerable processing, permitted the spatial analysis of collision events over time. Within each of the data sets, the intersections or locations at which the collision occurred were geocoded using Google Maps or ArcGIS software, depending on the data set. This processing of the data allows a more refined spatial analysis of collision events as compared with the location of bicycle activity. To show the spatial distributions of collision activity emerging from this geocoding, the authors present the basic heat maps of bicycle collision activity in each study area for the latest years of data collected (2012 and 2013). Figure 16 shows the corresponding distribution for the Minneapolis-St. Paul region (Hennepin and Ramsey Counties); Figure 17 presents the San Francisco Peninsula region; and Figure 18 shows the spatial distribution of Washington DC collisions. Not surprisingly, the heat maps show that the concentration of collision events occurs within the urban cores of the three regions. Although not shown here, a review of heat maps from all years shows that some change in the concentration has occurred, but in general the spatial pattern of collisions was found to be rather stable over time.

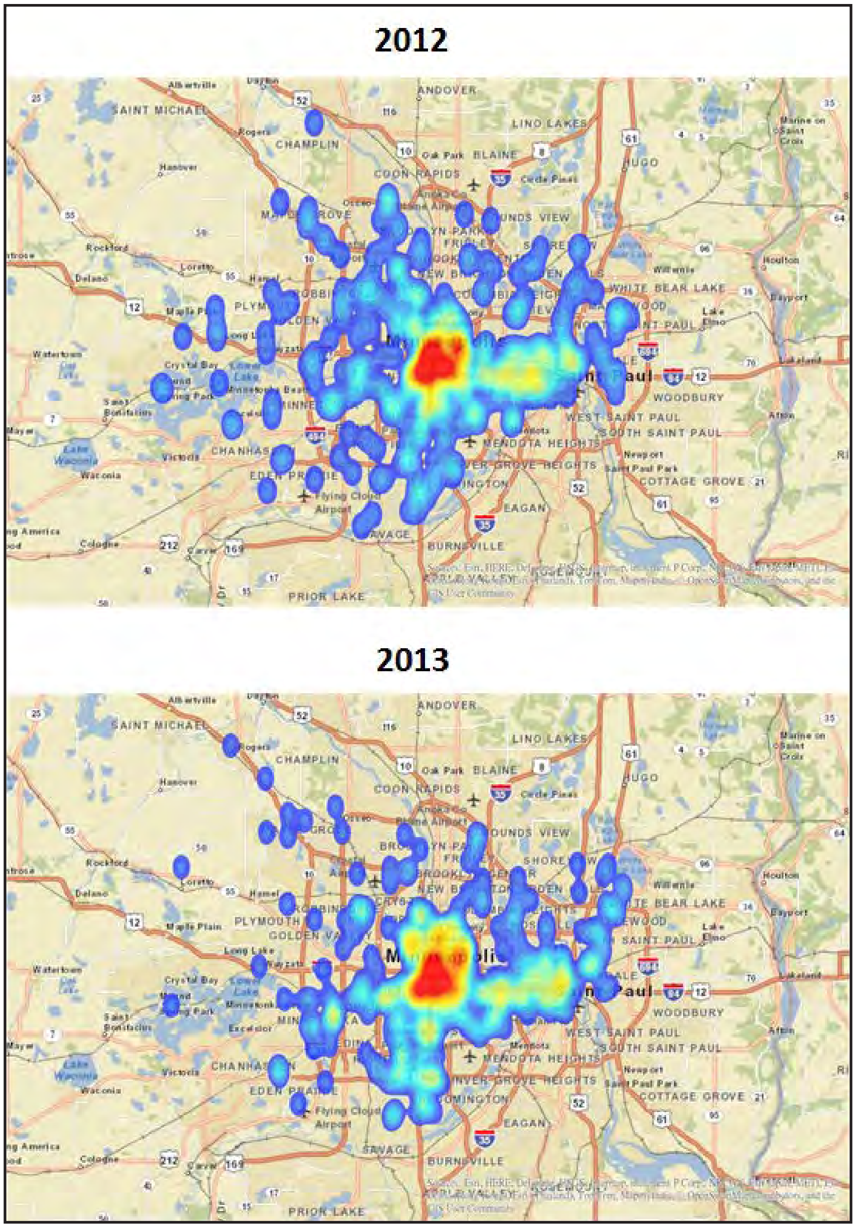

Figure 16. Spatial Distribution of Bicycle-involved Collisions in Minneapolis-St. Paul (Hennepin and Ramsey Counties MN)

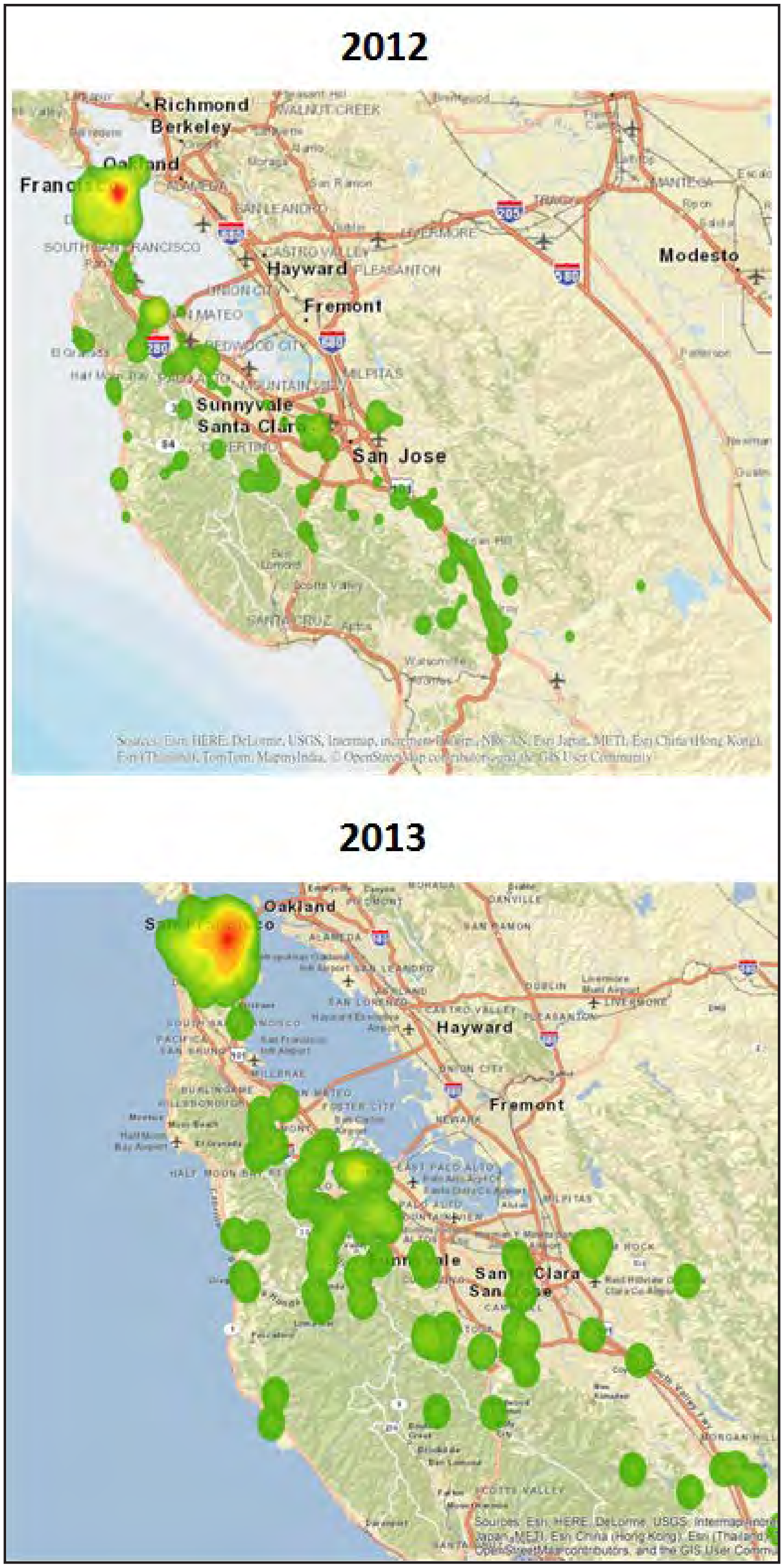

Figure 17. Spatial Distribution of Bicycle-involved Collisions in the San Francisco/San Jose Peninsula

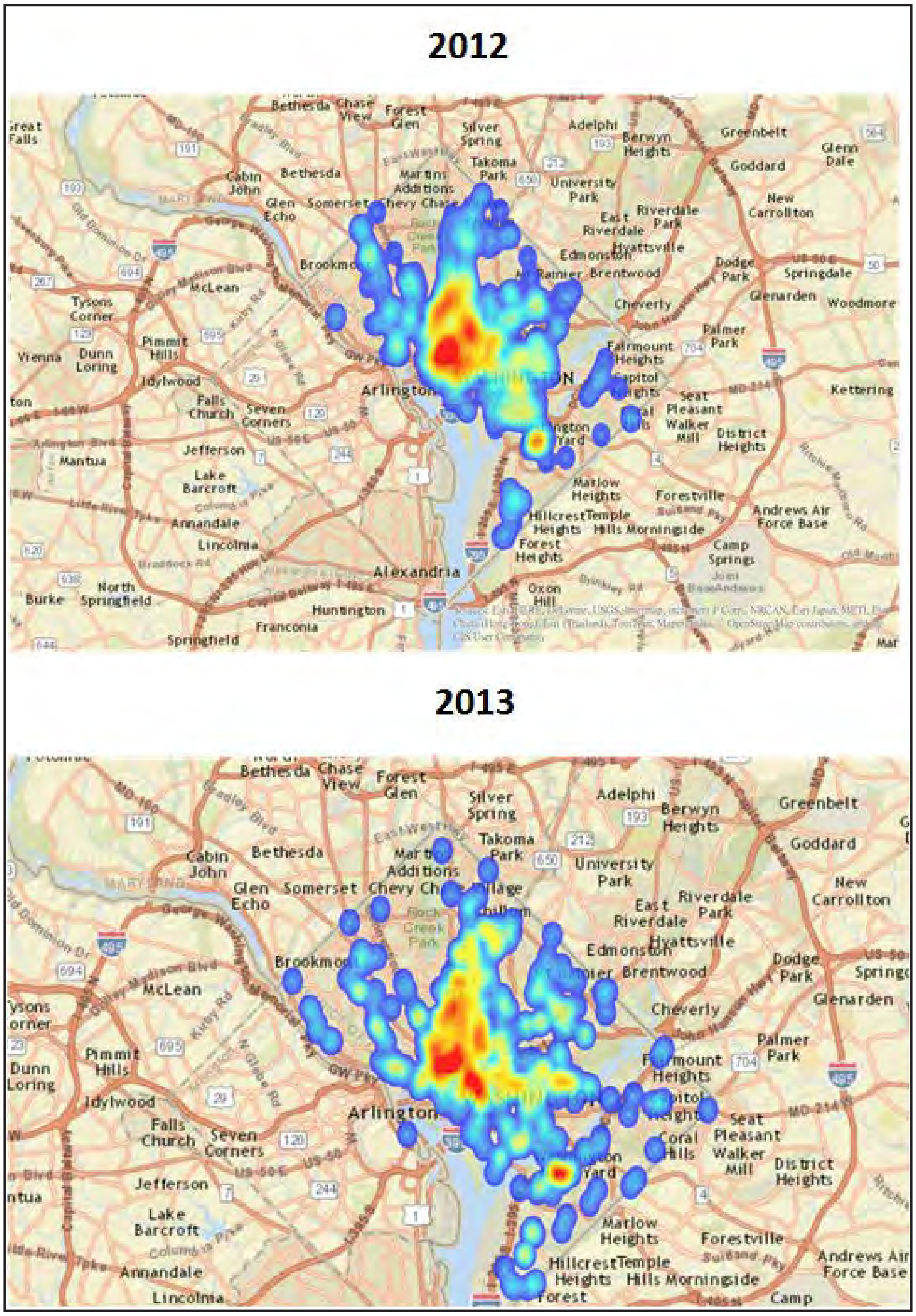

Figure 18. Spatial Distribution of Bicycle-involved Collisions in Washington DC

COLLISION DATA FROM BIKESHARING OPERATORS

The trends presented above show the high-level changes in bicycle collisions and bicycle activity. Collision data were also collected from the three bikesharing systems evaluated in this study. These data describe the collisions that the operators documented as resulting in an injury or damage during use of one of their bicycles. As mentioned earlier, no fatalities on bikesharing have been reported in the US to date, but there have been fatalities in Canada and Mexico.

The collision data presented in Table 5 reflects injury and damage events within the Capital Bikeshare, Nice Ride Minnesota, and Bay Area Bike Share systems. The data in Table 5 show a notable difference among the collision rates of the different operators. One of the reasons is the different reporting standards. For example, Nice Ride Minnesota does not record non-injury collisions. They track accidents with injuries that are reported through customer service and social media, or through any direct contact with police, ambulance, victim, or bystander.

Capital Bikeshare does record non-injury collisions when they are reported. Capital Bikeshare reports confirmed crashes, as long as the location is known, even if there is no police involvement or hospital visit. But like Nice Ride Minnesota, Capital Bike Share does not search police reports or emergency room data to find incidents. Those incidents must be reported back to the operator by police, emergency medical services, or a member. There do exist cases of “discovered damage,” in which incidents appear to have occurred but no report was made.

Bay Area Bike Share does maintain records of collisions that result in a hospital visit versus a non-hospital visit. As with collision data applying to general bicycle activity, some underreporting is known to occur, particularly with incidents of lower severity. Incidents that result in more moderate to serious injuries are believed to be covered by the existing data. The data showing collisions (which include hospital injuries) and hospital injuries separately are shown in Table 5.

Table 5. Bikesharing Collisions

	Confirmed Bikesharing Collisions/Crashes					
	Capital Bikeshare		Nice Ride Minnesota		Bay Area Bikeshare[1]	
Year	Collisions (all)	Hospital Injuries	Collisions (all)	Hospital Injuries	Collisions (all)	Hospital Injuries
2010	2	0	Not operational	Not operational	Not operational	Not operational
2011	17	5	0	0	Not operational	Not operational
2012	42	12	2	0	Not operational	Not operational
2013	24	9	0	0	0	0
2014	43	18	6	2	3	2
2015[2]	23	11	1	1	4	2
Total (to date)	**150**	**55**	**9**	**3**	**7**	**4**

[1] Bay Area Bikeshare’s reporting year goes from August to August, timing is approximated.
[2] 2015 data is only through mid-July.

As an example, Table 6 shows an injury record from Capital Bikeshare, which comprises fields of information in its data. The data structure cataloged by Capital Bikeshare contains all variables that would be necessary to construct safety metrics that are comparable to population level metrics that have been produced. Namely, cataloging police involvement, vehicle involvement, the nature of the injuries, and whether or not there was a hospital visit provides much of the key information necessary to generate cross comparisons with other accident data. Reporting vehicle involvement is also important.

Table 6. Example Crash Record of Capital Bikeshare

Crash Date - Time	Bike Number	Confirmation	Type of Crash	Crash Location	Description of Injuries	Police Involvement?	Hospital Visit?
<Date and Time>	<#>	Confirmed crash	Vehicle involved	<Location>	Minor scrapes on both legs and right arm	No	No

With this information, as well as detailed activity data, bikesharing services make it possible to compute a precise “collision rate per trip.” Because the total number of trips is known, collision rates are quantifiable to a degree of precision that has not been possible previously with bicycling more broadly. The raw collision rate per trip is simply the number of collisions divided by the number of trips. But most common safety metrics are not expressed as raw collision rates. Rather, they are commonly expressed as “Collisions/Injuries/Fatalities” per 100,000,000 (one hundred million) trips or 100,000,000 miles (or VMT) (160,934,400 km). These metrics are useful for understanding safety at national and regional scales. For motor vehicles, these metrics are calculated every year using well-maintained data on vehicle-involved injuries and fatalities tracking. Similarly, the FHWA regularly estimates VMT annually, providing the needed inputs to estimate rates year after year. Application of these metrics to bicycling is more limited because the estimations of total bicycle trips and miles are more infrequently done. However, some researchers have recently computed these metrics for comparison. Teschke et al., (2013) report distance and trip-based bicycle safety metrics for British Columbia, and Beck et al., (2007) report such metrics for the US. Based on the data in Table 5 and the known activity data shown earlier, collision rates are computed and shown for years in which data are available.

Table 7 shows a summary of the empirically-derived bikesharing collision rates for Capital Bikeshare, Nice Ride Minnesota, and the BABS system. Where data are available, three rates are presented:

1. <u>Collision Rate - Collisions per 100,000,000 Bikesharing Trips:</u> Based on the number of known collisions and the number of known trips within a given year, this is the number of collisions that would be expected after100,000,000 bikesharing trips at that rate.

2. <u>Hospital Injury Rate – Collisions per 100,000,000 Bikesharing:</u> This is the number of collisions that would be expected after 100,000,000 bikesharing trips resulting in a trip to the hospital by the bikesharing cyclist.

3. <u>Vehicle-Involved Collision Rate – Collisions per 100,000,000 Bikesharing:</u> This is the number of collisions that would be expected after 100,000,000 bikesharing trips that would have had vehicle involvement.

The Collision Rate (1) is the collection of all incidents that the bikesharing operator is aware of with respect to members riding their bicycles and experiencing some kind of collision. This consists of all incidents including: minor incidents of skin abrasions that result in no police involvement, no hospital visit, and no vehicle-involved collision. The hospital injury rate (2) is the subset of incidents that resulted in the bikesharing member being transported to the hospital as a result of the collision. The final rate (3) consists of those incidents that involved a vehicle. The significance of this subset is that it is more consistent with the broader General Estimates System (GES), which catalogs nonfatal bicycle collisions in the US. However, the GES includes only those events that involve a motor vehicle and a police report. The relevance of this will be apparent upon comparisons with the work of Beck et al. (2007). The data are not fully comparable with bikesharing collision data because the demographics are not quite the same. Children do not generally make use of shared bikes due to age restrictions of system membership.

Table 7. Empirical Collision Rates for Bikesharing Systems

			Collision Rate		Hospital Injury Rate		Vehicle-Involved Collision Rate
Year	**Number of Trips**	**Number of Collisions**	**Collisions per 100,000,000 Bikesharing Trips**	**Number of Hospital Injuries**	**Injuries per 100,000,000 Bikesharing Trips**	**Number of Vehicle Involved Collisions**	**Collisions per 100,000,000 Bikesharing Trips**
			Capital Bikeshare				
2011	1,243,103	17	1,368	5	402	13	1,046
2012	2,049,576	42	2,049	12	585	25	1,220
2013	2,584,945	24	928	9	348	16	619
Total	5,877,624	83	1,412	26	442	54	919
			Nice Ride Minnesota				
2011	217,530	0	0	0	0	0	0
2012	274,047	2	730	0	0	0	0
2013	308,051	0	0	0	0	0	0
Total	799,628	2	250	0	0	0	0
			Bay Area Bike Share				
2013	100,563	0	0	0	0	0	0
2014	246,926	3	1,215	2	810	2	810
Total	347,489	3	863	2	576	2	576

Table 7 shows the number of trips, collisions, hospital injuries, and vehicle-involved collisions for each system. The rates, as defined above, are also shown for each year and for all years in the “Total” row.

The cross-operator comparison shows a considerable difference among the three bikesharing operators: Capital Bikeshare, Nice Ride Minnesota, and BABS. Part of this difference can be attributed to the difference in size among the operators. By the end of 2013, Capital Bikeshare had experienced more than seven times as many trips as Nice Ride Minnesota. The incident data from Capital Bikeshare indicates that by 2013, it had an overall collision rate of 1,412 per 100 million trips, a hospital injury rate of 442 per

100 million trips, and a vehicle-involved collision rate of 919 per 100 million trips. It should be noted that the rates computed for Capital Bikeshare on an annual basis vary significantly. This is probably the result of having relatively few collisions and comparatively small changes in frequency, which can create relatively large differences in rates.

The authors compared these rates with the rates presented in the Beck et al., (2007) and Teschke et al., (2013) studies. Beck et al., (2007) used FARS and GES data to produce fatality and injury rates for the US from 1999 to 2003. They found a fatality rate among bicyclists of 21 per 100 million trips and a nonfatal injury rate among bicyclists of 1,461.2 injuries per 100 million trips. As mentioned earlier, GES includes only those events that involve a motor vehicle and have a police report. Teschke et al., (2013) computed similar rates for all police-reported injuries for bicycling in British Columbia. They found an injury rate of 1,398 injuries per 100 million trips from police-attended injuries from data spanning 2005 to 2007. Teschke et al., (2013) is comparable with the rates found by Beck et al., (2007).

Capital Bikeshare offers the most interesting comparison because it has the most trips and the highest collision rates across all categories. The collision rates of Nice Ride Minnesota and BABS are well below the US and Canadian rates in all categories. This may again be due to smaller size or recent establishment, although Nice Ride Minnesota is about the same age as Capital Bikeshare. The overall Capital Bikeshare collision rate of 1,412 includes a wider definition of events than the data used by Teschke or Beck. Taking the Capital Bikeshare vehicle-involved collision rate of 919, the incidence appears to be about 65% of the two regionally-computed numbers.

Fortunately, the fatality rate for these and all US bikesharing systems is zero at present (January 2016). But if just one fatality had occurred with Capital Bikeshare up to 2013, the rate would have been 17 per 100 million trips, close to the US rate of 21 reported by Beck. Through March 2015, Capital Bikeshare had recorded 9,424,393 trips (Capital Bikeshare, 2015). Until that point, if one fatality had occurred, the rate would have been 10.6 fatalities per 100 million trips for Capital Bikeshare alone. Naturally, it would be far lower if we were to include all bikesharing trips across the US.

At present, the evidence from these calculations suggests that bikesharing appears to have a lower nonfatal injury rate and fatality rate than personal cycling.

Bikesharing systems facilitate the imputation of a collision rate per mile. This requires some estimation of distances traveled by bikesharing bicycles. Bikesharing activity data contain information on the start and end location of each trip. This permits an estimation of distance traveled by system bicycles. Of course, this distance is subject to some uncertainty but nonetheless offers an opportunity to: 1) quantify the distances traveled on the system and 2) calculate the estimated collision rate per mile of the systems.

To compute the distances traveled on the system, the authors identified the distance between each location as if a bicyclist had traveled on the street grid illustrated in the Google Directions application. Each origin and destination was coded, and a complete origin-destination matrix was created for each system. The distances within this matrix were then used to calculate the distance per trip. When summed across all trips, the computation of a collision rate per mile becomes feasible. Table 8 provides a summary of these data including estimated miles traveled, collisions per mile, and miles per collision for bikesharing.

Table 8. Bikesharing Miles Traveled and Collision Rates per Mile

Year	Estimated Miles Traveled	Number of Collisions	Collision Rate: Collisions per 100,000,000 Bikesharing Miles	Number of Hospital Injuries	Hospital Injury Rate: Injuries per 100,000,000 Bikesharing Miles	Number of Vehicle Involved Collisions	Vehicle-Involved Collision Rate: Collisions per 100,000,000 Bikesharing Miles
Capital Bikeshare							
2011	3,797,063	17	448	5	132	13	342
2012	6,513,110	42	645	12	184	25	384
2013	8,809,847	24	272	9	102	16	182
Total	19,478,219	83	426	26	133	54	277
Nice Ride Minnesota							
2011	34,531	0	0	0	0	0	0
2012	45,731	2	4,373	0	0	0	0
2013	63,242	0	0	0	0	0	0
Total	143,504	2	1,394	0	0	0	0
Bay Area Bike Share							
2013	111,733	0	0	0	0	0	0
2014	271,602	3	1,105	2	736	2	736
Total	383,335	3	783	2	522	2	522

The computation of these rates for bikesharing in Table 7 and Table 8 presents safety metrics for cycling that can be tracked over time to assess system performance. These types of data are scarce for the general bicycling population. Teschke et al., (2013) estimated rates for fatalities and non-fatal injuries to be 2.6 and 264 per 100 million kilometers (or 4.2 and 425 per 100 million miles) using data from the “Traffic Collisions Statistics, Police-attended Injury and Fatal Collisions” for British Columbia. Review of this resource suggests that an incident is reported to it if it is vehicle-involved. In Table 8, it can be seen that the overall collision rate for Capital Bikeshare is comparable (almost equal at 426) with the Canadian rate, but the vehicle-involved collision rate is lower for Capital Bikeshare. It should be noted, however, that the vehicle-involved rates for 2011 and 2012 were almost double the rate experienced in 2013. That Capital Bikeshare’s overall rate is lower is a function of the fact that 2013 was a relatively safe year, with a high number of trips and low number of collisions. It also implies that a “bad” year for collisions could push the overall rate higher than existing benchmarks.

Although the rate of non-fatal injuries for shared bikes may be somewhat lower than for the general bicycling population, bicycling is a mode of travel with higher risk. According to the rates that Beck et al., (2007) calculated for different travel modes in the US, the nonfatal injury rates per 100 million trips are 1,461.2 and 803.0 for bicyclists and passenger-vehicle occupants respectively. This should convey that the scale of national safety statistics is incredibly large, and that relative to this scale, the sample sizes for bikesharing are still small. Thus, inferences presented here constitute what can be extracted from these early years.

COLLISION RATE MEASUREMENTS AT THE SCALE OF BIKESHARING

The measurements discussed in the previous section are useful for comparing safety-related measurements of bikesharing to more commonly used benchmarks. But bikesharing, at its current scale, simply does not have anything close to 100,000,000 trips per year, even when aggregated across the US. While the scaling of collisions to rates at 100,000,000 trips is useful for the purposes of comparison with national and regional statistics, more context sensitive metrics could be useful for safety monitoring of bikesharing. To better convey the rate of collisions at the scale of bikesharing systems, the authors calculate "Trips per Collision," "Trips per Hospital Injury," and "Trips per Vehicle Collision." These comprise a set of trackable metrics that bikesharing operators can use to understand their relative safety level. Table 9 presents the measures for the three study cases. Because collisions are in the denominator, a problem naturally occurs in cases in which the count of incidents is zero and the metric is undefined. These cases contain an "NA" in the fields shown.

Table 9. Trips-per-Incident Measures in Bikesharing

Year	Trips per Collision	Trips per Hospital Injury	Trips per Vehicle Involved Collision
2011	73,124	248,621	95,623
2012	48,799	170,798	81,983
2013	107,706	287,216	161,559
Total	70,815	226,062	108,845
Nice Ride Minnesota			
2011	NA	NA	NA
2012	137,024	NA	NA
2013	NA	NA	NA
Total	399,814	NA	NA
Bay Area Bikeshare			
2013	NA	NA	NA
2014	82,309	123,463	123,463
Total	115,830	173,745	173,745

These metrics describe the number of trips that occur before an incident within a given category occurs. It is effectively a measure of time. The higher the measure, the more trips are expected to occur before a collision, hospital injury, or vehicle involved collision. Bikesharing operators would want these metrics to be mathematically undefined (due to zero incidents) or as high as possible. As with the previous metrics, these metrics generally show that bikesharing injury and collision rates have been improving during this study period.

EVALUATION OF SAFETY IN NUMBERS AS RESULT OF BIKESHARING

Finally, the authors use available data to explore whether or not any evidence exists suggesting that the presence of bikesharing influences the relative rate of collisions in the areas in which it operates. In other words, does having more bikesharing in the area have any effect on the number of collisions in the broader region and influence the safety of other bicyclists? The question is particularly difficult to address when there is limited information on the number of overall bicycle trips at a refined spatial resolution, such as within a zip code. To explore whether or not there is any indication of this effect in the available data, the authors aggregate the general bicycle collision locations at a more refined level of spatial aggregation, beginning with Washington DC again as an example. The authors then establish a base year during which the total collisions within each region are equal to one. In this case, the base year is 2011, the first full year of operation for Capital Bikeshare. The difference between the overall change in collisions (relative to overall 2011 collision levels) and the change within zip codes (relative to within zip code 2011 collision levels) is computed for each year in the analysis. In zip codes where collisions grew more slowly than the overall region, this computed difference between the local trend and the overall trend is negative. In regions where the collisions grew more quickly than the overall region, the computed difference is positive.

For this dataset, a nearly equal share of zip codes was computed as having below average growth rates and above average growth rates. As the collisions in some zip code regions grow more quickly and others grow more slowly than the overall trend, the resulting series have a distribution of positive and negative values. Were the presence of bikesharing activity to have an effect on the rate of bicycle collisions in a localized area, the authors would expect to see regions with relatively higher ridership associated with zip codes to have more negative than positive values. In other words, when collisions are increasing overall, one would expect to see a pattern of collisions in regions with higher bikesharing ridership growing more slowly than the overall trend of collisions. When collisions overall are decreasing, one would be looking for a pattern in which collisions are falling faster than the broader downward trend. If a safety-in-numbers phenomenon exists, one way it might reveal itself is through the consistent association of relatively slower growth (or steeper declines) in the trend of localized collisions when compared with the overall trend in either direction.

The authors evaluate this question using geocoded data from Capital Bikeshare and Nice Ride Minnesota. To test the hypothesis, they run a linear OLS regression with the zip code-level relative change in collisions as the dependent variable and the number of bikesharing trips in the same area as the independent variable with a constant. In total, 44 zip codes were analyzed in Washington DC, and 76 zip codes were analyzed in Minneapolis-Saint Paul. In Washington DC, 20 of these zip codes exhibited a collision growth greater than the trend, while the remaining 24 zip codes exhibited less growth than the trend. In Minneapolis-Saint Paul, 36 of these zip codes exhibited a collision growth greater than the trend, while the remaining 40 zip codes exhibited growth less than the trend.

The results, presented in Table 10 suggest that in Washington DC, there is little to no relationship between the relative change in collisions within a zip code and the number of bikesharing trips in that zip code. *This result suggests that there is little evidence in the collision and activity data to support a safety-in-numbers effect resulting from Capital Bikeshare*. *At the same time, it also does not suggest that the presence of Capital Bikeshare is contributing to an increase in collisions within high-volume zip codes.* The number of Capital Bikeshare trips within an area is not found to alter the localized change in bicycle collisions from the broader trend that is underway. That is, a growth in collisions occurred in the evaluated region (Washington DC), but as shown earlier in Figure 15, this growth was broadly correlated with a general increase in cycling activity. The results of this regression analysis are shown in Table 10.

Table 10. Analysis of Relative Change in Collisions to Bikesharing Trips (Washington DC)

Relative Change in Collisions with Capital Bikeshare Region against Bicycle Activity				
Multiple R				0.08
R Square				0.01
Adjusted R Square				-0.02
Standard Error				0.72
Observations				44.00
	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.03042099	0.1490520	0.20	0.84
Number of Capital Bikeshare Trips	6.06E-07	1.16E-06	0.52	0.61

Analysis of similar data from Nice Ride Minnesota and collisions in the Minneapolis-St. Paul region also show low significance in the number of trips variable for data structured the same. However, the variable did appear more negative and closer to being statistically significant. That is, relative drops in collisions were more negatively correlated with measurements of bikesharing activity in Minneapolis-St. Paul, as shown in Table 11.

Table 11. Analysis of Relative Change in Collisions to Bikesharing Trips (Minneapolis-St. Paul MN)

Relative Change in Collisions with Nice Ride Minnesota against Bicycle Activity				
Multiple R				0.18
R Square				0.03
Adjusted R Square				0.02
Standard Error				1.01
Observations				76.00
	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.33	0.14	2.35	0.02
Number of Nice Ride Minnesota Trips	-1.59E-05	1.03E+05	-1.53	0.13

The nearness of this coefficient to statistical significance does point to some dynamic that is evident within Minneapolis St.-Paul. This is a metropolitan area that seemed to experience a rise in bicycle commuting without the commensurate rise in collisions that was observed in the other two regions. Further, areas with higher bikesharing activity seem to have below-trend growth changes in collisions. While the relationship is not statistically significant, this nearness of significance, coupled with the insights from the general population data (Figure 15) and the low count of incidents that have occurred with bikesharing overall, suggests that certain factors seem to make the Minneapolis-St. Paul region relatively safe for cycling. Evidence is not strong enough here to assert that there is a definitive bikesharing-driven safety-in-numbers phenomenon.

This same analysis could not be completed for BABS, which was too new to have more than one base year for this type of analysis. Overall, while bikesharing exhibits safety metrics in line with or better than national estimates, the presence of bikesharing activity at its current scale may not be large enough effect to have any impact on the broader bicycling safety of the general population.

Study Limitations

A couple of caveats should be noted in the analysis. For one, the R^2 values are very low. This, of course, means that the fit of the model and the variance in the dependent variable is primarily unexplained by the bikesharing activity data. One would not use bikesharing activity data to predict relative changes in collisions, as the coefficient is insignificant and the fit of the overall model is otherwise very poor. Further, the analysis does not disentangle whether or not other exogenous factors are at play in influencing the movement of collisions within the cities analyzed. Infrastructure improvements (or retrogressions) could change the trend of collisions and bicycle activity together, and they are otherwise unseen in this analysis. Such changes to infrastructure could simultaneously improve safety and increase bicycle traffic, creating effects that would be difficult to fully disentangle. These would be larger concerns were the activity variables able to explain more of the variance when they are by themselves. The correlation of these variables is otherwise very low. In Washington DC, activity data and localized movements in collision data are weakly positive in correlation, and in Minneapolis-St. Paul, they are weakly negative. *These results again suggest that if there is a safety-in-numbers impact from bikesharing on other bicyclists, it appears not to be strong enough to move collision events substantively.*

Overall, bikesharing data offer a new and unprecedented window into evaluating bicycle safety. Because bikesharing data provide precise trip counts and good information for estimating distances, metrics like trip collision rates and miles traveled per collision can be estimated with accuracy never before possible. The tracking of these metrics ultimately may be useful for tracking bicycle safety overall. Second, the collision data sets evaluated in this section suggest that increased bicycle activity is the primary driver of changes in bicycle collisions. The correlation between estimated bicycle activity from the US Census journey-to-work data and bicycle collisions is very strong in two of the three large regions. In Minneapolis-St. Paul, the association is not so strong. At the same time, an exploration of bicycle activity at a more refined spatial resolution shows that the relationship between the growth in bicycle collisions at more local scales and the level of bikesharing activity is weak. *This suggests bikesharing is not imposing—at least at the levels observed in this dataset or at this early stage of industry development—any detectable safety-in-numbers effect.* At the same time, it is also not causing a “danger-in-numbers” effect. *The absence of a relationship in the simple analysis above suggests a limited prospect that this effect is significant.*

There is, of course, the possibility that a more complex model, with better information on overall bicycle activity at these spatial scales and perhaps other variables, might find some marginal effect. But when the level of bikesharing activity serves as the only variable to explain the variance in growth rates (to which all variance would be attributed), it is notable that no statistically significant relationship was found. These and other aspects of the study will be discussed in the conclusion.

VII. SUMMARY AND CONCLUSIONS

This study makes a number of observations related to bikesharing and bicycle safety, while at the same time raising new questions.

Key findings of the focus groups included:

- People considered cycling with bikesharing bikes to be somewhat safer than cycling with regular bikes, largely as a result of bikesharing bicycle design.

- Because bikesharing bicycles are designed to be larger, slower, and sturdier than personal bicycles, they are not ridden as aggressively as personal bicycles. Members of the bikesharing focus groups noted that people riding bikesharing bicycles appeared to do so more cautiously. This was noted despite the widely observed fact that helmet usage is lower for bikesharing bicycles.

The expert interviews found that several industry and governmental officials recognized the challenges with bikesharing safety, but they also considered bikesharing to have a number of plausible safety benefits. The experts also cited design of the bicycle as one of the key reasons for bikesharing appearing to have a good safety record despite the acknowledged lack of helmet use. Overall, the experts interviewed considered bikesharing to be relatively safe, but it differed somewhat on whether or not helmets should be mandatory. One expert insisted that they should be, while others believed that the health benefits of cycling outweighed the elevated risk of not using a helmet.

The study conducted an analysis of bicycle safety using data describing bicycle activity, bicycle collisions, bikesharing activity, and bikesharing collisions. The analysis established that within the bikesharing cities studied, bicycle collisions were generally rising, but this rise was very likely due to rising bicycle activity overall. The correlation between growth in bicycle collisions and the estimated population commuting by bicycle was found to be high, particularly in Washington DC and the San Francisco Bay Area. The analysis proceeded to use bikesharing activity data and bikesharing collision data to compute key safety metrics. Bikesharing data permits precise knowledge of the number of bicycle trips, something that is only estimated for the broader population of bicyclists. Furthermore, processing bikesharing activity and station location data permits a calculation of estimated distances traveled by bikesharing bicycles. These processed data were used to calculate several standard safety bikesharing measures. From these calculations, the authors found that:

- *Bikesharing generally had lower nonfatal injury rates than comparable measures available for both the US and Canada.*

The lower rates are evident in Capital Bikeshare, which has the highest rates among the three operators studied. Although Capital Bikeshare's non-fatal crash rate was comparable to a rate reported in a US study, the vehicle-involved collision rate for Capital Bikeshare was found to be 65% of the latest available computed US rate. This national rate was computed using earlier 1999 to 2003 data, and there are limits to the strength of this comparison. However, it was also found that about 65% of the more recent rate computed (for the 2005-2007 period) in British Columbia, which strengthens the conclusion that there is a substantive difference. Further, *as there have been no fatalities on bikesharing to date in the US, the bikesharing fatality rate is currently zero (as of this writing), as compared with the US fatality rate of 21 per 100,000,000 trips.*

- *These metrics suggest that, at present, bikesharing appears to be operating at reduced injury/fatality rates as compared with personal cycling.*

However, although the rate of non-fatal injuries for shared bikes may be lower than for the general bicycling population, bicycling is a mode of travel with higher risk. Recall that Beck et al., (2007) calculated the nonfatal injury rates per 100 million trips for different travel modes in the US and found that they were 1,461.2 and 803.0 for bicyclists and passenger-vehicle occupants, respectively.

Naturally, there are questions and points of discussion regarding why these rates are lower for bikesharing.

- Consensus from the qualitative research components of this study pointed to the bicycle design repeatedly. This design—being bulky, sturdy, and slow—may inhibit the risk-taking behavior that can put bicyclists into dangerous situations.

- Further, other behavioral modifications by bikesharing users—including using additional caution, paying more attention to rules of the road, and better bicycle visibility and lighting—may also play a role.

- The reason is definitely not due to increased helmet use, which is widely documented to be lower among bikesharing users.

For all their well-documented safety benefits, helmets, like seatbelts in cars, mitigate the severity of injuries when a collision does occur, but they do not prevent the collision from occurring. *Nevertheless, the widespread use of helmets in this environment would unequivocally improve bikesharing safety.*

Overall, the issue of comparative safety is complicated by the question of whether or not the use of shared bikes improves cycling safety and in the process actually increases overall transportation safety. Serious injuries do happen on bikesharing bicycles, including head trauma and incapacitating spinal injuries. While the overall injury rate of bikesharing appears lower than general cycling, it still carries considerable risk and exposure that should not be underestimated.

Finally, the dynamics of safety in numbers for bicyclists may persist even though the data did not show its presence in this study. The risk of cycling could be reduced if bicyclists, such as shared-bike users, are added in areas where there are relatively more bicyclists, such as in downtown areas and where there are relatively fewer motor vehicles—and under conditions that make it safer for bicyclists, such as smaller differences in travel speeds. While not all of the issues outlined in this study could be fully addressed here, some issues related to the relative safety of using shared bikes were addressed, and the findings could be used for future research.

VIII. RECOMMENDATIONS FOR FUTURE RESEARCH

The resulting insights from the focus groups and experts suggest there is the perception that bikesharing is safer than general bicycling. The crash data analysis showed that bikesharing is at least as safe or safer than bicycling overall. But there are important caveats to this conclusion. The safety in bikesharing appears to come from a reduction in incidents per trip and incidents per mile. That is, for some reason, bikesharing users are not involved in serious, reported, collisions as often as suggested by the rates most recently measured for personal bicyclists. Key questions not addressed in this study pertain to why these results were found.

It has been suggested that bicycle design may be playing a role in slowing down the bikesharing bicyclist, making them engage in less risky behavior. The wide body and sturdy build of the bicycle has the feel of heavy mountain bike, and this design may reduce the degree to which dangerous maneuvers are made on these bicycles. This would imply that the bicycle design is influencing the bicyclist to act in a safer way.

Another design-based theory is that bikesharing bicycles are more visible and recognizable. Bikesharing bicycles light up at night and are painted in standard bright colors. These indicators may play a role in drivers being more cautious around bikesharing bicyclists, and they imply that the bicycle design is influencing drivers to be safer around bicyclists.

Another possibility may relate to the behavior of bikesharing bicyclists while riding them. *Bikesharing bicyclists may be inherently more cautious while riding such bicycles given the more limited familiarity. Demographics could also play a role. Surveys of bikesharing users consistently suggest that they do not reflect the general population, but among other characteristics, they are younger and more educated.* The broader population of bicyclists also does not reflect the general population, so comparisons of these populations might be useful.

One challenge encountered in this study (a challenge well known to researchers) was a lack of good data on basic bicycle activity. Better data on bicycle travel activity—as related to number of trips, distances traveled, demographics, trip purpose, and crashes—would be useful. Bicycle activity is difficult to measure or estimate. Today, researchers still do not have a good consistent measurement of changes in bicycle trips or miles traveled. The most comprehensive measure of trips and distance traveled comes from the NHTS, which was last conducted in 2009. Measures from this vast resource are derived from weighted samples of travel diaries to scale up a snapshot of activity at US national and sub-national scales. Regional US surveys conducted by metropolitan planning organizations can periodically provide localized snapshots of activity, but these too are estimates in the same manner as the NHTS. Understanding the number of bicycle trips and miles traveled more regularly and continuously would aid researchers so they could more rigorously track movements as well as injury and fatality rates. The best continuous data the authors do have on bicycling is from the American Community Survey journey-to-work data. This ACS data is comprehensively produced for geographies across the country and is updated annually. But it provides only a mode share from which the authors can obtain a general sense as to whether bicycling is increasing or decreasing relative to other forms of travel.

But bicycle miles traveled and bicycle trips are unknown from these measures. Bikesharing data represent substantial improvements in the precision and continuity of such data for its activity. As more continuous measures are developed for bicycle activity broadly, it would improve the research community's ability to compare and track safety statistics from the same year over time.

APPENDIX A – FOCUS GROUP PROTOCOLS

BAY AREA BIKESHARING USER FOCUS GROUP – SAN FRANCISCO

Pre- Focus Group with Participants (10 minutes)

- Sign-in
- Consent forms
- Permission to record
- Intake questionnaire

Introduction: (10 minutes)

- Moderator introduction and focus group purpose/overview
- Project Overview: Thank you all for attending this focus group. The purpose of this project is to evaluate the impacts that bikesharing systems have on overall bicycle safety by understanding whether or not the presence of bikesharing makes cycling for everyone safer, less safe, or imposes no change.
- As part of this project, the purpose of this focus group is to get your opinions on your experience as members of bikesharing within the Bay Area.
- We are specifically interested in the utility and safety aspects of bikesharing when you use the system. We would like to know when and where conflicts with drivers and pedestrians arise and why they arise. We would also like to know about experiences you have had as a Bay Area Bikesharing member in which you have felt safe, as well as unsafe.
- You should feel free to express your opinion openly and to disagree with the opinions of others. The purpose of this focus group is to capture the details of your experiences.
- As moderator, it is my job to make sure that everyone is participating and that the conversation remains on topic.
- At this moment, can everyone acknowledge that they signed the consent form giving us permission to record this focus group by nodding? (START RECORDING)

Participant introductions – Please tell us your name and the mode of transportation you use most frequently to get around.

Experience with Cycling and Bay Area Bike Share (25 minutes)

1. How comfortable or experienced are you with cycling in general?
2. How often do you use Bay Area Bike Share: daily, weekly, or less often?
3. If you own a personal bicycle, do you use BABS more than that bike?
4. Would you say that BABS has increased, decreased, or imposed no change on your overall amount of cycling?
5. For what trip purposes do you use BABS (commuting, shopping, exercising, personal business, recreation)? Do these purposes differ substantially from how you use a regular bicycle?
6. In your opinion, what cycling behaviors, if any, distinguish BABS bicycle riders?
7. Have you perceived a noticeable increase in the number of bicycle riders in this city since BABS was implemented?
8. Does the presence of BABS change your perception of cycling as a transportation mode?

Experience with the Bay Area Bike Share System and Safety (30 minutes)

Now we are going to shift our discussion to focus on your experience with BABS and safety.

1. How safe do you feel while cycling (in general) in this city, and do you feel less safe, safer, or no difference when riding with other cyclists? [*Cycling in general*]
   a. What would you consider to be a large number of bicyclists riding a group?
   b. In general do you feel that other bicyclists who ride in groups are acting less safe, safer, or no difference?
   c. What about being in a group influences your perception of your own safety as a bicyclist (one way or another)?
   d. What sort of behavior exhibited by bicyclists do you think most negatively affects the safety of people around them? [*Bicyclists in general*]

1. Do you perceive that BABS bicyclists are more or less likely to engage in problematic behavior versus regular cyclists (hindering traffic, being a nuisance, breaking traffic laws, and engaging in unsafe behavior)?

2. While using BABS, can you describe any specific problematic encounters that you had personally or witnessed in this city that were exceptionally dangerous for you or another bicyclist nearby?

    a. As a pedestrian have you personally encountered or witnessed a dangerous situation involving a BABS user?

    b. How frequently do you witness these specific behaviors: daily, weekly, or less often?

3. When and where, if ever, do you feel unsafe while cycling as a BABS cyclist?

4. When you use BABS, do you feel safer, less safe, or just as safe as when cycling with a personal bicycle?

    a. If relevant, what about riding a BABS bike makes you feel safer or less safe?

5. When riding a BABS bicycle, do you feel that you are more visible to drivers and pedestrians? *[Only ask if this is not referenced in the previous questions.]*

6. How often do you wear a helmet when riding a BABS bicycle: Always, Sometimes, Rarely, or Never?

    a. If not “Always”, what are some of the main reasons you do not wear a helmet?

    b. Do you think that wearing a helmet while riding BABS should be mandatory? Why or why not?

    c. If sanitized or sanitary helmets were provided at bikesharing stations, do you think you would use them?

    d. What changes to the BABS system (if any) do you think would increase the use of helmets by bikesharing riders?

7. When riding a BABS bicycle, how do you choose your route? For example,

    a. Do you primarily go the most direct route?

    b. Do you primarily choose the route with minimal traffic?

    c. Do you primarily choose routes with bike lanes (if on high traffic routes)?

        1. What factors (among others you can think of) most influence how choose your route?

8. (Time permitting) Does riding in bike lanes as a BABS rider make you feel safer, less safe, or no difference compared to riding on streets with no lanes?

9. *(Time permitting)* What type of cycling infrastructure do you think does the most to improve your safety? (e.g., separated bike lanes, bicycle traffic signals, bike boxes, etc.)

10. (*Time permitting*) Do you consider signaling by bicyclists to be helpful to you as a driver?

Improving Bicycle Safety (25 minutes)

1. What would be the top three things that bicyclists could do that would improve their own safety with relationship with drivers?

    a. Collectively, we will make a list of suggestions you have, and then by voting, we'll rank them. You will first vote for your first choice, then your second choice, and then your third choice.

2. What would be the top three things that drivers could do that would improve bicycle safety?

    a. Collectively, we will make a list of suggestions you have, and then by voting, we'll rank them. You will first vote for your first choice, then your second choice, and then your third choice.

3. What would be the top three things that local governments could do that would improve bicycle safety?

    a. Collectively, we will make a list of suggestions you have, and then by voting, we will rank them. You will first vote for your first choice, then your second choice, and then your third choice.

4. What would be the top three things that law enforcement agencies could do that would improve bicycle safety?

    a. Collectively, we will make a list of suggestions you have, and then by voting, we'll rank them. You will first vote for your first choice, then your second choice, and then your third choice.

5. What would be the top three things that BABS could do that would improve bicycle safety?

    a. Collectively, we will make a list of suggestions you have, and then by voting, we will rank them. You will first vote for your first choice, then your second choice, and then your third choice.

6. Do you think that an increase in bicyclists would result in a change in overall road collisions for all road users? Would it make roads more safe, the same, less safe?

7. (*Ask only if this has not already been made clear*) Do you think that encouraging cycling among the public is a good idea or bad idea?

    a. (Moderator to encourage participants to pick a side.)

8. Last question, thinking creatively, what safety improvements, related to safety that involve bicyclists, do you NOT see today, but think would improve safety for all road users?

Thank you for your participation. Incentives will be administered via the email address that each of you provided when completing the screening process. You will receive that email within five business days from now. Please confirm your email address on your way out.

DRIVER AND NON-BICYCLIST FOCUS GROUP – SAN FRANCISCO

Pre- Focus Group with Participants (10 minutes)

- Sign-in
- Consent forms
- Permission to record
- Intake questionnaire

Introduction: (10 minutes)

- Moderator introduction and focus group purpose/overview
    - Project Overview: Thank you all for attending this focus group. The purpose of this project is to evaluate the impacts that bikesharing systems have on overall bicycle safety. That is, the project is trying to understand whether the presence of bikesharing makes cycling for everyone, safer, less safe, or imposes no change.
    - As part of this project, the purpose of this focus group is to get your opinions on interactions with bicyclists on the streets of the Bay Area. We want to get an understanding of what you think of the behavior of bicyclists in general, and what you think of the behavior of bicyclists when driving.
    - We're specifically interested in the safety aspects of your interactions while driving, cycling, or walking. We would like to know when and where conflicts arise, and why they arise.
    - You should feel free to express your opinion openly and to disagree with the opinions of others. The purpose of this focus group is to capture the details of your experiences.

- As moderator, it is my job to make sure that everyone is participating and that the conversation remains on topic.
- At this moment, can everyone acknowledge that they signed the consent form giving us permission to record this focus group by nodding? (START RECORDING)

Participant introductions – Please tell us your name and the mode of transportation you use most frequently to get around.

Bicycle Experience (10 minutes)

1. How comfortable or experienced are you with cycling?
2. For those of you that have ridden a bicycle within the last year, where do you ride (neighborhood, busy streets, rural roads) and for what trip purposes do you typically use a bicycle? (e.g., commuting, shopping, exercising, personal business, recreation, etc.)
3. For what trip purposes have you typically used a bicycle (commuting, shopping, exercising, personal business, recreation), if you used a bicycle during the past year?
4. How safe do you generally feel while cycling in this city and do you feel less safe, safer, or no difference when riding with other cyclists? For non-cyclists, do you feel that bicyclists who ride in groups are acting less safe, safer, or no difference?
5. When and where, if ever, do you feel unsafe while cycling?

Driving Experience with Bicyclists in General (30 minutes)

During this section, we would like to discuss your perspective as a driver and as a pedestrian, and in particular your experience as a driver and pedestrian encountering bicyclists in this city.

1. How often, if ever, do you encounter bicyclists while driving or walking and how often are those encounters problematic in terms of safety, if ever? Please provide estimates for driving and walking separately. (Daily, weekly or less often)
2. Can you describe any specific problematic encounters that you recall that were exceptionally dangerous for the bicyclist, for you in the vehicle, for you as a pedestrian or for someone else involved? How frequently do you witness this specific behavior? (Daily, weekly, or less often)
3. Do you adjust your driving behavior when you are driving around bicyclists? If so, how?
4. In terms of driving adjustments, are you more careful when you drive around more than one cyclist or do you drive the same?

5. What aspects of sharing the road with bicyclists when driving do you find most challenging?

6. (*Time permitting*) What would you consider to be a large number of bicyclists? In other words, what number of bicyclists would get your attention as a driver?

7. What sort of behavior exhibited by bicyclists negatively affects you most while walking?

8. *(Time permitting)* Do you consider signaling by bicyclists to be helpful to you as a driver?

Experience with Bay Area Bikesharing (15 minutes)

Have you heard of Bay Area Bike Share? Take a tally of those who have and have not heard of the system.

Moderator to explain Bay Area Bike Share (BABS for short) and how it works. Be sure to mention the teal colored bicycles, but also mention that all shared bikes to not look like that.

Notes: Launched in summer 2013 in San Francisco and select cities along the Peninsula. For those that have heard of BABS:

1. Do you have a positive, negative, or neutral opinion of BABS?

2. Have you witnessed people riding BABS while driving in the Bay Area?

3. What cycling behaviors, if any, distinguishes BABS bicycle riders?

4. Do you perceive a noticeable increase in the number of bicycle riders that you have encountered overall since BABS was implemented?

5. Does the presence of BABS change your perception of cycling as a mode of transportation?

6. (*Time permitting*) Do you perceive that BABS bicyclists are more or less likely to engage in problematic behavior versus regular cyclists (hindering traffic, being a nuisance, breaking traffic laws, engaging in unsafe behavior)?

Improving Bicycle Safety (25 minutes)

1. What would be the top three things that bicyclists could do that would improve their own safety with relationship with drivers?

    a. Collectively, we'll make a list of suggestions you have, and then by voting, we'll rank them. You will first vote for your first choice, then your second choice, and then your third choice.

2. What would be the top three things that drivers could do that would improve bicycle safety?

   a. Collectively, we will make a list of suggestions you have, and then by voting, we will rank them. You will first vote for your first choice, then your second choice, and then your third choice.

3. What would be the top three things that local governments could do that would improve bicycle safety?

   a. Collectively, we will make a list of suggestions you have, and then by voting, we'll rank them. You will first vote for your first choice, then your second choice, and then your third choice.

4. What would be the top three things that law enforcement agencies could do that would improve bicycle safety?

   a. Collectively, we will make a list of suggestions you have, and then by voting, we'll rank them. You will first vote for your first choice, then your second choice, and then your third choice.

5. What would be the top three things that BABS could do that would improve bicycle safety?

   a. Collectively, we will make a list of suggestions you have, and then by voting, we'll rank them. You will first vote for your first choice, then your second choice, and then your third choice.

6. Do you think that an increase in bicyclists would result in a change in overall road collisions for all road users, starting with drivers, then on bicyclists, and then pedestrians (more safe, the same, less safe)?

7. (*Ask only if this hasn't already been made clear*) Do you think that encouraging cycling among the public is a good idea or bad idea?

   a. (Moderator to encourage participants to pick a side.)

8. Last question, thinking creatively, what safety improvements, related to safety that involve bicyclists, do you NOT see today, but think would improve safety for all road users?

Thank you for your participation. Incentives will be administered via the email address that each of you provided when completing the screening process. You will receive that email within five business days from now. Please confirm your email address on your way out.

APPENDIX B – EXPERT INTERVIEW PROTOCOL

INTRODUCTION

Hello, my name is XXXX. I am contacting you per our previous arrangement to ask you some questions about your experience with bikesharing (reference previous telephone conversation or email).

Before we begin the interview I would like to confirm that you have reviewed the consent form that I sent previously. Do you have any questions? We would like to record this interview for accuracy purposes. We will erase the recording after we transcribe the interview. Is this okay with you?

PRELIMINARY INFORMATION

a. Identify name, position, and organization of interviewee.

b. What are the specific pedestrian/bicycle safety responsibilities of your organization?

c. What are the pedestrian/bicycle safety responsibilities of your job?

d. What are the main safety-related (but not necessarily bicycle-related) concerns of your organization and in your city and state?

e. What are the main bicycle-safety-related concerns of you organization and your city/state?

GENERAL KNOWLEDGE ABOUT BIKESHARING – REGIONAL EXPERTS ONLY

a. What do you think are the greatest benefits of bikesharing in the San Francisco Bay Area?

b. What do you think are the greatest challenges for bikesharing in the San Francisco Bay Area?

c. Are you aware of the new Bay Area Bike Share (BABS) program?

GENERAL KNOWLEDGE ABOUT BIKESHARING – ALL EXPERTS

a. Overall, do you believe that public bikesharing is safer, less safe, or equally as safe to private cycling?

b. Overall, do you think that bikesharing users act differently than other bicyclists? In what ways do you think they behave differently? Consider obeying laws, wearing helmets, choosing to ride in bicycle lanes etc.

c. Overall, do you think that the implementation of bikesharing causes (or will cause) an overall increase or decrease in bicycle accidents? Do you think bike-sharing will make cycling more or less safer for other cyclists?

BICYCLE-RELATED SAFETY CRASHES/COLLISIONS AND IMPROVEMENTS

Causes

a. What do you think are the biggest causes of bicyclist crashes when only the cyclist is involved? Do you think they differ from causes of bikesharing crashes? If so, what do you think are the biggest causes of bikesharing crashes when only the cyclist is involved?

   Examples of some causes include: 1) bicyclist inattention (phone or electronics, listening to music, etc.); 2) lack of riding skills; 3) evasive maneuvers to avoid other objects (bicyclists, pedestrians, vehicles, fixed objects etc.); 4) faulty equipment; and 5) inclement weather, among others.

b. What do you think are the biggest causes of bicyclist crashes when other road users involved? Do you think they differ from causes of bikesharing crashes? If so, what do you think are the biggest causes of bikesharing crashes when other road users involved?

   Examples of some causes include: 1) bicyclists not obeying laws, 2) drivers not obeying laws, 3) unsafe bicyclist behavior, 4) unsafe driver behavior, 5) aggressive behavior of bicyclists or drivers, 6) lack of bike lanes or separated bikeways, 7) problems with intersection operation, 8) bicyclists not being visible, and 9) weather, among others.

c. Do you think most accidents “just occur,” or do you think they are caused by aggressive or unsafe behavior by either the bicyclist or someone else (such as a driver, bus, etc.)? Do you think that this is the same or different for bikesharing users?

d. Who do you think is at fault for the majority of bicycle accidents? The bicyclist, someone else, or no one specifically? Do you think this is different for bikesharing accidents?

   Examples include: the cyclist, another cyclist, buses, taxis, private motorists, pedestrians, or “acts of God” (such as weather, etc.).

Risk Related to Crashes

a. What percentage of bikesharing crashes do you think involve ***only*** the bicyclist? Do you think this percentage is different for bikesharing users?

b. What percentage of bicyclist crashes do you think involve ***another*** party (e.g., driver, pedestrian, etc.), and do you think this percentage is different for bike-sharing users?

c. Do you think bikesharing crashes tend to be more, less, or equally severe than other cycling crashes? Why?

d. Do you think bikesharing users who are infrequent users (users who ride once a month or less) are more or less prone to have an accident? Why?

Bikesharing User Behavior and Infrastructure

a. Do you think bikeshare users plan their trips to take advantage of bike lanes that are separated from traffic (e.g., cycle tracks)? Do you think that this behavior differs from bicyclists in any way.

b. What is the maximum speed limit do you think is safe for bikeshare users to ride alongside traffic? Do you think this speed limit is different for bicyclists?

c. What is your opinion on allowing bicyclists to ride on sidewalks?

d. Given the choice of riding on sidewalks or trails with pedestrians, or riding on streets with vehicles and buses, which do you think is perceived to be safer by bikesharing riders? Do you think that this is really safer? Why?

e. Are there any demographic populations that you would not want to encourage riding bicycles in specific urban environments? If so, why?

f. What kind of crashes/collisions do you think that bicycle rights of way, such as bike lanes, separated bikeways prevent?

PUBLIC POLICY

a. [If relevant] Does the cost of insurance or risk of liability factor into your agencies decision to support or operate bikesharing? How?

b. Can you identify any policies (related to law enforcement, education, training, improved bicycle equipment, separate lanes etc.) that you think could ***reduce the frequency*** of bicyclist crashes? Can you identify any distinct policies that would uniquely help bikesharing members reduce the frequency of crashes?

c. Can you identify any policies (related to law enforcement, education, training, improved bicycle equipment, separate lanes etc.) that you think could ***reduce the severity*** of bicyclist crashes? Can you identify any distinct policies that would uniquely help bikesharing members reduce the severity of crashes?

d. Could you describe any bikesharing or cycling safety initiatives that your organization has undertaken?

e. What is your agency's process for evaluating safety initiatives compared to other initiatives or no initiatives? (e.g., benefit-cost analysis, accident/crash analysis etc.)

f. How does your agency balance between limited funds and competing demands for bicycle or bikesharing safety improvements and other transportation-safety related improvements?

g. Please state whether you think that wearing helmets should be mandatory for all bikesharing users. Why?

h. Are you aware of helmet dispensing machines? Has your organization adopted any policies to implement or support the implementation of helmet dispensing machines?

i. Has your organization adopted any policies or partnerships to support free or reduced cost helmets (e.g. partnerships with local businesses)?

j. What lessons have you learned from planning and implementing bicycle and/or bikesharing safety initiatives from other nations?

k. Are there any other strategies that you can share to improve bicycle and/or bikesharing safety?

l. Are there any other things could your agency do to assist you in addressing bikesharing safety?

Do you have any recommendations for resources we should consult or other experts to speak with?

Thank you for your time.

ABBREVIATIONS AND ACRONYMS

APBP	Association of Pedestrian and Bicycle Professionals
BAAQMD	San Francisco Bay Area Air Quality Management District
BABS	Bay Area Bike Share
CHP	California Highway Patrol
DALY	Disability Adjusted Life Years
DDOT	District Department of Transportation
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GES	General Estimates System
MET	Metabolic Equivalent of Tasks
MN DPS	Minnesota Department of Public Safety
MTI	Mineta Transportation Institute
NACTO	National Association of City Transportation Officials
NCBW	National Center for Bicycling and Walking
NEISS	National Electronic Injury Surveillance System
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic Safety Administration
PDO	Property Damage Only
SFMTA	San Francisco Municipal Transportation Agency
SWITRS	Statewide Integrated Traffic Records System
TSRC	Transportation Sustainability Research Center (UC Berkeley)
VMT	Vehicle Miles Traveled

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