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16. ABSTRACT

Increasing bicycle mode share has begun to show promise as a successful public health and environmental strategy in the United States. As communities across California expand bicycle infrastructure, business owners in these transitioning corridors have much at stake. Yet, very little is known about the actual, quantifiable effects of bicycle infrastructure on business establishments. This puts local governments in the difficult position of 'flying blind' by implementing bicycle infrastructure in commercial corridors with little to no contextualizing research. At the same time, cycling projects continue to be controversial and often face delays due to opposition led by merchants and their political allies. This delay costs taxpayer dollars, occupies government employee time, and prevents potentially beneficial projects from rolling out on schedule. Neither the private sector nor academia has stepped up to resolve the lack of clarity on this topic, until now.

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Bicycle Infrastructure and Commercial District Change

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Executive summary

Cities and counties can provide bicycle infrastructure to prompt existing cyclists to bicycle more frequently and encourage hesitant would-be cyclists to make trips by bike. One relatively understudied aspect of bicycle infrastructure is its impact on business establishments. Advancing the understanding of this relationship is increasingly relevant as cities across California continue to push for more bicycle infrastructure projects—and face opposition from business constituencies, among others.

This research explores this relationship in two ways. First, we use secondary data on business performance to analyze the impact bicycle infrastructure has had on sales and business closures in two counties in the San Francisco Bay Area, San Francisco County and Alameda County. Second, an intercept survey of shoppers on matched pair corridors helps to further illuminate the relationship between bicycle infrastructure, mode choice for shopping trips, and consumer behavior.

Does bicycle infrastructure impact business sales? It depends. In San Francisco and Alameda Counties, location on Class II facilities (dedicated bike lanes) was not associated with a significant change in sales, except for on neighborhood roads, which saw an increase. Further, automobile-oriented businesses and businesses selling home goods that were located on corridors with Class II facilities did see a decline in sales (of around $100,000 per year each). Location on Class III facilities (shared roadways) in San Francisco had no significant impacts on sales for businesses. In Alameda County, location on Class III infrastructure was associated with a generally positive change in sales, though in the case of facilities on secondary roads, there was a negative association.

This generally disproves business owners' claims that bike infrastructure is bad for business, though it generally does not confirm cyclist advocates' claims that bike infrastructure is good for business. Instead, it appears that for businesses in San Francisco, there are a multitude of other factors that do have a determining effect on the change in sales over time. Business characteristics were overall the most reliable predictors of sales. Neighborhood characteristics were likewise poor predictors. Corridor characteristics were somewhat predictive, with primary roads associated with sales declines.

In terms of business turnover, both classes of bike infrastructure in San Francisco showed no significant relationship with the likelihood of turnover. Change in on-street parking was also not significant in the Class II model for San Francisco. In Alameda County, businesses abutting Class II and Class III corridors saw a lower likelihood of turnover. The models suggest that bicycle infrastructure either has no effect or has a positive effect for pro-business outcomes by not affecting or reducing the likelihood of turnover.

In sum, the models suggest that bicycle infrastructure has a generally mixed effect on the change in sales over time on an individual business level, with the most positive effects occurring on neighborhood roads. The relationship between business turnover and bicycle infrastructure is either neutral in the case of San Francisco or pro-business in the case of Alameda County, with location on bicycle infrastructure of all types resulting in a reduced likelihood of turnover.

Through a survey of shoppers on matched pair corridors in San Francisco and Alameda Counties, we failed to find a coherent distinction in shopper behavior on corridors with and without bicycle infrastructure. Similar rates of shoppers arriving by bike were registered for corridors with and without bicycle infrastructure. When asked about the general frequency with which they visit the corridor by bike for shopping trips, all respondents, those who arrived by bike and otherwise, reported coming to corridors without bicycle infrastructure more frequently to shop. It appears that cyclists in the survey sample were wealthier on the whole than shoppers who arrived by other modes and that any differences in shopping patterns were likely due to that difference, rather than the mode used or the presence of bicycle infrastructure.

This research indicates that overall, bike infrastructure does not have a definitively positive or negative effect on business performance. Instead, there are a multitude of other factors outside of planners' control that determine sales or the likelihood that a business closes, our two measures of business performance. There is some evidence to support planning new bike facilities on low-volume roads, but planners should carefully assess potential impacts when placing lanes on other roadway types. This research can inform future conversations around the relationship between bikes and business, and will hopefully inspire further research into this complex relationship.

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Introduction

Research has shown that increasing the use of active modes of transportation, including cycling, can have numerous public health and environmental benefits. Providing bicycle infrastructure is one action that cities and counties can undertake to prompt existing cyclists to bicycle more frequently and encourage hesitant would-be cyclists to make trips by bike (Dill and McNeil 2013). One relatively understudied aspect of bicycle infrastructure is its impact on business establishments. Advancing the understanding of this relationship is increasingly relevant as cities across California continue to push for more bicycle infrastructure projects. This research explores this relationship in two ways. First, secondary business performance data is used to quantify the impact bicycle infrastructure has had on sales and business productivity in two counties in the San Francisco Bay Area, San Francisco County and Alameda County. Second, an intercept survey of shoppers on matched pair corridors helps to further illuminate the relationship between bicycle infrastructure, mode choice for shopping trips, and consumer behavior.

Bicycle infrastructure has come under attack throughout the Bay Area from a number of constituencies, including but not limited to the business community. Small business owners hold considerable clout when it comes to influencing local policy and decision-making. Few elected officials or government bureaucrats want to find themselves characterized as being anti-business, typically supporting the case made by local businesses on an individual or organized level (Drennen 2003).

As discussed in more detail below, news articles from different sources around the Bay Area have revealed a number of justifications for merchant opposition to bicycle infrastructure, including concerns about removing parking, obstructing commercial loading, or creating the perception of new hassles for customers arriving by car. Merchants have opposed bicycle infrastructure installation at all phases of the planning process, including exploratory studies for complete streets plans.

Understanding the relationship between bicycle infrastructure and business outcomes can inform policy in several dimensions. First and foremost, a clear understanding of this relationship supported by reliable data will be key in future community outreach for planners at the local, regional, and state levels. Business owners clearly see bicycle infrastructure as a potential threat to their businesses, but these concerns generally relate to expectations of future harm, as opposed to demonstrated impacts. Equipping planners with facts they can use to conduct outreach could go a long way towards gathering consensus in favor of bicycle infrastructure.

Furthermore, there is considerable heterogeneity within the business community, and not all businesses will be affected by bicycle infrastructure in the same way. Identifying certain vulnerable industries or business types is a key first step in designing mitigation measures that can help businesses avoid adverse outcomes related to bicycle infrastructure. Knowing more about vulnerable businesses could inform the design and location of bicycle infrastructure, allowing planners to bypass concentrated areas of vulnerable businesses where possible.

In this report, we examine impacts of three of the four classes of bicycle infrastructure designated by the Federal Highway Administration, Caltrans, and local governments (Caltrans 2017). The primary distinction between the different classes is the degree of physical separation between cyclists and vehicular traffic. There are also cost differentials between the different classes.[1]

This report begins with a review of literature on the adoption and performance of bike infrastructure from the perspective of local residents and businesses. After a description of bike facilities – and reaction to them – in the Bay Area, the report discusses the methods used to understand their impact on local businesses. The following section presents descriptive statistics on change in sales, followed by multivariate regression analysis of change in sales and business turnover. The conclusion summarizes findings and offers suggestions for further research.

[1] Class IV facilities were excluded from analysis because they were not differentiated from Class II facilities in the secondary dataset we used to locate bicycle infrastructure in the Bay Area. This facility type is rare in the Bay Area, though becoming increasingly more popular with cyclists and advocates alike due to the increased perception of safety and comfort provided by the physical separation.

Background: Bicycle infrastructure and responses in the Bay Area

There are a number of factors that influence where bicycle infrastructure is installed, as well as the facility type. From the technical standpoint, vehicular traffic volumes and speeds typically dictate the infrastructure class (Caltrans 2017). Higher speeds and volumes tend to translate into more intensive infrastructure projects, with higher volume streets typically seeing Class II bike lanes or Class IV separated bike lanes. Low volume and low speed streets are more appropriate for Class III bike boulevard facilities. Roadway capacity is another determining factor; narrower roads may not have the space to accommodate dedicated space for bike lanes and shared streets markers may be the only feasible choice. Class I segregated facilities are only feasible when right of way is already in public hands or can be acquired. As such, these facilities are found primarily in parks, along waterfronts and creeks, or in abandoned rail right of way.

However, these decisions are far from being solely technical. Stakeholder participation and political concerns also play a role in deciding if, when, where, and what type of bicycle infrastructure gets installed. Communities throughout the Bay Area have successfully advocated to bring bicycle infrastructure to their neighborhoods, successfully advocated to remove existing infrastructure projects, and successfully fought off proposed infrastructure and studies. When planners and policymakers weigh public input related to bicycle infrastructure projects, business owners are a key constituency.

The following section first describes the bicycle infrastructure currently located in the Bay Area, and then examines how locals, particularly business owners, have responded to bicycle infrastructure in their communities.

Types of bicycle infrastructure

Bicycle infrastructure refers to a broad set of amenities that encourage and facilitate cycling as a mode of transportation. This includes facilities for bicycle parking and maintenance and rights of way, either in mixed traffic or in exclusive bicycle-only right of way. For the purposes of this report, we focus on right of way, or facilities where cycling is encouraged through the provision of infrastructure. There are four classifications of right of way bicycle infrastructure in the Bay Area, described briefly below.

Class I facilities

Class I facilities, also known as shared use paths or bike paths, offer an element of horizontal separation from auto traffic. These facilities are for cyclists only, or for cyclists and pedestrians; automobile traffic is not permitted. These facilities are found running parallel to streets for automobile traffic, alongside creeks and drainage ditches, in decommissioned rail rights of way, or in parks. In urbanized areas, these facilities are most commonly located in parks and are used for both recreation and transportation. This type of infrastructure is the least prevalent in the Bay Area, with 658 miles of Class I facilities in 2014, the most recent year for which this data is available (MTC Regional Bike Facilities 2014).

Figure 1: Example of Class I Facility: Central County Bikeway, Suisun City

Image source: http://www.sta.ca.gov/Content/10088/Biking_and_Walking_in_Solano_County.html

Class II facilities

Class II facilities are also frequently referred to as bike lanes. A Class II facility is defined by a striped line indicating that a certain portion of the road space is reserved for cyclist use only. Bike lanes can be painted with a solid green treatment to maximize visibility. They can also feature a striped buffer, which increases cyclist comfort by increasing the space between moving vehicles and the bike lane. This is the most prevalent infrastructure type in the Bay Area in terms of lane miles, with over 1,500 miles of Class II facilities in the Bay Area in 2014 (MTC Regional Bike Facilities 2014).

Figure 2: Example of Class II Facility: Broadway, Oakland

Image source:
http://www2.oaklandnet.com/government/o/PWA/o/EC/s/BicycleandPedestrianProgram/OAK043750

Class III facilities

Class III facilities refer to low-speed and low-traffic volume roadways that are meant to be shared between cars and cyclists. Class III facilities are often distinguished into two categories: bike routes and bike boulevards. Bike routes designate a preferred route for cyclists on streets shared with low volume automobile traffic, using signage and optional street markings to denote the shared space. These optional road markings are called sharrows, a portmanteau of "share" and "arrow." Bike boulevards, like bike routes, are also located on low volume streets. They feature additional traffic calming elements including traffic circles and pedestrian crossing bulb-outs, and can also feature sharrows to indicate shared space. For the purposes of this analysis, the two sub-types of Class III facilities are analyzed as one typology. The Bay Area featured just under 1,000 miles of Class III facilities in 2014 (MTC Regional Bike Facilities 2014).

Figure 3: Example of Class III Facility: Milvia Street, Berkeley

Image source:
https://www.cityofberkeley.info/Public_Works/Transportation/Bicycle_Boulevard_Signage_System.aspx

Class IV facilities

Class IV infrastructure is the newest infrastructure classification permitted by roadway design manuals. Like Class II facilities, Class IV bicycle infrastructure runs parallel to automobile traffic in the same roadspace. However, like Class I infrastructure, there is an element of physical separation between traveling bicycles and vehicles. Class IV facilities are characterized by vertical physical separation in the form of parked cars, soft-hit posts, planters, or grade separation. This facility type is not distinguished from Class II facilities in the MTC regional bike infrastructure shapefile for 2014, but the region has seen several physically separated facilities installed since the dataset was last updated, including a parking protected bike lane on Telegraph Avenue in downtown Oakland, multiple soft-hit post separated facilities in Berkeley, and soft-hit post separated bikeways on Market Street in San Francisco (shown below).

Figure 4: Example of Class IV Facility: Market Street, San Francisco

Image source: https://www.sfmta.com/blog/sfmta-public-meetings-may-2-may-16

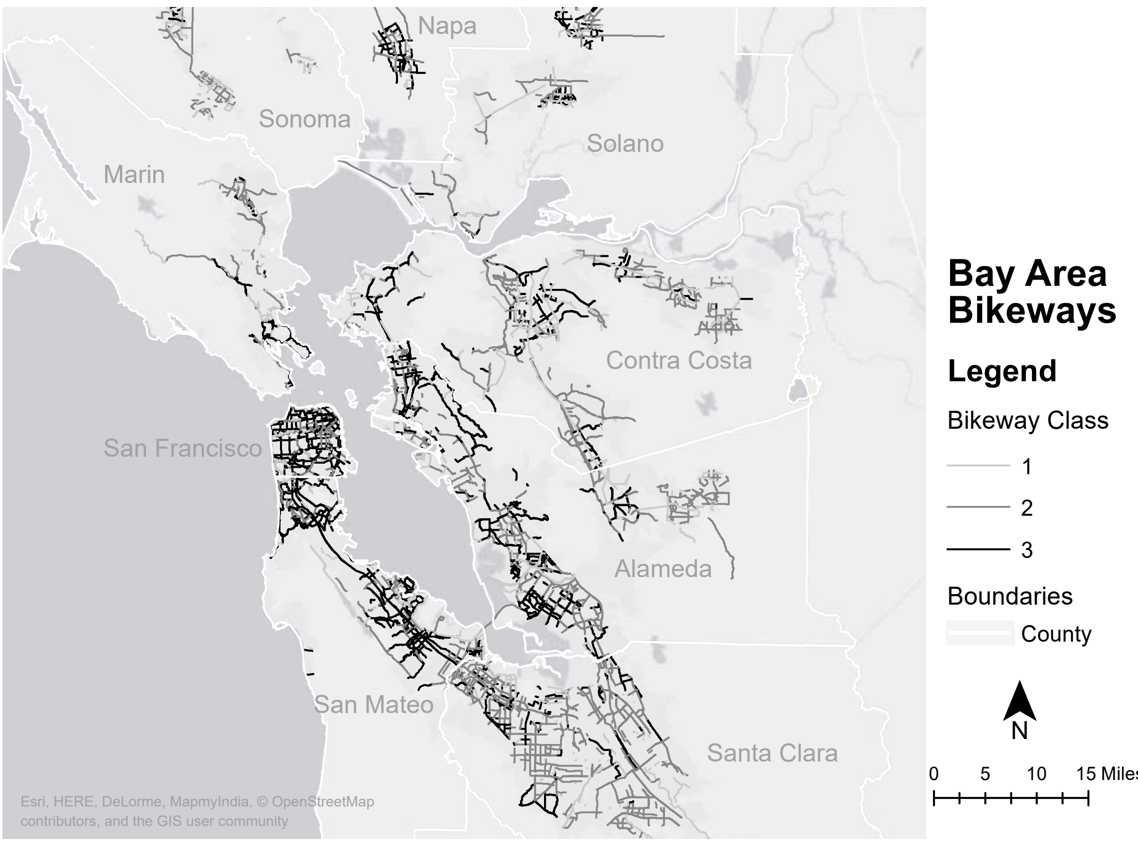
Based on MTC's Regional Bike Facilities dataset, which dates back to 2014, Table 1 summarizes the distribution of miles of bike facilities by class for each county in the Bay Area. Each class of bike infrastructure is present in each county. Mileage varies, ranging from over 700 miles of infrastructure (predominantly Class II) in Alameda and Santa Clara Counties to 104 miles of infrastructure in Napa. The distribution of bike facilities varies by county, with some counties providing mostly Class II facilities while others rely on Class IIII facilities.

Table 1: Miles of Bicycle Infrastructure by County

	Class I	**Class II**	**Class III**	**Total**
Alameda	138	335	278	**751**
Contra Costa	150	263	60	**473**
Marin	39	60	46	**145**
Napa	10	57	37	**104**
San Francisco	32	52	147	**231**
San Mateo	78	96	241	**415**
Santa Clara	97	512	117	**726**
Solano	53	109	51	**213**
Sonoma	61	115	21	**197**
Total	**658**	**1599**	**998**	**3,255**

Bicycle infrastructure has been installed throughout the Bay Area in urban, suburban, and rural communities. There are facilities located in isolated areas and predominantly used for recreation, regional connectors that are predominantly used for commuting, and facilities on local streets that could be used for a wide array of trip purposes. Figure 5 illustrates the location of bicycle infrastructure in the Bay Area by facility type. Maps of bicycle infrastructure for each county in the Bay Area are included in Appendix 32.

Figure 5: Map of Bicycle Infrastructure



Data source: MTC Regional Bike Facilities Dataset

Local response to bicycle infrastructure in the Bay Area

Bicycle infrastructure projects are highly political processes throughout the region. As bicycle infrastructure projects are largely considered discretionary, the public has considerable influence over the shape that these projects take. Below is a summary of news coverage of contentious bicycle infrastructure projects from throughout the Bay Area.

A 2011 bike lane on West Spain Street in Sonoma was derailed by strong neighborhood opposition, including a vocal and organized contingent of business owners (Moore 2011). Merchants presented a united front, submitting a petition in opposition that was signed by every merchant on West Spain Street (Moore 2011).

There is currently no bicycle infrastructure on the corridor, and no talk of a future effort to install bicycle infrastructure.

Merchants in San Jose spoke out against a 2014 plan to add four bike lanes to the city's bike network east of downtown (Boone 2014a). A similar plan for installing bike lanes or sharrows on six streets west of downtown was similarly opposed (Boone 2014b). Although San Jose Department of Transportation had recently completed a parking study indicating that the proposed plan would leave adequate parking both east and west of downtown, merchants in the commercial district disagreed (Boone 2014b). A local beauty salon owner was quoted saying, "I'm all for biking, that's a healthy lifestyle I support. But we need to take care of car parking for businesses too" (Boone 2014b). Business owners went on to characterize the removal of parking as a "competitive disadvantage" (Boone 2014b).

Concerned merchants regularly use parking removal as a hot button issue to stir up opposition. In 2013, an anti-bike lane group by the name of Save Polk Street advocated against a parking protected bike lane in downtown San Francisco (Bialick 2013). The group alerted business owners along the corridor that all parking within a 20 block stretch of the corridor would be removed, contradicting published planning documents by SFMTA (Bialick 2013). Ultimately, three blocks of the corridor received a protected bike lane and the full stretch received a temporary pilot treatment, a much less intensive intervention than was originally planned (San Francisco Bicycle Coalition 2017). The planning process for a bike lane on a stretch of Polk Street was reignited in 2017, and time will tell if business owners will come out to oppose the plan (SFMTA 2017).

Business owners east of downtown San Jose also brought up the issue of commercial loading (Boone 2014a). For businesses that do not have loading docks accessible via an alley, curb space for delivery vehicles is a necessity for operations. While this narrative has received less attention and been used less frequently than the narrative of on-street parking removal for customers, it is another factor that could influence business opposition.

In Oakland, the parking protected bike lanes on Telegraph Avenue have been touted by Oakland Department of Transportation and transportation publications as an overall success, reducing collisions and increasing bike traffic (Curry 2017). However, that narrative is not universal. Business owners along the corridor doubt that cyclists constitute a substantial pool of customers and characterize driving conditions as unsafe and confusing (Curry 2016).

Not only have merchants opposed infrastructure projects, they have even organized to oppose studies that could yield findings that encourage bike infrastructure projects. Business owners on San Pablo and Solano Avenues in Albany opposed a 2013 City Council vote to authorize a Caltrans-funded Complete Streets study (Esper 2013). Planners reinforced that the study would result in a guiding document and that any plan would have to pass through the standard approval process (Esper 2013). However, merchants still opposed the project, seizing on a proposed intersection treatment that would relocate a bus stop and result in the removal of 2-3 parking spaces (Esper 2013). The campaign against bicycle infrastructure on these corridors was successful, and currently neither corridor features any form of bicycle infrastructure.

Literature Review

Policymakers and activists have characterized bicycle infrastructure as either a blessing or a curse to business owners. Despite all of the conversation surrounding bicycle infrastructure and its effect on financial outcomes for businesses, there is a relative paucity of academic work examining the relationship. Literature that examines the connection between bicycle infrastructure and business performance can be broken down into the following categories: 1) interview-based analysis of opposition, 2) surveys on shopper behavior and perceptions, 3) surveys of merchants on perceived effect and support or opposition, and 4) analysis of secondary data in the form of taxable receipts or tax records. Studies summarized in this literature review come from academics, planning practitioners, and advocates; the perspectives of different types of authors will be examined, as will the analysis and interpretation of the results.

Interview-based analysis of opposition

Researchers have documented opposition to bike lanes from a political economy or critical theory perspective. When it comes to project support or opposition, business owners carry a substantial amount of clout. Politicians and government officials are beholden to small business interests for political reasons; actions taken to hurt small businesses could easily become electoral handicaps (Drennen 2003). Opposing bicycle infrastructure can be a political asset; such was the case in the 2010 Toronto mayoral election where a candidate won after promising to "[stop] the war on the car" and pledged to remove a contentious bike lane (Siemiatycki, Smith, and Walks 2016).

Wild et al. (2017) reviewed literature documenting contested bike infrastructure to distill narratives in opposition or support of such projects. The authors found that planners tend to view bike infrastructure through a rational, technocratic lens, characterizing infrastructure projects as minor interventions to make cycling more comfortable. By not engaging in a more critical discussion over the social, economic and political values embedded in cycling and bicycle infrastructure, planners make themselves vulnerable to being blindsided by "bikelash." Planners saw the bike lanes as neutral interventions outside the realm of political contention (Vreugdenhil 2013, Vreugdenhil and Williams 2013). In an opinion piece for New York Mag, Shaer describes bike lanes as being not ''simple strips of pavement festooned with green and white paint' but 'sponges for a sea of latent cultural and economic anxieties" (Shaer 2011, p. 2). Situating narratives related to bicycle infrastructure within theory helps to set the stage for larger conversations surrounding gentrification and displacement.

Businesses typically characterize their opposition to bike infrastructure not within the sociocultural narratives described above, but rather in more practical terms. Through their review of published opposition, Wild et al. (2017) determined that merchants oppose bicycle infrastructure on the grounds of parking loss, driver confusion, and pedestrian safety. Bicycle infrastructure represents the first time motorists are being asked to cede road space that was once solely theirs (Vreugdenhil and Williams 2013). Understanding the rationale provided by business owners will inform later analyses on the effect of on-street parking loss.

Shopper behavior

Published studies of shopper behavior primarily consist of surveys of shoppers. These surveys ask questions about spending, frequency of patronage, and mode choice. As these studies rely on self-reported figures, they are subject to respondent error. Furthermore, most of these surveys relied on intercept surveys within small geographic areas, casting doubt on the generalizability of the findings beyond the survey location and sample in question.

In perhaps the best-known paper on the economic impacts of bicycle infrastructure, an intercept survey-based examination of various travel mode users in Portland, Oregon showed that, on average, cyclists spent more at certain business types and patronized them more often (Clifton 2012). This research has been widely celebrated and implemented as a policy tool in bicycle advocacy circles (Maus 2010; Campbell 2015; Szczepanski 2013). However, the Portland study addressed a limited sampling frame, surveying only the patrons of eating and driving establishments and 24 hour convenience stores. Restaurants, bars, cafés, and convenience stores do not represent the wide cross section of businesses that could be impacted by bicycle infrastructure. Namely, purchases at these establishments are small, with almost any purchase being possible to carry home on a bicycle without any extra equipment such as a trailer. Given the heterogeneity of the business community, a study based on patrons of such a narrow subset of businesses does not lend itself well to generalizability.

Other survey-based research on shopper mode choice and spending habits has been conducted by various public agencies in the United States. In 2008, the San Francisco County Transportation Authority conducted a shopper survey on the Columbus Avenue corridor, finding that those who bicycle, ride in a taxi, or use 'other' modes of transportation spent more in the corridor than those who drove or those who took transit ("Columbus Avenue Neighborhood Transportation Study" 2010). The following year, SFCTA conducted another study of mode choice and consumer behavior at several sites in downtown San Francisco, finding that while people who drove to downtown San Francisco shopping destinations spent the most money per trip, they visited business less frequently than shoppers who arrived by transit, walking, or biking (Bent and Singa 2009). When the average dollar amount spent was multiplied by the average number of visits per month, drivers spent the least on average and walkers spent the most (Bent and Singa 2009).

In New York City's East Village neighborhood, a 2012 survey study concluded that the total aggregate spending of bicyclists in the neighborhood was more than drivers, bus riders, taxi users, and 'select bus service' riders combined ("East Village Shoppers Study: A Snapshot of Travel and Spending Patterns of Residents and Visitors in the East Village" 2012). The same survey also found that cyclists had the highest per capita spending in the neighborhood ("East Village Shoppers Study: A Snapshot of Travel and Spending Patterns of Residents and Visitors in the East Village" 2012). This high level of cyclist spending was attributed partially to the fact that cyclists visited local businesses more often and also to increased cyclist traffic due to the addition of protected bicycle lanes on First and Second Avenues ("East Village Shoppers Study: A Snapshot of Travel and Spending Patterns of Residents and Visitors in the East Village" 2012). However, a key limitation to this study is that the survey collected limited demographic information on shoppers. Perhaps most notably, the survey did not report data on household income. This is a key missing data point in the survey, and attempts to characterize shopper behavior with accounting for income present an incomplete picture.

Two studies of shopper behavior in Davis, California examined spending and mode choice decisions for shoppers. The first study, which contrasts the purchasing behavior of shoppers who arrived by car or by bike, found that cyclists spend roughly the same amount per purchase as drivers, and spent more cumulatively over a month, though this difference was not statistically significant (Popovich and Handy 2014). A second study based on the results of the same survey sought to understand the decision to cycle for shopping purposes. The authors found that shoppers who agreed with the statement "it is convenient to cycle to my final destination" tended to be more likely to cycle, with drivers exhibiting the same effect when driving was perceived as convenient (Popovich and Handy 2015). This finding is intuitive, but could be extrapolated to consider the role cycling infrastructure has in trip comfort. Individual definitions of convenience are up to interpretation, but enabling infrastructure could reasonably be expected to be included as at least part of this judgment. While Davis is a smaller city than other cities subject to the research covered in this literature review, it is an extreme case study with a high share of cyclists—in other words, an optimal case that illustrates the maximum potential of infrastructure.

Researchers have also used survey data to model impact of bicycle infrastructure on businesses. A 2008 masters thesis used survey data to examine the shopping habits of cycling- and car-borne customers at inner Melbourne, Australia shopping strips. In this research, Lee argued that if public auto parking spaces in commercial areas were reallocated to cyclist parking, 3.6 times the current retail spending could be achieved in the area, with cafés, restaurants, and clothing retailers being the primary beneficiaries of such a shift (Lee 2008). Lee's argument was based upon a customer survey conducted in Melbourne, which estimated auto and cyclist spending behavior. Lee then multiplied the average reported cyclist spending by the number of cyclists that could park in a single auto parking space (Lee 2008, p. 39). Next, the author compared the multiplied cyclist spending product to the average spending of an auto driver occupying the same amount of space, producing the 3.6 times value of cyclists (Lee 2008, p. 39). This line of reasoning, while perfectly logical, is fraught with assumption and context-specific dependencies. For example, Lee assumes that there is an unlimited number of cyclists waiting in the wings to take the place of auto users and also that the mixture of local businesses would remain unchanged with the loss of auto parking. Further, the paper's geographic context is highly specific – "inner suburban Melbourne" has a particular built environment, climate, and demographic mix, making it difficult to generalize results as applicable to other communities (a problem with any small-geography study of this kind) (Lee 2008, p. 8).

Merchant perspectives

While research based on surveys of shoppers tended to reveal an expectation that bicycle infrastructure would have a positive effect on business performance, the results from studies examining merchants' perceptions are much more mixed.

Interviews with merchants before and after the installation of a segregated bike path in Sydney, Australia showed initial worry over the effect the infrastructure would have which went away after the installation was completed (Crane et al. 2016, 20). Merchants specifically named impact to parking access as a negative aspect of the project. When merchants were interviewed after installation was completed, this narrative did not re-emerge. When pressed, some merchants even admitted that their fears might have been overblown. Researchers interviewed three business owners who had moved to the cycleway after the construction was complete. These informants indicated that they viewed the bicycle infrastructure as a positive amenity of the location. This analysis highlights the divergent narratives that business owners profess before and after the installation with bicycle infrastructure, highlighting the importance of information that shows what business owners can expect from a project.

A survey of merchants and shoppers conducted in downtown Dublin, Ireland showed that merchants routinely overestimated the percentage of customers that arrived by car and underestimated the share of customers arriving on foot or by bus (O'Connor et al. 2011). This study highlights misperceptions that may exist within the merchant community, providing a possible explanation for Crane's finding of initial merchant apprehension surrounding bicycle infrastructure projects. A similar parallel survey of restaurateurs and patrons in downtown Brisbane, Australia revealed that 18% of patrons arrived by car as opposed to the 52% estimated by restaurant owners (Yen, Tseng, and Ghafoor 2015). 7% of customers can by bike instead of the 2% expected by the business owners. The survey also revealed that restaurateurs underestimated the amount of money spent by users of active modes and transit (Yen, Tseng, and Ghafoor 2015).

A 2003 interview-based study examined bicycle lanes that were installed in San Francisco's Mission District uncovered strong merchant support for the lanes, including the belief amongst 65% of interviewees that bicycle lanes have had positive impacts on sales and their business overall (Drennen 2003). This research was published 15 years ago, when dynamics in the Mission were quite different from what exists today.

There are several studies that investigate the effect of bicycle infrastructure through self-reported data on sales and profit collected through surveys of business owners. Planners in Vancouver, British Columbia surveyed business owners after the installation of a separated bikeway. The sampling frame consisted of all ground floor businesses abutting the bikeway, as opposed to previous studies which focused on a subset of businesses. Business owners reported declines in sales and profit. The report predicted that "the moderate negative impact of the lanes will diminish over time as long as mitigation strategies take effect" (Stantec Consulting Ltd. 2011, p. iii).

Dual survey-based studies performed on the Bloor Street corridor in Toronto found that overall, merchants and shoppers alike supported the addition of bicycle lanes to the right-of-way and that those arriving by bicycle, transit, and foot were likely to spend more in the commercial district than those arriving by auto (Sztabinski 2009 and Forkes and Smith-Lea 2010). Survey results from the 2009 research revealed that "75% of merchants thought a bike lane or widened sidewalk would improve or have no effect on business, and patrons preferred a bike lane to widened sidewalks at a ratio of almost four to one" (Sztabinski 2009, p. 23). The 2009 analysis roundly concluded "that merchants in this area are unlikely to be negatively affected by reallocating on-street parking space to a bicycle lane. On the contrary, this change will likely increase commercial activity" (Sztabinski 2009, p. 1). In 2010, a similar survey-based analysis conducted in the area found that more than half of merchants believed reducing parking and adding a bike lane would increase or have no impact on their number of customers" (Forkes and Smith-Lea 2010, p. 10). The same study found that "The majority of people surveyed (58%) preferred to see street use reallocated for widened sidewalks or a bike lane, even if on-street parking were reduced by 50%" (Forkes and Smith-Lea 2010).

Important to note of any survey-based research is that the responses are self-reported and thus vulnerable to misremembering, exaggeration, or other forms of bias. These analyses – as with most of the research cited in this literature review– do not cite sales tax receipts or other business sales data, however, and measure only the perception of merchants and customers, not hard sales data or measures of productivity. While perception is important, analysis using unbiased and universal data could provide a clearer picture of the effect of bicycle infrastructure on business performance. Tax and sales data is relatively hard to come by, and often comes from proprietary sources that charge hefty access fees. The dearth of published research using these sources is understandable.

Analysis of secondary data

Analysis of secondary data has used taxable receipt data to gather an unbiased picture of trends in business performance before and after the implementation of bicycle infrastructure. However, such analysis has generally been conducted in an opaque way on datasets that are not publicly available for verification. As this paper relies primarily on analysis of secondary business performance data, these sources have been of critical importance to the development of our methodology.

A 2012 New York City Department of Transportation (DOT) publication claimed increases in retail sales of "up to 49%" along new protected bicycle lanes on Ninth Avenue from 23rd to 31st streets in Manhattan, compared to increases of three percent borough-wide ("Measuring the Street: New Metrics for 21st Century Streets" 2012, p. 4). Similarly, a 2017 Oakland DOT planning document using sales tax receipt data stated that retail sales in the Telegraph corridor had increased nine percent year-over-year after a protected bicycle lane intervention (Fine 2017). However, in neither DOT study were the bicycle lane corridors compared to control corridors or nearby areas, making it difficult to separate the effect of bicycle infrastructure from general economic trends.

A taxable retail sales-based analysis of two bicycle lane interventions in Seattle, Washington included dual control regions for each of the two study areas, showing no negative sales impact on businesses resulting from either bicycle lane intervention (Rowe 2013). The study suggested the possibility of a wildly successful economic impact produced by a climbing lane installed on NE 65th Street, which removed 12 parking spots was correlated with a 400% increase in sales in the district (Rowe 2013, p. 2). Rowe 2013 used a more sound and transparent methodology than both the NYC and Oakland DOT reports, with more appropriate control regions and greater discussion of the results.

Bicycle infrastructure and commercial gentrification

A cross-cutting theme across the research is the relationship between bicycle infrastructure and commercial gentrification, a theme associated with the broader literature on environmental or "green gentrification" (Gould and Lewis 2017). This discussion connects public and private investment in environmental amenities with a subsequent increase in real estate prices, gentrification, and displacement. Cities promote livability as a tool to attract capital and its talent (Kreugeran Gibbs 2007, Raco 2005). For instance, in Seattle, an ecological agenda for urban open spaces displaces and excludes the homeless (Dooling 2009). In Vancouver, developers use discourses of sustainability for marketing purposes and to spur gentrification (Quastel 2009).

The Complete Streets movement itself raises questions. Complete Streets processes revamp streets, with the idea of providing safe access for all users rather than just facilitating automobility (McCann and Rynne 2010). Yet, as Zavestoski and Agyeman ask, complete for whom? Most complete street projects are implemented on just a few blocks, with designs that try to accommodate diverse users from disabled pedestrians to bicycles to delivery trucks, but tend to fall short in meeting some needs (Zavestoski and Ageyeman 2014).

The primary method for examining the relationship between bike infrastructure and gentrification has been interviews and ethnography. Valencia Street in San Francisco has served as a case study site for several critical theory articles. The early advocacy of the San Francisco Bike Coalition adopted a narrative about the project centering on the uptick in commercial activity, while ignoring the social and cultural ramifications that the project had brought (Stehlin 2015). The corridor is described as a "key material, ideological, and practical linkage between bicycle infrastructure, cosmopolitan urbanity, and economic growth" (Stehlin 2015, p. 125). This critique of the progressive concept of urban livability for its disregard for gentrification is shared by Rankin and McLean, who point to the correlation between bicycle infrastructure and other amenities designed to appeal to creative types and initiate economic change in urban commercial corridors (Rankin and McLean 2015). Lubitow further unpacks this relationship through a study that used interviews and observation to uncover the dynamics behind community opposition to a bike lane on Paseo Boricua in Chicago, a principal artery for the city's largest Puerto Rican neighborhood (Lubitow, Zinschlag, and Rochester 2016). Some community members revealed that they were not opposed to bicycle infrastructure itself, but rather the top down approach that the city had taken to the planning process. Others identified the project as "pav[ing] the way for gentrification (Lubitow, Zinschlag, and Rochester 2016, p. 2643). Since the research summarized in this section of the literature review relies primarily on small sample interviews and review of historical documents, there are limitations to the generalizability of the findings.

Role of advocacy publications

Much of the findings summarized in this literature review have been interpreted and reported by cycling advocacy groups in an attempt to convince business owners that bicycle lanes increase sales (Tolley 2011, Flusche 2012, Szczepanski 2013, Andersen and Hall 2014). In an attempt to advocate across broad geographies, advocates have taken corridor specific studies and cast them as generalizable findings, a practice that could be seen as misleading. The need for analysis that speaks to the effect of bicycle infrastructure across a broad geography is evident, though difficult to meet given the lack of comprehensive data sources reporting business performance metrics or the location of bicycle infrastructure. This is the gap in the literature that this study seeks to fill through analysis at the county and regional levels.

Summary

Researchers from across disciplines have examined the impact of bicycle infrastructure on business performance, but a clear narrative has not emerged. While advocacy organizations have seized on research that finds a positive or neutral effect on businesses, there are limitations to applying this research at the broad scale that advocates would like. Research has also indicated that there could be a negative impact for businesses on corridors with bike infrastructure. Merchant opposition has been clearly documented, but research that looks at merchant attitudes over time tends to show a more neutral or even pro-bike infrastructure stance. This research seeks to carve a niche in the literature by applying empirical methods to analyze the effect of bicycle infrastructure on businesses at the county level, as opposed to simply examining conditions at the corridor level like the majority of studies have done. The survey of shoppers on matched pair corridors complements this research by examining the effect of such infrastructure on an individual's purchase decisions. Through the triangulation of these multiple methods, we hope to fill a gap in the literature and paint a more comprehensive picture of the state of bicycle infrastructure and business performance in the Bay Area.

Methodology

Data sources

Business performance

Business performance data come from the National Establishment Time Series (NETS) database, a proprietary database assembled by Don Walls & Associates that combines Dun & Bradstreet data on individual establishments into an annual time series from 1990 through 2014. As is typical of business data, this database has shortcomings, including inaccuracy of data (both self-reported and estimated) and infrequency of updates (Kroll, Lee, and Shams 2010; Neumark, Zhang, and Wall 2007). NETS is a census of businesses with 99% of businesses in the state of California reporting (Walls & Associates 2017). Businesses of all sizes are included in the dataset, from freelancers earning a few hundred dollars per year on a passion project to healthcare systems earning millions of dollars and employing thousands. The dataset includes data about businesses that were open at any time during the period 1990 to 2014.

For the purposes of our analysis, the primary variables of interest were sales, number of employees, physical address, industry (6 digit NAICS code), first year, and last year. Other variables including the first year of operation and the number of related businesses were also used as control variables in the models.

Roadway characteristics

We hypothesized that business performance would vary based on corridor characteristics. Measuring the performance of businesses located on principal arteries against that of businesses on side streets is not an intuitive one to one comparison. As such, we created a gradient of four corridor typologies ranging from statewide connectors to neighborhood streets.

Corridor data came from OpenStreetMap, a global open source mapping resource. OpenStreetMap, or OSM, includes linear features representing roads and paths. Each linear feature has a class designation, with 27 total road class designations present in the dataset (Ramm 2017). Feature classes that represented horse trails, recreational bike facilities, hiking trails, staircases, ferry routes, private roads, or features of unknown uses were excluded from the corridor typologies. Interstates were also excluded from the typologies classification due to their limited access design. The remaining feature classes were condensed into four corridor typologies, summarized in Table 2.

Table 2: Miles of roadway types by county

County	Road classification	Miles
Alameda	Primary roads	1,990
	Secondary roads	3,348
	Tertiary roads	4,073
	Neighborhood roads	11,170
Total		**20,581**
San Francisco	Primary roads	1,176
	Secondary roads	1,716
	Tertiary roads	3,150
	Neighborhood roads	7,899
Total		**13,941**

Primary roads are often state owned and operated facilities that promote statewide connectivity. This typology also includes roads designated as trunk corridors, which are corridors similar to primary roads that also feature a median dividing traffic flows in opposite directions. In the Bay Area, these corridors include University Avenue or Broadway in the East Bay. While these facilities are typically among the highest automobile traffic corridors, some are equipped with bike infrastructure. Bike infrastructure on primary roads is predominantly Class II, due in part to the need for clear delineation of road space for bicycles due to high traffic speeds and volumes.

Secondary roads offer regional connectivity. These facilities are also high automobile traffic and bike infrastructure tends to consist of mostly Class II facilities as a result. In the Bay Area, roads classified with the corridor typology of secondary roads include Mission Street in San Francisco or Telegraph Avenue in Oakland.

Tertiary roads provide local connectivity. This is OSM's lowest volume "major road" classification (Ramm 2017). In the Bay Area, these corridors typically feature a mix of Class II and Class III facilities. Examples of tertiary roads in the Bay Area include Valencia Street and 24th Streets in San Francisco or College Avenue in Berkeley.

The fourth and final road typology, neighborhood streets, is the largest by far in terms of mileage. This typology includes roads designated as neighborhood streets as well as service facilities (alleys and other narrow access streets) and living streets, or streets where pedestrian access is privileged. Due to the relatively low traffic volumes and speeds, these corridors tend to be designated as bicycle boulevards and feature Class III facilities, although some are equipped with Class II bike lanes.

Bicycle infrastructure

Data on the location and class of bicycle infrastructure came from two sources. Metropolitan Transportation Commission (now Bay Area Metro), the metropolitan planning organization that oversees regional planning in the Bay Area, publishes data on the location and class of bike infrastructure throughout the Bay Area. This dataset features information on bicycle infrastructure through the year 2014, which conveniently matched the time frame of the NETS dataset. The MTC data was available in spatial (shapefile) and tabular (csv) formats. A drawback to the MTC data is that it does not include installation date for any infrastructure. However, installation dates were manually assigned to facilities in Alameda County using historic satellite imagery from Google Earth.

The MTC dataset was supplemented by San Francisco Municipal Transportation Agency (SFMTA)'s Bikeway Network dataset. This dataset, also in dual file format, includes the location and class of bicycle infrastructure for San Francisco, as well as install month and year.

On-street parking

On-street parking counts before and after the installation of bicycle lanes were conducted for San Francisco. Parking counts were only conducted for corridors with Class II facilities, as Class III do not affect the number of parking spaces and Class I facilities were not found in San Francisco outside of parks. Parking counts were not conducted for Alameda County due to time constraints, though future research should seek to add this data.

On-street parking counts were conducted using Google Street View. Google provides Street View imagery from 2007 to 2018, though not all locations have imagery dating back to 2007. Researchers counted the number of parking spaces on the block in the most recent Google Street View imagery. They then navigated back in time to Street View imagery from before the bike lane was installed and counted the number of on-street spaces present before installation.

Researchers counted the number of unpainted curb parking spaces as well as the number of yellow, green, white, and blue spaces. Yellow curb space is meant to facilitate commercial loading by designating space specifically for commercial vehicles. Knowing the number of yellow loading zone spaces was of special interest given that difficulty with commercial loading is a reason given by merchants who oppose bicycle infrastructure projects. Noting the placement of white curb space for passenger loading is also potentially of interest, as transportation network companies and taxis make use of these spaces to drop off passengers. As TNCs are a newer phenomenon, there has not been as much of a clamor for passenger loading space as there has been for commercial loading space, though this could be an issue in coming years.

The change in the number of parking spaces of each type (standard, color curb) was then calculated using the before and after counts. There were instances where the bike lane predated Street View; in those cases, parking change was not calculated. This variable is used in the sales and business turnover models for San Francisco.

It is possible that parking spaces were removed on corridors without bicycle infrastructure for projects other than bicycle infrastructure, including pedestrian facilities, parklets, bike corrals, or transit facilities. Future research should also seek to capture a comprehensive picture of change in on-street parking.

Data processing

NETS data cleaning

As mentioned in the dataset description, NETS covers all businesses in the state of California. We first limited the data to businesses in Alameda and San Francisco Counties using a variable in the NETS dataset indicating FIPS code. Next, we spatialized the businesses using latitude and longitude data from NETS to confirm that the address was within the county corresponding to the designated FIPS code. Businesses that had been assigned an incorrect FIPS code were eliminated.

The NETS dataset also noted the years in which businesses moved. For businesses that moved, NETS provides the establishment's first and last address. The dataset did not provide information on intermediate addresses for businesses that had moved more than once during their time in operation. As such, businesses that moved more than once were excluded from analysis. This represented a small fraction of businesses in the sample at roughly 2,500 businesses in the Bay Area.

Once we were confident that the dataset consisted of only businesses that were actually located in Alameda and San Francisco counties, the dataset was subset again to include only storefront businesses. Using 6 digit NAICS codes, we selected a list of 106 industry designations that characterized businesses of interest – storefront retail, food service, and other service-providing businesses that stand to be affected by bicycle infrastructure. Businesses that aren't dependent on consumer access, such as office-based workplaces or manufacturing sites, were excluded from analysis. The list of storefront NAICS codes can be found in Appendix 1.

To analyze general trends along industry lines, 10 industry classifications were created using 6 digit NAICS codes. Not every business in the sample falls into one of the industry categories, but they represent prominent industries. Table 3 lists the ten industry classifications and presents the total number of businesses within each classification. The industry breakdowns are generally similar between the two counties. Note that percentages do not sum to 100 due to rounding. The NAICS codes that correspond to each industry grouping are found in Appendix 2.

Table 3: Industry by number of businesses

Industry	San Francisco County N	%	Alameda County N	%
Bar	1,177	2%	765	1%
Restaurant	7,714	13%	7,269	9%
Grocery	3,497	6%	4,000	5%
Personal goods	7,708	13%	10,457	13%
Home goods	4,021	7%	6,664	9%
Services	7,952	14%	10,300	13%
Entertainment	61	<1%	68	<1%
Financial	2,782	5%	3,552	5%
Health	10,349	18%	12,864	16%
Automobile-oriented	2,585	4%	8,882	11%
Uncategorized	9,652	17%	13,480	17%
Total	**57,498**	**99%**	**78,301**	**99%**

A major component of this research is analysis of change over time. All sales figures were inflation-adjusted to 2014 dollars using CPI rates provided by the Bureau of Labor Statistics.

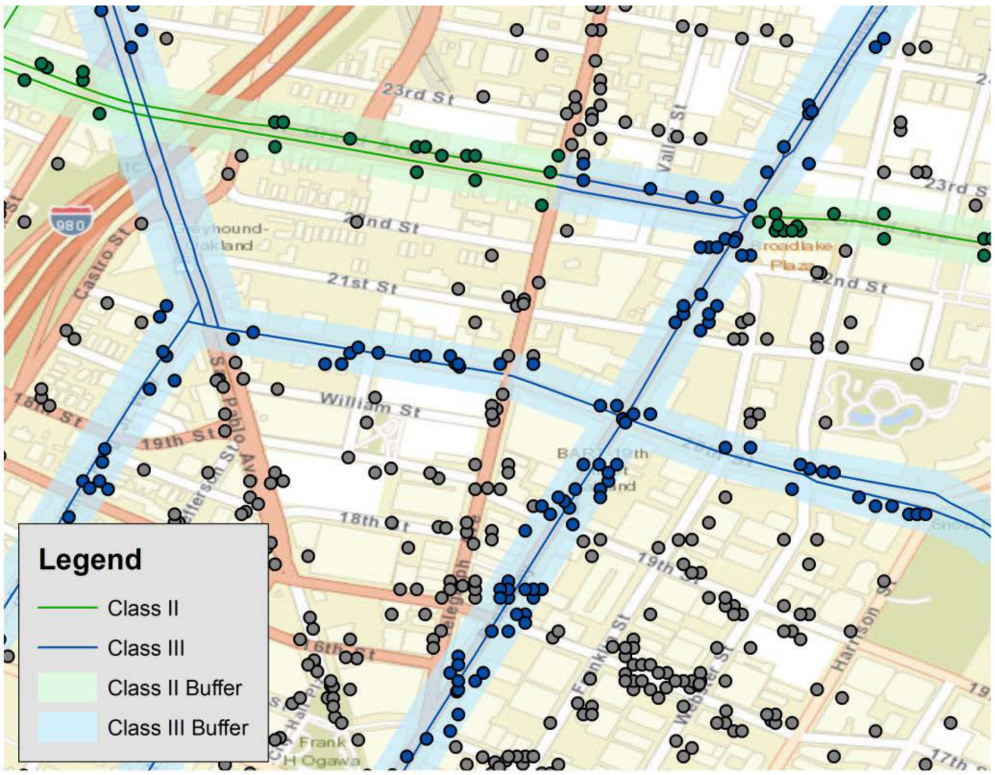
The final step in NETS data processing was to eliminate outlier businesses. Businesses with 1 or fewer employees were eliminated, as were businesses with sales larger than the 99th percentile for that given year.

Designating abutting businesses

Throughout this report, businesses that abut bicycle infrastructure will be compared against businesses that do not abut bicycle infrastructure. The following process was used to assign an abutting dummy variable to businesses that directly face bicycle infrastructure. The bicycle infrastructure shapefiles from MTC and SFMTA both used street centerlines as the alignment of bicycle infrastructure. Meanwhile, NETS data placed the point feature for each business inside the parcel.

Using ArcGIS, we drew a 100 foot buffer around the bicycle infrastructure street centerlines to capture the business point features located. Buffers of varying lengths were spot tested to determine the minimum distance necessary to capture abutting businesses without also beginning to capture non-abutting businesses within the buffer zone. The polygon buffer features could then be spatially joined to business point features to create a dummy variable for abutting businesses. This process was repeated for Class I, Class II, and Class III corridors to create dummy variables for each type of infrastructure. Figure 1 illustrates the process. It depicts corridors with Class II facilities and their buffers in green and Class III corridors and their buffers in blue. Businesses that fall within the green or blue buffers would be coded as being Class II or Class III, respectively. All other businesses would be coded as non-abutting. Businesses at the intersection of two or three buffers were dropped from analysis, as there was no way to automate the process of determining whether the business had an entry way on the Class II or Class III corridor. However, these businesses represented a small fraction of all businesses in the sample at less than 1% of businesses in Alameda County (315 of 78,301) and less than 3% of businesses in San Francisco (1,489 of 57,498).

Figure 6: Bike infrastructure buffer process in downtown Oakland



Other built environment variables

Population density classes were calculated using percentiles, with block groups under the 33rd percentile being classified as rural, block groups in the middle tercile classified as suburban, and block groups in the 66th percentile and above classified as urban. This translated to cutoff points of 7 people per acre or less for rural block groups, 8-15 people per acre for suburban block groups, and greater than 15 people per acre for urban block groups.

To compare across corridors that see similar traffic volumes and offer similar degrees of local, regional, or statewide connectivity, we also created a four-tiered roadway classification by condensing OpenStreetMap's road classification feature. The road classes range from high volume primary roads that provide statewide connectivity to neighborhood streets that see a considerably lower volume of cars and people. Interstates were not included in the typologies. The four road classifications are all inclusive, meaning that each business in the sample falls into one of the four classifications. Table 4 summarizes the number of businesses located on each of the four roadway classifications, as well as the number of businesses abutting and not abutting bike infrastructure.

Table 4: Abutting and non-abutting businesses by roadway classification

County	Roadway classification	Bicycle infrastructure	Businesses N	Businesses Percent
Alameda	Primary roads	Non-abutting	8,632	91%
		Abutting	808	9%
	Secondary roads	Non-abutting	11,793	96%
		Abutting	459	4%
	Tertiary roads	Non-abutting	9,652	94%
		Abutting	585	6%
	Neighborhood roads	Non-abutting	43,263	96%
		Abutting	1,828	4%
Total			**77,020**	
San Francisco	Primary roads	Non-abutting	5,405	65%
		Abutting	2,952	35%
	Secondary roads	Non-abutting	7,012	74%
		Abutting	2,401	26%
	Tertiary roads	Non-abutting	7,190	51%
		Abutting	6,942	49%
	Neighborhood roads	Non-abutting	19,066	78%
		Abutting	5,389	22%
Total			**56,375**	

Alameda County shows relatively little variation in the share of businesses abutting bike infrastructure, with an average hovering between 4 and 9% of all storefront businesses abutting corridors of any class. As a more urban county, San Francisco shows a considerably higher proportion of businesses abutting bike infrastructure, with upwards of a 50/50 split of businesses on tertiary roads abutting bicycle infrastructure.

Modeling the relationship between bicycle infrastructure and business performance

Introduction

The following section presents several statistical models that further elaborate on the relationship between bicycle infrastructure and business performance. The models control for business, neighborhood, and corridor characteristics to present the effect of bicycle infrastructure in isolation.

Dependent variables

There are two primary outcomes of interest in determining the relationship between bicycle infrastructure and business performance: change to sales volume and likelihood of turnover. The sales change model looks at the effect of bicycle infrastructure on the change to sales volume over the years 1990 to 2014. The change in average sales is calculated as the average sales for a business in the years prior to the installation of bike infrastructure subtracted from the average sales for a business after the installation of bike infrastructure, with the change reported in 2014 dollars. For non-abutting businesses, the same change is calculated using the year of installation for the closest bike infrastructure project as the year around which before and after averages are calculated. Examining the sales change outcome is of interest to business owners and planners alike because sales volume is perhaps the easiest to understand measure of business performance. Given that different infrastructure types may have different effects, models are presented for each class of bicycle infrastructure in Alameda and San Francisco counties.

The second set of models differ from the first set in that it does not model the linear relationship between bicycle infrastructure and business performance. Rather, these models estimate the probability of a business closing versus staying open. Understanding whether location on a corridor with bicycle infrastructure changes the likelihood that a business will close is of interest because remaining open is one of the most basic definitions of business success. This section also includes models for each infrastructure type in each county.

The San Francisco models include a set of variables related to parking and curb management, including the change in number of on-street parking spaces and dummy variables indicating the presence of commercial or passenger loading zones on the block where the business is located.

There were very few businesses abutting Class I infrastructure (0 businesses for San Francisco and 17 businesses for Alameda County). This sample size is so small that estimating the effect of location on Class I infrastructure would not be statistically robust. As such, this section only presents models for Class II and Class III infrastructure.

Independent variables

Bicycle infrastructure

Bicycle infrastructure variables are the primary variables of interest. The model accounts for infrastructure class with a dummy variable indicating whether or not the business abuts a Class I, Class II, or Class III corridor. This enables us to tease out the differing effects that different types of infrastructure may have. There are relatively few businesses abutting Class I facilities in both counties. San Francisco County only had one corridor with Class I infrastructure installed in the period 1990 to 2014, and there were no businesses abutting this corridor. As a result, there are no models for sales change or turnover for Class I facilities in San Francisco.

Corridor characteristics

The second set of independent variables relates to characteristics of the corridor. Comparing businesses on a principal artery against businesses on a side street is not necessarily a fair comparison. As such, the model includes the four ordinal roadway classifications. Neighborhood streets are excluded from the model and serve as the reference category against which the other three road classes can be compared.

Business characteristics

There are a number of business characteristics that could theoretically influence business performance outcomes. The model takes these into consideration and calculates their effect apart from the effect of the bicycle infrastructure. The first major distinction to take into account is the industry (the 10 overarching industry categories).

Other variables related to the business include a variable representing business age and a dummy variable representing whether or not the business was a chain The chain dummy variable includes national and local chains, with any business that had one or more related business locations in the dataset being marked as a chain.

Neighborhood characteristics

The neighborhood where a business is located can also have an effect on business performance. Understanding and controlling for the built environment characteristics and demographic profile of the neighborhood was a key step in the modeling process. All neighborhood characteristic data points are aggregated at the Census Tract level, which is the most granular level at which data from the US Census Bureau's American Community Survey is available for the years 2009 to 2014. Neighborhood characteristic data are current to the year of installation (or the year of installation for the nearest bicycle infrastructure project in the case of non-abutting businesses). ACS data was not available for the years before 2009. In these cases, data from either the 2000 Census or the 2009 ACS were assigned to the business. Businesses on bike infrastructure projects that were installed before 2004 were assigned demographic data from the 2000 Census; businesses on infrastructure installed between 2004 and 2009 were assigned demographic data from the 2009 ACS. There were very few businesses on bike infrastructure projects installed in the 1990s. Data from the 1990 Census was not available online, so it could not be used for model estimation.

To understand the urban form surrounding the businesses in the sample, we looked into density of people and businesses. The model includes an establishment density variable calculated as number of businesses per acre and dummy variables representing urban, suburban, and rural densities. The density dummy variables were calculated using terciles: the first tercile was marked as rural (density of less than 7 residents per acre), the middle tercile was marked as suburban (7 to 15 residents per acre), and the third tercile was marked urban (greater than 15 residents per acre). The final built environment variable represents the percent of housing that is renter occupied.

To better understand the profile of people living in the neighborhood surrounding businesses, the model also controls for various economic and demographic features. Median household income in 2014 dollars represents the general affluence of the surrounding neighborhood. In a region with growing income inequality, the median controls for unusually high incomes and presents a more representative picture of incomes in the neighborhood. The model also includes some information on the household tenure (percent of housing that is renter occupied), along with the racial and ethnic composition of the neighborhood (with variables that account for the percent of the population that identifies as Hispanic, Latino, or Spanish origin and the percent of the population that is Black or African American).

Parking and curb management (San Francisco Class II corridors only)

Google Street View was used to manually count the change in on-street parking before and after the installation of bike lanes. Counts were only registered on corridors where Class II facilities were installed after the year 2007. Google Street View imagery first became available in 2007; bike lanes that were installed before 2007 could not be considered using the Google Street View methodology. Only corridors with bike lanes were evaluated for on-street parking change because Class III facilities do not typically necessitate the removal of on-street parking and Class I facilities in San Francisco are largely located in parks where on-street parking was not located before the bike paths were installed.

Additionally, this category includes dummy variables that indicate the presence of passenger loading zones (white curb space) or commercial loading zones (yellow curb space) on corridors with bike infrastructure. This data was collected during the Google Street View parking counts, so it is only available for corridors with bike lanes installed after 2007. Curb management is an emerging planning issue of great interest to planners and businesses, especially given the growing role that transportation network companies (TNCs) like Uber and Lyft play in the transportation system. Commercial loading zones are also of interest, especially for businesses that do not have alley access for receiving deliveries. The introduction of this report summarizes numerous news articles where business owners cite loss of loading access as a chief concern related to bicycle infrastructure projects. Future research should account for all loading zones in San Francisco or the Bay Area to determine a more comprehensive assessment of the role that curb management has to play on business performance.

Interactions

The models also include two sets of interactions, one between roadway class and bike infrastructure and one between business type and bike infrastructure. Including interaction terms within the model seeks to identify and quantify any differing effects that bike infrastructure has based on the volume of the corridor and the business industry.

The interaction between bike infrastructure and corridor type seeks to understand if bike infrastructure has a different effect when installed on high volume primary or secondary roads as opposed to low volume tertiary or neighborhood roads. The interaction between bike infrastructure and business type has a similar aim: to identify whether certain industries benefit from bike infrastructure and others are negatively affected.

Sales change models

Average sales change

Table 5 summarizes the overall change in sales for businesses in San Francisco and Alameda Counties, as well as the change in sales for non-abutting businesses and businesses abutting Class II and Class III corridors. Sales declined across the board, likely due to on overall market shift away from storefront retail towards e-commerce and goods provided via the sharing economy. Sales were declining more swiftly in Alameda County across all subsets of the data except for businesses abutting Class II infrastructure. Businesses on Class II bike infrastructure saw the largest declines in both counties. The smallest decline was seen by businesses abutting Class III infrastructure in San Francisco and non-abutting businesses in Alameda County, those the margins were close between non-abutting and Class III facilities in both counties. These patterns could be due to an effect by bike infrastructure, or they could be due to other patterns, including the types of businesses located on corridors with bike infrastructure, the corridors where bike infrastructure is located, or the neighborhoods in which the businesses are located. The following models seek to control for other factors that could have an effect on how businesses fare in terms of sales to isolate the relationship between bike infrastructure and change in sales.

Table 5: Average change in sales (all years)

	San Francisco	Alameda County
Average sales change	-49,967	-53,223
Average sales change non-abutting businesses	-47,676	-53,519
Average sales change businesses abutting Class II	-75,342	-64,524
Average sales change businesses abutting Class III	-40,239	-54,596

San Francisco County

Change in sales volume is perhaps the most easily interpretable definition of business performance. An increase in sales volume suggests a business is doing well, while declining sales could indicate the business is headed for closure. Table 6 presents the results of a linear regression that models the change in sales before and after the installation of Class II facilities in San Francisco. The change in sales for abutting businesses is calculated as the average of sales across all years 1990-2014 before the installation of the bicycle infrastructure subtracted from the average of sales across all years after the installation of infrastructure. The installation year itself is excluded from analysis. Non-abutting businesses were assigned the same installation date as the nearest corridor with bicycle infrastructure using a nearest neighbor spatial join in ArcGIS. For simplicity, the nearest corridor was calculated using orthogonal, or as the crow flies distance, instead of network distance. The average change was then calculated in the same manner as for abutting businesses.

Table 6: Change in sales for Class II facilities in San Francisco

	Coefficient	Sig.	Standard Error	T Statistic
Roadway characteristics				
Class II	2,642		18,200.00	0.15
Primary road	-18,780	*	9,756.95	-1.93
Secondary road	-31,630	***	10,600.00	-2.98
Tertiary road	-165		8,056.16	-0.02
Change in on street parking	194		2,305.05	0.08
Commercial loading zone	53,200		60,600.00	0.88
Passenger loading zone	4,686		28,100.00	0.17
Business characteristics				
Years Old	-2,094	***	202.51	-10.34
Chain	-18,280		12,200.00	-1.50

Bar	57,940	***	17,600.00	3.28
Restaurant	15,720		10,600.00	1.48
Grocery	1,400		13,800.00	0.10
Personal goods	287		11,000.00	0.03
Home goods	-10,250		14,900.00	-0.69
Services	40,050	***	10,200.00	3.92
Entertainment	39,860		68,600.00	0.58
Financial services	42,630	**	19,400.00	2.20
Health services	-12,660		9,989.91	-1.27
Automobile-oriented	-26,520		17,200.00	-1.54
Bike infrastructure and road class interactions				
Primary roads x Class II	10,470		21,100.00	0.50
Secondary roads x Class II	-17,200		24,600.00	-0.70
Tertiary roads x Class II	-19,690		16,500.00	-1.20
Neighborhood roads x Class II	29,060	**	14,300.00	2.04
Business and bike interactions				
Bike x bar	-16,740		60,400.00	-0.28
Bike x restaurant	-25,580		31,500.00	-0.81
Bike x grocery	-10,440		34,900.00	-0.30
Bike x personal goods	-956		35,400.00	-0.03
Bike x home goods	-94,250	**	43,000.00	-2.19
Bike x services	-17,080		30,400.00	-0.56
Bike x entertainment	0		0.00	1.64
Bike x financial services	0		0.00	-1.35
Bike x health services	-14,500		29,200.00	-0.50
Bike x automobile-oriented	-162,800	***	41,500.00	-3.92
Neighborhood characteristics				
Establishment density (businesses/ per acre)	-414		451.26	-0.92
Urban	16,040		10,200.00	1.58
Suburban	0		0.00	1.29
Median household income ($1,000)	-212		158.19	-1.34
Percent housing renter occupied	40		230.24	0.17
Percent Latino	199		263.64	0.76
Percent Black	-279		496.89	-0.56
Installation year				
1996	-5,685		21,600.00	-0.26
1997	2,892		15,000.00	0.19

1998	-4,023		48,700.00	-0.08
1999	-29,730		23,700.00	-1.26
2000	4,936		21,200.00	0.23
2002	2,532		21,900.00	0.12
2003	-13,240		15,000.00	-0.89
2004	35,090		24,200.00	1.45
2005	-2,581		9,595.55	-0.27
2006	-14,390		11,500.00	-1.25
2008	6,881		38,800.00	0.18
2009	22,660	*	13,100.00	1.72
2011	21,860	**	10,300.00	2.11
2012	30,580	**	12,500.00	2.46
2013	1,648		20,400.00	0.08
Constant	-11,230		30,700.00	-0.37

Sig. ** = p <0.10, ** = p < 0.05, *** = p < 0.00*

N = 1,966, Adjusted R-squared = 0.11

Abutting = 243 Non-abutting = 1,723

Location on Class II bike infrastructure was not associated with a significant change in sales before and after installation of bike infrastructure. There was also no significant relationship between the change in on-street parking and the change in sales volume over time. This indicates that removing parking may not be as damaging as business owners claim. The curb management variables representing the availability of a commercial or passenger loading zone were also not significant.

The model identified a number of other predictors that did have a significant effect on the change in sales volume. The only corridor variables to have a significant association were dummy variables indicating the business was located on a primary or secondary road. These roads, which tend to provide state and regional connectivity, were both associated with a negative change in sales over time when compared to the reference category, neighborhood roads. In this model, neighborhood roads are low volume roads providing local connectivity. This could indicate that larger automobile traffic counts do not necessarily translate to larger numbers of customers or higher sales. Instead, it appears that calmer local streets see higher sales.

Characteristics of the individual business proved to be some of the strongest predictors of business performance. Industry was a reliably predictive variable, though not across the board, and business age was also significant. Business age was associated with a decline in sales, indicating that older businesses had slightly lower sales on average than their newer counterparts, all else equal. Bars, service providing businesses, and financial businesses all saw increases in sales, while automobile-oriented businesses, businesses providing health services, and businesses selling goods for the home saw declines in sales.

Neighborhood characteristics were generally insignificant, indicating that the surrounding population is a poor predictor of how a business will fare. Finally, to control for temporal fluctuations in the market, dummy variables indicating the year that served as the midpoint between the average sales before and average sales after was also included within the model. These variables do not have a strong policy connection, but rather serve to control for market fluctuations.

Interactions between the presence of Class II facilities and road classification were generally not significant, except for the interaction term between Class II facilities and neighborhood roads. This interaction was associated with an increase in sales volume of around $20,000 dollars, indicating that businesses on low volume neighborhood roads with Class II facilities saw their sales rise on average $20,000 before and after the installation of bike infrastructure. Businesses on lower volume streets may benefit more from bike infrastructure because these streets are already the most bikeable, and the addition of bike infrastructure may enable even more shoppers to access the corridor who might have not chosen to bike otherwise.

When Class II facilities were interacted with business industry, two significant associations emerged. Automobile-oriented businesses like gas stations and car dealerships and businesses selling goods for the home (such as furniture or carpet stores) both saw significant declines in sales. These industries did not see general significant sectoral decline, which would have been indicated with a negative coefficient on the general industry variable, which suggests that Class II infrastructure has a differing negative effect on businesses in these industries. Home goods stores tend to sell goods that may be too large to reasonably transport on a bicycle, which could be at the root of this negative association. Automobile-oriented businesses could see some customers deterred by the increased presence of cyclists on the corridor; they may see these cyclists as a complication that could be avoided by patronizing a different business on a different corridor without infrastructure.

Table 7 summarizes the model that examines the change in sales for businesses abutting Class III infrastructure against non-abutting businesses. Location on Class III infrastructure was not associated with significant change in sales over time. Location on primary and secondary roads demonstrated a negative association with change in sales of about $19,000 and $32,000, respectively, indicating that location on a higher automobile traffic corridor was not necessarily associated with higher sales, as was seen in the model of Class II corridors.

Business characteristic variables generally showed similar patterns to those seen in Table 6, with business age and chains exhibiting negative associations with change in sales. Services, financial services, bars, and restaurants saw increases in sales change, perhaps hinting at a market shift away from traditional retail outlets for purchasing goods and towards businesses offering services. Of the neighborhood variables, the only significant association was a positive change in sales for businesses in denser urban parts of San Francisco (greater than 15 people per acre).

The interactions between bike infrastructure and road classification were not significant, and those between Class III facilities and business type were also not significant. The lack of significant associations between interactions could be due to the relatively low intensity change to dynamics of the street presented by Class III infrastructure projects. These facilities may not have a very strong effect on way or the other on business dynamics on the corridor.

Table 7: Change in sales for Class III facilities in San Francisco

	Coefficient	Sig.	Standard Error	T Statistic
Roadway characteristics				
Class III	52,060		53,000.00	0.98
Primary road	-18,500	**	9,179.56	-2.02
Secondary road	-32,460	***	9,982.64	-3.25
Tertiary road	-4,901		7,549.93	-0.65
Business characteristics				
Years Old	-1,896	***	176.95	-10.72
Chain	-32,870	***	11,400.00	-2.89
Bar	57,930	***	16,600.00	3.48
Restaurant	16,250		10,000.00	1.62
Grocery	560		13,000.00	0.04
Personal goods	2,031		10,300.00	0.20
Home goods	-10,260		14,000.00	-0.73
Services	39,790	***	9,636.91	4.13
Entertainment	42,630		64,600.00	0.66
Financial services	40,200	**	18,300.00	2.20
Health services	-13,020		9,406.37	-1.38
Automobile-oriented	-26,030		16,100.00	-1.61
Bike infrastructure and road class interactions				
Primary roads x Class II	-17,580		57,500.00	-0.31
Secondary roads x Class II	-9,272		54,300.00	-0.17
Tertiary roads x Class II	-63,840		52,200.00	-1.22
Neighborhood roads x Class II	-40,480		50,900.00	-0.80
Bike infrastructure and business interactions				
Bike x bar	-12,190		37,100.00	-0.33

Bike x restaurant	-5,681		24,600.00	-0.23
Bike x grocery	-21,840		29,000.00	-0.75
Bike x personal goods	-3,235		27,400.00	-0.12
Bike x home goods	28,120		31,200.00	0.90
Bike x services	-7,993		24,300.00	-0.33
Bike x entertainment	17,500		25,100.00	0.70
Bike x financial services	-18,020		37,200.00	-0.49
Bike x health services	-103,200		131,000.00	-0.79
Bike x automobile-oriented	40,990		40,200.00	1.02
Neighborhood characteristics				
Establishment density (businesses/ per acre)	-251		399.27	-0.63
Urban	17,360	*	9,025.08	1.92
Suburban	0		0.00	0.21
Median household income ($1,000)	-54		143.32	-0.37
Percent housing renter occupied	156		205.60	0.76
Percent Latino	170		246.48	0.69
Percent Black	-213		422.68	-0.50
Installation year				
1996	-7,849		21,600.00	-0.36
1997	13,190		14,800.00	0.89
1998	-4,168		45,900.00	-0.09
1999	14,850		27,000.00	0.55
2000	-19,140		23,400.00	-0.82
2002	11,120		25,500.00	0.44
2003	-18,820		16,300.00	-1.16
2004	22,620		21,300.00	1.06
2005	-13,030		8,396.35	-1.55
2006	-8,434		9,746.94	-0.87
2008	7,199		36,500.00	0.20
2009	15,500		11,700.00	1.32
2011	17,290	*	9,904.18	1.75
2012	30,790	***	10,700.00	2.89
2013	1,823		20,000.00	0.09
Constant	-35,640		27,800.00	-1.28

Sig. ** = p <0.10, ** = p < 0.05, *** = p < 0.00*

N = 1,985, Adjusted R-squared = 0.1

Abutting = 172 Non-abutting = 1,812

Overall, the sales change models for San Francisco suggest that location on bicycle infrastructure has a neutral effect on change in sales overall, with a few cases where bike infrastructure may benefit businesses and a few cases where it may have a detrimental effect. Overall, location on Class II infrastructure did not result in a significant change in sales one way or the other. However, when looking only at businesses on neighborhood roads with bike infrastructure versus all other businesses, these businesses saw an increase in sales of around $20,000. Automobile-oriented businesses and businesses selling home goods that were located on corridors with Class II facilities did see a decline in sales of around $100,000 per year each. Location on Class III facilities was not associated with a statistically significant change in sales. This generally disproves business owners' claims that bike infrastructure is bad for business, though it generally does not confirm cyclist advocates' claims that bike infrastructure is good for business. Instead, it appears that for businesses in San Francisco, there are a multitude of other factors that do have a determining effect on the change in sales a business sees over time.

Alameda County

The following section presents models for businesses in Alameda County, broken down by infrastructure type. The models include the same set of independent variables that were used in the estimation above, only without the parking change variable for the Class II model as this data was not collected for Alameda County.

The model for Class II facilities in Alameda County can be found in Table 8. This model shows no significant association between location on a Class II corridor and change in sales. The model exhibited similar relationships to those discussed above in terms of business and neighborhood characteristic effects. Roadway classification was significant at the 90% confidence level for primary roads., with a decline in sales of around $7,000..

The model exhibited similar relationships between business characteristics and business performance, with business age and being a chain associated with negative change in sales. Automobile-oriented businesses and stores for home goods saw declines in sales, as did grocery stores, unlike in the San Francisco models. Bars, restaurants, services providing businesses, and financial services saw increases in sales. Dummy variables indicating an urban or suburban environment were associated with increases in sales, indicating that increased population density was associated with significantly higher sales.

The interaction between Class II facilities and tertiary roads was significant, with an associated increase in sales of $20,000. Interestingly, in San Francisco, businesses on lowest volume streets saw the significant increase. In Alameda County, an increase of a similar magnitude was seen for businesses on slightly higher volume tertiary roads. Across both models, infrastructure seemed to have a positive effect when located on lower volume roads. The interaction between Class II facilities and automobile-oriented businesses also showed a significant negative association.

Grocery stores on Class II facilities also saw a significant decline. Perhaps counterintuitively, restaurants on Class II facilities saw a significant decline in sales. However, an important note is that this model only includes businesses that were active before and after the installation of bike infrastructure. New restaurants that opened after the installation of bike infrastructure could be performing better, but this model does not speak to outcomes for new businesses.

Table 8: Change in sales for Class II facilities in Alameda County

	Coefficient	Sig.	Standard Error	T Statistic
Roadway characteristics				
Class II	9,610		8,134.17	1.18
Primary road	-7,026	*	4,113.33	-1.71
Secondary road	-1,170		3,978.49	-0.29
Tertiary road	2,837		4,269.66	0.66
Business characteristics				
Years Old	-1,780	***	96.33	-18.48
Chain	-59,080	***	5,782.77	-10.22
Bar	32,890	***	12,300.0,0	2.68
Restaurant	11,160	**	5,365.50	2.08
Grocery	-45,790	***	6,488.51	-7.06
Personal goods	6,038		5,526.21	1.09
Home goods	-11,490	*	6,318.97	-1.82
Services	32,030	***	4,775.27	6.71
Entertainment	41,020		41,100.00	1.00
Financial services	34,770	***	7,419.03	4.69
Health services	-7,829		4,815.75	-1.63
Automobile-oriented	-13,860	**	5,455.79	-2.54
Bike infrastructure and road class interactions				
Primary roads x Class II	-7,925		8,024.61	-0.99
Secondary roads x Class II	5,728		6,733.27	0.85
Tertiary roads x Class II	20,800	***	7,943.36	2.62
Neighborhood roads x Class II	-8,997		5,467.44	-1.65
Bike infrastructure and business interactions				
Bike x bar	18,760		38,200.00	0.49
Bike x restaurant	-30,490	**	13,500.00	-2.25
Bike x grocery	-41,060	**	17,400.00	-2.36
Bike x personal goods	4,033		15,800.00	0.26

Bike x home goods	-6,350		17,900.00	-0.35
Bike x services	-10,780		13,000.00	-0.83
Bike x entertainment	8,461		92,600.00	0.09
Bike x financial services	-17,270		21,200.00	-0.82
Bike x health services	-18,550		12,400.00	-1.50
Bike x automobile-oriented	-34,730	**	15,600.00	-2.22
Neighborhood characteristics				
Establishment density (businesses/ per acre)	-45		190.74	-0.24
Urban	8,431	*	4,348.76	1.94
Suburban	7,990	*	4,339.54	1.84
Median household income ($1,000)	-34		84.01	-0.41
Percent housing renter occupied	-41		99.85	-0.41
Percent Latino	140		104.95	1.33
Percent Black	28		101.14	0.28
Installation year				
1997	35,660		22,600.00	1.58
1998	-5,739		20,200.00	-0.28
1999	-9,861		10,500.00	-0.94
2000	594		14,700.00	0.04
2001	-19,810	**	9,537.81	-2.08
2003	-45,710	***	9,165.18	-4.99
2004	-23,570	**	10,900.00	-2.17
2005	-35,330	***	10,300.00	-3.43
2006	-16,530		11,700.00	-1.41
2007	-30,280	***	9,356.32	-3.24
2008	-25,780	***	9,784.41	-2.64
2009	-7,841		11,800.00	-0.66
2010	-7,994		12,000.00	-0.67
2011	-8,569		12,100.00	-0.71
2012	-12,940		9,492.36	-1.36
Constant	581		15,600.00	0.04

Sig. ** = p <0.10, ** = p < 0.05, *** = p < 0.00*

N = 8,815, Adjusted R-squared = 0.09

Abutting = 1,310 Non-abutting = 7,505

The final sales change model is found in Table 9, summarizing the model estimated for the change in sales for businesses abutting Class III and all non-abutting businesses. The model found a negative association between Class III bicycle infrastructure and change in sales in Alameda County. However, the coefficients associated with each of the four interactions between road classification and Class III facilities are all significant, positive, and generally larger than the negative association between Class III infrastructure and change in sales. All businesses are located on one of the four corridor types. As such, the effect of Class III infrastructure on sales could be interpreted as the sum of the Class III coefficient plus the coefficient for the interaction between bike infrastructure and the roadway classification. So businesses on primary roads with Class III facilities exhibited an increase in sales of $23,600. Businesses on tertiary and neighborhood roads with Class III facilities also saw an increase in sales of $16,400 and $5,700 respectively. Businesses on secondary roads with Class III facilities saw a decline in sales of nearly $15,000. While the coefficient for Class III facilities on its own looks large, when accounting for the interaction terms, it is actually generally not effectual.

Like was seen with the other sales change models, business age and chains were associated with significant declines in sales. Bars, services, and financial services were associated with significant increases over time. Grocery stores, stores selling home goods, health service providers, and automobile-oriented businesses was significant declines. Neighborhood variables were not significant, save for a dummy variable indicating a higher population density urban environment.

Interactions between industry and Class III bike infrastructure were generally insignificant. Financial service providing businesses on Class III facilities were associated with a decline in sales, despite a general positive trend for businesses in the financial services industry. Considering the general trends and the interaction between bike infrastructure and industry, financial service providing businesses on Class III facilities saw a decline in sales of about $30,000.

Table 9: Change in sales for Class III facilities in Alameda County

	Coefficient	Sig.	Standard Error	T Statistic
Roadway characteristics				
Class III	-561,900	***	115,000.00	-4.88
Primary road	-6,834	*	3,751.69	-1.82
Secondary road	1,088		3,532.44	0.31
Tertiary road	6,582	*	3,848.75	1.71
Business characteristics				
Years Old	-1,816	***	92.84	-19.56
Chain	-61,630	***	5,506.37	-11.19
Bar	34,030	***	11,600.00	2.94
Restaurant	5,672		4,868.68	1.17
Grocery	-51,960	***	5,982.52	-8.69

Personal goods	6,347		5,148.87	1.23
Home goods	-12,190	**	5,880.44	-2.07
Services	30,590	***	4,410.72	6.94
Entertainment	41,220		36,600.00	1.13
Financial services	33,000	***	6,905.53	4.78
Health services	-10,370	**	4,395.80	-2.36
Automobile-oriented	-17,660	***	5,076.47	-3.48
Bike infrastructure and road class interactions				
Primary roads x Class III	585,500	***	117,000.00	5.02
Secondary roads x Class III	547,000	***	117,000.00	4.69
Tertiary roads x Class III	578,300	***	116,000.00	4.97
Neighborhood roads x Class III	567,600	***	116,000.00	4.89
Bike infrastructure and business interactions				
Bike x bar	-29,280		50,200.00	-0.58
Bike x restaurant	-23,930		19,800.00	-1.21
Bike x grocery	40,960		26,900.00	1.52
Bike x personal goods	-31,160		22,300.00	-1.40
Bike x home goods	-3,498		27,000.00	-0.13
Bike x services	-15,080		19,900.00	-0.76
Bike x entertainment	-8,627		16,700.00	-0.52
Bike x financial services	-64,690	**	26,500.00	-2.44
Bike x automobile-oriented	26,540		23,000.00	1.16
Neighborhood characteristics				
Establishment density (businesses/ per acre)	24		180.65	0.13
Urban	7,194	*	4,155.62	1.73
Suburban	5,762		4,156.65	1.39
Median household income ($1,000)	-39		81.84	-0.48
Percent housing renter occupied	-71		96.09	-0.74
Percent Latino	134		94.85	1.42
Percent Black	93		93.71	1.00
Installation year				
2001	-17,870	***	5,437.38	-3.29
2003	-42,030	***	4,808.95	-8.74
2004	-20,250	***	7,652.33	-2.65
2005	-31,420	***	6,502.60	-4.83
2006	-15,290	*	8,783.90	-1.74
2007	-26,980	***	5,074.68	-5.32

2008	-23,300	***	5,734.33	-4.06
2009	-8,979		8,551.36	-1.05
2010	-6,913		9,000.29	-0.77
2011	-4,305		9,006.22	-0.48
2012	-9,069	*	5,085.82	-1.78
Constant	573		13,700.00	0.04

Sig. ** = p <0.10, ** = p < 0.05, *** = p < 0.00*

N = 9,377, Adjusted R-squared = 0.1

Abutting = 562 Non-abutting = 8,815

To summarize, in Alameda County, bike infrastructure generally did not have a significant effect, though there were a few exceptions. The models suggest that Class II infrastructure has no significant effect on sales. Class III infrastructure was associated with a decline in sales, though this effect generally flipped to be an increase in sales for businesses on primary, tertiary, and neighborhood roads. Class III infrastructure on secondary roads did have an overall negative effect on sales.

In Alameda County, as in San Francisco, business characteristics were overall the most reliable predictors of sales. Neighborhood characteristics were likewise poor predictors. Corridor characteristics were somewhat predictive, with primary roads associated with a decline in sales for Class II and III models for Alameda County.

Corridor characteristics were not reliably predictive across models, nor were neighborhood characteristics. Population density was occasionally significant, with higher population densities associated with positive changes in sales.

The models suggest that business characteristics overwhelmingly predict business performance, and this is something that planners cannot control. While bicycle infrastructure generally does not have a blanket positive effect on sales as cyclist advocates may like to say, it equally does not have an overall negative effect on businesses either. Instead, there are other factors that have a much larger say over how a business fares.

Turnover models

Business turnover is another axis along which business performance can be defined. Understanding whether bicycle infrastructure affects the likelihood that a business will close is relevant to business owners and planners alike as they try to understand the relationship between bicycle infrastructure and business performance.

Abutting businesses were coded as having turned over if their last year in the NETS dataset was within three years of the date of installation for the bicycle infrastructure project. Businesses that closed more than three years after the infrastructure had been installed, or that were marked as open in 2014, were coded as having remained open. Non-abutting businesses were joined to the nearest corridor with bicycle infrastructure, and turnover was calculated in a similar way to compare similarly across abutting and non-abutting businesses.

Abutting businesses that closed before the infrastructure was installed were omitted from analysis. Moves out from the corridor are another form of business turnover, though they represent a small fraction of all businesses in the NETS dataset. Businesses that moved were excluded from analysis, though further research could incorporate a multinomial logistic regression to estimate the decision to move, close, or remain open.

A binary logistic regression on the outcome of 1 equal to a business closing and 0 equal to a business remaining open was conducted to identify statistically significant predictors of business closure. The results are presented in odds-ratio format for ease of interpretation. Odds ratio coefficients that are greater than one indicate an increase in the likelihood that the business closes. Odds ratio coefficients that are less than one indicate a decrease in the likelihood that a business closes. Like the models of sales change, models were estimated for each infrastructure type within each county to account for heterogeneous relationships that may exist between different types of bicycle infrastructure.

San Francisco County

As with the sales change models, the turnover models include characteristics about the business, the neighborhood, and the corridor, including the change in number of on-street parking spaces for Class II facilities. The models also include dummy variables for the installation year to control for temporal patterns.

Abutting a Class II facility did not have a significant relationship with the likelihood of a business in San Francisco turning over. Similarly, the presence of a passenger loading zone or the change in the number of on-street parking spaces also did not exhibit a statistically significant impact. Table 10 summarizes the full model output. Businesses on high volume primary roads were more likely to turn over, though this was the only corridor-specific variable that demonstrated a statistically significant relationship. Older businesses and larger businesses were less likely to turn over, as would be expected. Similarly, grocery stores and businesses providing health services were significantly less likely to turn over. Establishment density was associated with a reduction in the likelihood of turning over, though no other neighborhood variables were statistically significant.

Table 10: Likelihood of turnover for Class II facilities in San Francisco

	Odds Ratio	Sig.	Z Statistic
Roadway characteristics			

Class II	0.77		-1.16
Primary road	1.42	*	1.93
Secondary road	1.00		0.01
Tertiary road	0.90		-0.65
Change in on street parking	1.43		1.34
Passenger loading zone	0.83		-0.31
Commercial loading zone	0.00		-0.01
Business characteristics			
Number of employees (last year)	0.87	***	-3.69
Sales ($1,000, last year)	1.00	***	5.55
Years Old	0.98	***	-4.14
Chain	0.84		-0.58
Bar	1.00		0.00
Restaurant	0.80		-0.87
Grocery	0.29	***	-3.83
Personal goods	0.79		-1.21
Home goods	0.93		-0.29
Services	0.94		-0.27
Entertainment	0.00		0.00
Financial services	0.83		-0.48
Health services	0.41	***	-4.87
Automobile-oriented	0.65		-1.36
Neighborhood characteristics			
Establishment density (businesses/ per acre)	0.97	***	-3.41
Urban	1.05		0.25
Median household income ($1,000)	1.00	***	-2.58
Percent Latino	1.00		-0.49
Percent Black	0.99		-1.13
Installation Year			
1996	0.19	***	-3.75
1997	0.33	***	-4.17
1998	0.22	**	-2.43

1999	0.12	***	-3.52
2000	0.34	***	-2.78
2001	0		0.00
2002	0.16	***	-3.83
2003	0.17	***	-4.65
2004	0.28	**	-1.99
2005	0.25	***	-6.46
2006	0.52	***	-2.75
2008	0.86		-0.18
2009	0.72		-1.18
2011	0.68	*	-1.74
2012	0.22	***	-3.82
2013	0		0.00

Sig. ** = p <0.10, ** = p < 0.05, *** = p < 0.00*
N = 9,377, Adjusted R-squared = 0.09

Abutting a Class III facility also did not register a statistical association with an increased likelihood of closure. Table 11 shows the results of the model estimation for Class III facilities in San Francisco. Similar to the previous model, location on primary roads was associated with an increase in the likelihood of a business turning over. The other trends related to business characteristics also held true, with older and larger businesses seeing a reduced likelihood of turning over. This model differs from the model of Class II facilities in that it registers a strong association between the share of black residents and the likelihood that a business turns over.

Table 11: Likelihood of turnover for Class III facilities in San Francisco

	Odds Ratio	Sig.	Z Statistic
Roadway characteristics			
Class III	0.89		-0.81
Primary road	1.33	**	1.79
Secondary road	0.97		-0.17
Tertiary road	0.8		-1.64
Business characteristics			
Number of employees (last year)	0.87	***	-4.09
Sales ($1,000, last year)	1.00	***	4.68
Years Old	0.98	***	-4.13

Chain	1.00		-0.02
Bar	1.09		0.28
Restaurant	1.01		0.05
Grocery	0.51	***	-2.68
Personal goods	1.29		1.42
Home goods	1.37		1.50
Services	1.03		0.11
Entertainment	2.61		0.83
Financial services	0.80		-0.62
Health services	0.63	***	-2.76
Automobile-oriented	1.14		0.52
Neighborhood characteristics			
Establishment density (businesses/ per acre)	0.99	**	-1.79
Urban	1.06		0.31
Suburban	1.23		0.37
Median household income ($1,000)	1		0.47
Percent Latino	0.72		-0.54
Percent Black	8.82	***	2.65
Installation Year			
1996	0.10	***	-4.17
1997	0.13	***	-5.19
1998	0.09	***	-3.49
1999	0.06	***	-4.51
2000	0.06	***	-5.12
2001	0.00		0.00
2002	0.04	***	-4.91
2003	0.04	***	-5.41
2004	0.06	***	-4.88
2005	0.10	***	-6.52
2006	0.28	***	-3.47
2008	0.35		-1.23
2009	0.23	***	-3.40
2010	0.37	***	-2.99
2011	0.27	***	-3.39
2012	0.10	***	-5.20

2013	0.00	0.00

Sig. * = p <0.10, ** = p < 0.05, *** = p < 0.00
N = 3,806, Pseudo R-squared = 0.09

Both the models for Class II and Class III infrastructure in San Francisco indicate no significant association between location on bicycle infrastructure and the likelihood of a business turning over. While other characteristics of the business, the neighborhood, and the corridor seem to have an effect, it seems that bicycle infrastructure may not play such a deterministic role in whether or not a business closes.

Alameda County

The following set of models describes the relationship between abutting bicycle infrastructure and the likelihood of a business closing for Alameda County. The independent variables are the same as the San Francisco turnover models, save for the exclusion of on-street parking variables for the model estimation for businesses abutting Class II infrastructure.

Abutting a Class II facility decreases the likelihood of a business closing at a weakly significant (90% confidence) level (Table 12). Businesses are about 22% less likely to close if they are located on Class II infrastructure, all else equal. Unlike in San Francisco, location on a primary road was associated with a decrease in the likelihood of a business closing, while other road types showed no significant association. This inversion is trends between primary roads in San Francisco and Alameda County could be influenced by the relative auto-orientedness of Alameda County, which encompasses a much wider array of densities than San Francisco. Direct access to high volume automobile corridors may actually be a positive for businesses in Alameda County, while businesses in San Francisco may have suffered due to the availability and attractiveness of other modes.

The model for Class II infrastructure otherwise presented a similar picture to what has been seen in previous models in this section. Business age and number of employees were associated with a decrease in the likelihood of a business closing. Grocery stores, personal goods stores, and providers of health services were less likely to close, while service industry businesses were more likely to close.

Table 12: Likelihood of turnover for Class II facilities in Alameda County

	Odds Ratio	Sig.	Z Statistic
Roadway characteristics			
Class II	0.78	*	-1.80
Primary road	0.76	***	-3.31
Secondary road	0.94		-0.85
Tertiary road	0.92		-1.04

Business characteristics			
Number of employees (last year)	0.87	***	-9.09
Sales ($1,000, last year)	1.00	***	14.79
Years Old	0.93	***	-20.28
Chain	1.17		1.25
Bar	1.24		0.97
Restaurant	0.97		-0.24
Grocery	0.69	***	-3.13
Personal goods	0.89	*	-1.15
Home goods	0.98		-0.23
Services	1.27	**	2.30
Entertainment	1.23		0.25
Financial services	0.95		-0.34
Health services	0.55	***	-6.69
Automobile-oriented	0.91		-0.91
Neighborhood characteristics			
Establishment density (businesses/ per acre)	1.00		0.26
Urban	1.10		1.16
Suburban	1.06		0.67
Median household income ($1,000)	1.00		-0.07
Percent Latino	1.04		0.17
Percent Black	1.61	*	1.87
Installation year			
1997	0.21	***	-4.00
1998	0.21	***	-5.42
1999	0.22	***	-8.14
2000	0.16	***	-6.10
2001	0.2	***	-8.99
2003	0.21	***	-8.99
2004	0.22	***	-8.02
2005	0.27	***	-6.75
2006	0.61	***	-2.65
2007	0.59	***	-3.26

2008	0.82		-1.22
2009	0.53	***	-3.12
2010	0.78		-1.23
2011	0.46	***	-3.26
2012	0.28	***	-6.53
2013	0		-0.01

Sig. ** = p <0.10, ** = p < 0.05, *** = p < 0.00*

N = 14,504, Pseudo R-squared = 0.12

The final model, presented in Table 13, shows the factors influencing the likelihood of a business closing for businesses abutting Class III infrastructure in Alameda County. Location on a corridor with Class III infrastructure is associated with a decline in the likelihood of turnover (albeit at a 90% confidence level). Businesses on primary roads are similarly less likely to turn over, as was seen in the Class II model. Business characteristic patterns exhibited in the Class II model were replicated in the Class III model. Additionally, the share of black residents in the surrounding neighborhood was associated with a slight increase in the likelihood of a business closing.

Table 13: Likelihood of turnover for Class III facilities in Alameda County

	Odds Ratio	Sig.	Z Statistic
Roadway characteristics			
Class III	0.78	*	-1.80
Primary road	0.76	***	-3.31
Secondary road	0.94		-0.85
Tertiary road	0.92		-1.04
Business characteristics			
Number of employees (last year)	0.87	***	-9.09
Sales ($1,000, last year)	1.00	***	14.79
Years Old	0.93	***	-20.28
Chain	1.17		1.25
Bar	1.24		0.97
Restaurant	0.97		-0.24
Grocery	0.69	***	-3.13
Personal goods	0.89		-1.15
Home goods	0.98		-0.23
Services	1.27	**	2.30
Entertainment	1.23		0.25

Financial services	0.95		-0.34
Health services	0.55	***	-6.69
Automobile-oriented	0.91		-0.91
Neighborhood characteristics			
Establishment density (businesses/ per acre)	1.00		0.26
Urban	1.10		1.16
Suburban	1.06		0.67
Median household income ($1,000)	1.00		-0.07
Percent Latino	1.04		0.17
Percent Black	1.61	*	1.87
Installation year			
1997	0.21	***	-4.00
1998	0.21	***	-5.42
1999	0.22	***	-8.14
2000	0.16	***	-6.10
2001	0.2	***	-8.99
2003	0.21	***	-8.99
2004	0.22	***	-8.02
2005	0.27	***	-6.75
2006	0.61	***	-2.65
2007	0.59	***	-3.26
2008	0.82		-1.22
2009	0.53	***	-3.12
2010	0.78		-1.23
2011	0.46	***	-3.26
2012	0.28	***	-6.53
2013	0		-0.01

Sig. * = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.00$
N = 13,504, Pseudo R-squared = 0.12

The turnover models suggest that location on bike infrastructure has either no significant effect or a pro-business effect. This differs from the picture that emerged from the models of sales over time. This being said, characteristics related to the business itself were still reliably predictive factors, which means that infrastructure is not the only determinant of outcomes for businesses.

Summary

The models presented above seek to control for characteristics of the corridor, neighborhood, and business itself to illuminate the effect of bicycle infrastructure in isolation. All else equal, the relationship between location on bicycle infrastructure and change in sales is mixed, with bike infrastructure appearing to have a neutral effect on change in sales and a neutral or positive effect on likelihood of turnover.

In San Francisco and Alameda Counties, location on Class II facilities was not associated with a significant change in sales, except for on neighborhood roads, which saw an increase. Location on Class III facilities in San Francisco was not associated with a significant change in sales. In Alameda County, location on Class III infrastructure was associated with a generally positive change in sales, though in the case of facilities on secondary roads, there was a negative association.

The control variables also provided unique insights. Business characteristics, particularly industry, were reliably significant predictors. Across both counties, bars, services, and financial services all registered significant increases in sales. Meanwhile, businesses automobile-oriented businesses saw significant declines in sales. Older businesses generally saw decreases in sales, as did chains.

Neighborhood characteristics were generally not significant. Businesses in higher density urban environments tended to see increases in sales. In San Francisco, location on primary and secondary roads was associated with a decline in sales when compared against the reference category, neighborhood roads. Location on primary roads was found to have a weak negative association for businesses on Class II infrastructure in Alameda County, though no effect was found for the Class III model in Alameda County. This suggests that high automobile volumes do not necessarily translate to increased sales, especially in San Francisco. In San Francisco, the model for Class II facilities showed no significant association between parking removal and sales, indicating that parking removal may not be detrimental to business performance.

In terms of turnover, both classes of bike infrastructure in San Francisco showed no significant relationship with the likelihood of turnover. Change in on-street parking was also not significant in the Class II model for San Francisco. In Alameda County, businesses abutting Class II and Class III corridors saw a lower likelihood of turnover. The models suggest that bicycle infrastructure either has no effect or has a positive effect for pro-business outcomes by not affecting or reducing the likelihood of turnover.

In San Francisco, the business age and number of employees were associated with a decline in the likelihood of turnover, as were certain industries, including grocery stores and health care service providers. Additionally, establishment density tended to be associated with a reduced likelihood of turnover. In Alameda County, similar trends held true, with the likelihood of a business closing also decreasing as businesses grew in size and age. Additionally, location on a primary road reduced the likelihood of closure for businesses in Alameda County. Businesses that provided services were more likely to close in Alameda County, while grocery stores and healthcare providers were less likely. Similar to the sales change models, neighborhood characteristics were rarely predictive of the likelihood of a business turning over.

Interesting contrasts emerge when comparing the results of the sales change models and the turnover models. For example, while service industry businesses generally saw an increase in sales over time, they also saw an increase in the likelihood of turnover. Conversely, grocery stores saw significant decreases in sales, but a strong decrease in the likelihood of closing. The variable representing sales in the business's last year of operation was significant in all of the turnover models, though the magnitude of the effect was small, even when converted into thousand dollar increments.

In sum, the models suggest that bicycle infrastructure has a generally mixed effect on the change in sales over time on an individual business level, with the most positive effects occurring on neighborhood roads. The relationship between business turnover and bicycle infrastructure is either neutral in the case of San Francisco or pro-business in the case of Alameda County, with location on bicycle infrastructure of all types resulting in a reduced likelihood of turnover.

Intercept survey of shoppers

Introduction

This section presents findings from an intercept survey of shoppers conducted in San Francisco, Oakland, and Berkeley. The survey was conducted on two matched pair corridors, each consisting of one corridor with a Class II bike facility and one corridor with no bike infrastructure. The survey results provide some insight into how the presence of bicycle infrastructure affects consumers' decisions on how to arrive to a commercial corridor and the differences in purchasing behavior of users of different modes on corridors with and without bicycle infrastructure.

Methodology

Site selection process

The survey was conducted at four locations forming two matched pair sets. The first parameter of survey site selection was that one site should be in San Francisco and the second in Alameda County to complement analysis of secondary data and to provide a broader picture of the relationship between bicycle infrastructure and consumer behavior in the Bay Area. With this parameter in place, researchers then examined a number of potential survey corridors in San Francisco and Alameda Counties, evaluating potential sites based namely on the density of storefront establishments. Additionally, corridors with bicycle infrastructure that was installed after 2014 were also excluded so that intercept survey data could be contextualized by data from NETS. This excluded high density commercial corridors in the East Bay such as Telegraph Avenue in downtown Oakland or Piedmont Avenue in North Oakland. Ultimately, researchers selected Valencia Street in San Francisco's Mission District and Broadway in Northeast Oakland as the study corridors with bicycle infrastructure.

Researchers then used suitability analysis in ArcGIS to methodologically identify matched pairs for the two pre-defined corridors with bicycle lanes. The matched pair identification process was limited to the county within which the corridor with bike infrastructure fell. Corridors were characterized using demographic data about the residents in the surrounding area from the 2014 American Community Survey and data about establishment density and industry mix from NETS.

The corridor average and standard deviation was calculated for each criterion at the Census Block Group level. Census Block Groups in the study county were then weighted based on their distance from the corridor average. Block Groups received a weight of 3 for a criterion if the Block Group average was within one standard deviation from the corridor mean. Block Groups received 2 points for a criterion if they were between 1 and 2 standard deviations from the corridor mean, and 1 point if they were between 2 and 3 standard deviations. The weights for each criterion were summed together to produce a composite weight. Researchers then used these weights in conjunction with qualitative assessments of the various potential comparison corridors to select a fitting match.

Table 14 shows the criteria that were included in the matched pair identification process and the average and standard deviation for the corridors with bicycle infrastructure. Figures 7 and 8 show the suitability analysis for Valencia Street and Broadway, respectively.

Table 14: Matched pair selection criteria

	Valencia Street		Broadway	
	Mean	S.D.	Mean	S.D.
Commercial characteristics				
Establishment density (est/acre)	6.1	2.1	3.3	1.1
Percent storefront	19.5%	084	8.9%	.053
Percent eating/drinking establishments	8.3%	.049	3.7%	.025
Neighborhood characteristics				
Population density (persons/acre)	61.6	18.0	22.1	8.4
Median household income	80, 693	34,887	39,780	12,722
Auto commute mode share	25.1%	7.3	42.5%	10.2
Bike commute mode share	8.2%	4.6	10.5%	5.2

Figure 7 Suitability analysis for Valencia Street

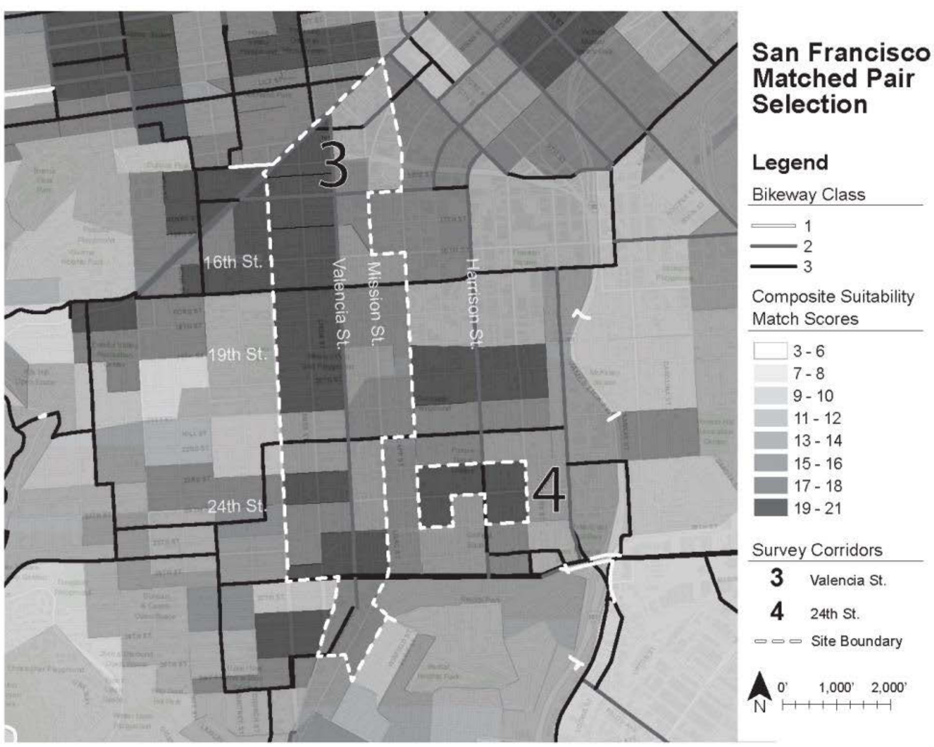
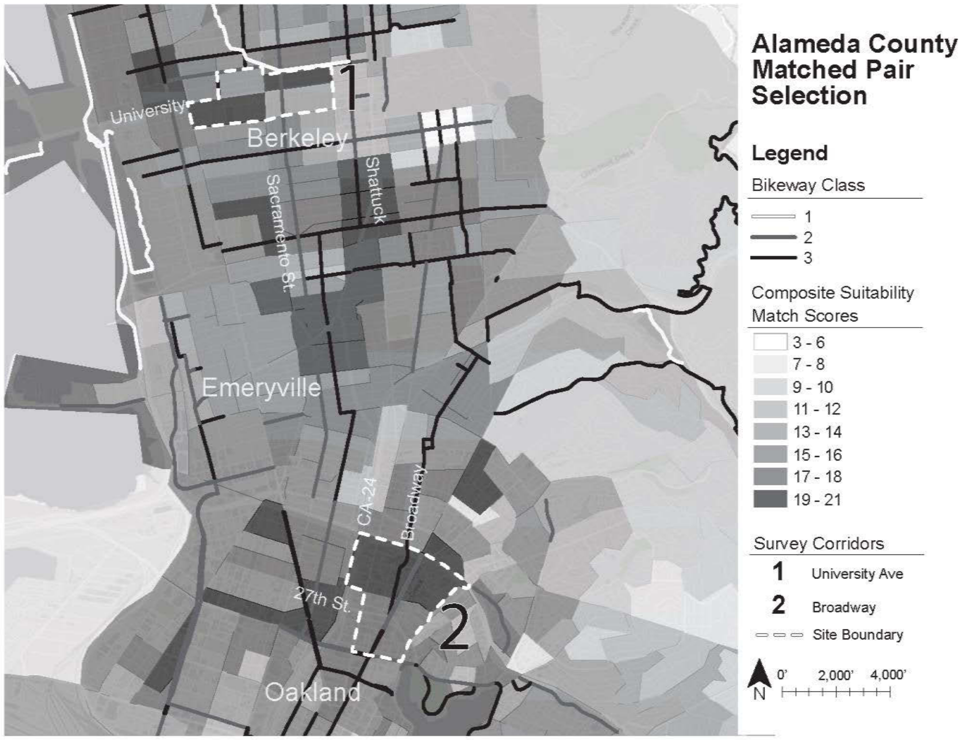


Figure 8: Suitability analysis for Broadway



Survey sites

Surveys were conducted at four locations throughout the Bay Area identified through the process described above. Figure 9 shows a map of the four survey sites. The following section briefly describes commercial conditions and transportation amenities accessible at the various sites.

Figure 9: Survey sites

Broadway

Broadway is located in northeast Oakland and serves as the dividing line between Pill Hill to the West and Westlake to the east. The corridor features two travel lanes in each direction separated by a grassy median. In 1998, Class II facilities were installed on both directions. The corridor also features metered on-street parking and is served by AC Transit's 51A bus route.

The corridor has a moderate commercial density when compared to Oakland as a whole, with some auto-oriented business uses as well as some new commercial construction near the Kaiser Permanente Hospital, including a Sprouts grocery store. The Broadway Avenue Class II facility becomes a Class III facility south of 25th Street, as it nears downtown.

Figure 10: Broadway

Image source:
http://www2.oaklandnet.com/government/o/PWA/o/EC/s/BicycleandPedestrianProgram/OAK043750

University Avenue

University Avenue connects UC Berkeley in the east to predominantly residential neighborhoods to the west. University Avenue has 2 lanes in each travel direction separated by a median and metered on-street parking. The corridor is served by AC Transit's 51B and 52, as well as weekday commute period service to San Francisco via the AC Transit TransBay FS route. There is no bicycle infrastructure on the corridor.

The corridor consists of medium density mixed residential and commercial development and some auto oriented uses at the western extent. Residential density decreases as distance from UC Berkeley increases. Two blocks to the north of University is the Hearst Avenue Class II facility, which provides a connection to the Ohlone Greenway Class I facility. The Virginia Ave bike boulevard is 5 blocks north of University and the Channing Way bike boulevard is 4 blocks south.

Figure 11: University Avenue

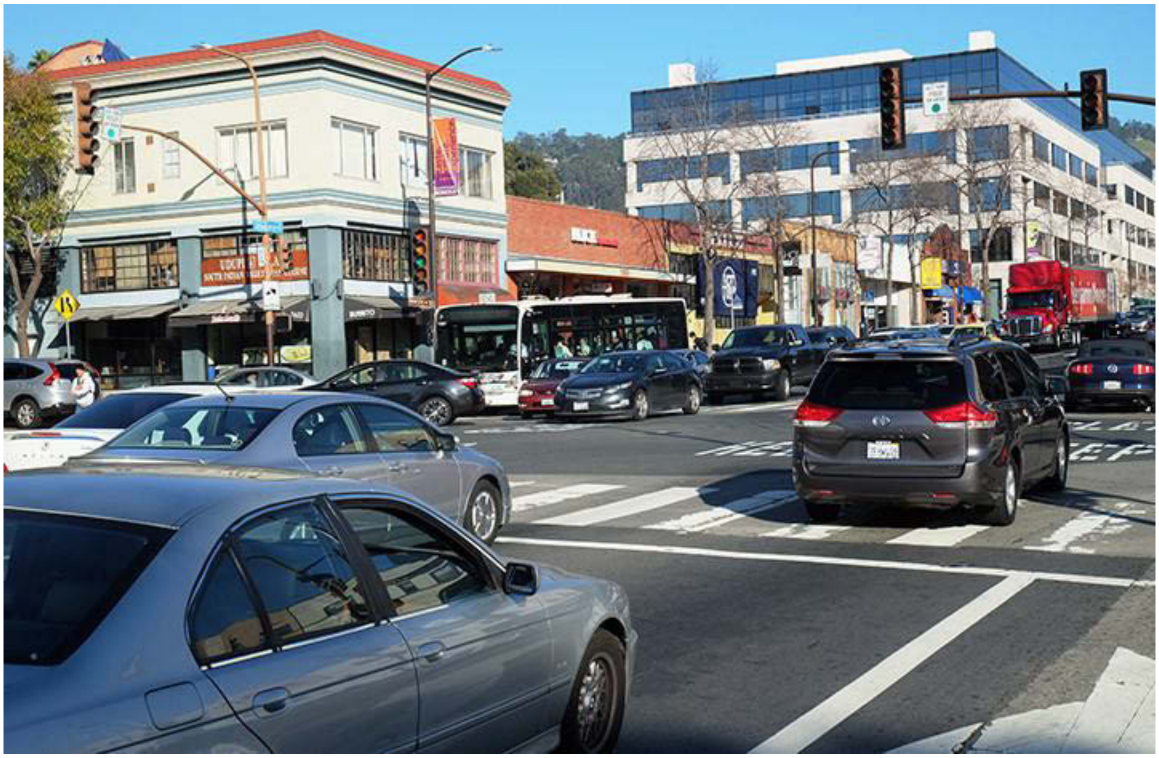


Image source: http://www.berkeleyside.com/2015/01/23/cyclist-hurt-5-elevator-rescues-in-berkeley-power-outage

Valencia Street

Valencia Street is a mixed use commercial and residential corridor in the Mission District of San Francisco. Considered one of the primary bicycle arteries in San Francisco, Valencia has featured bidirectional Class II facilities since 1998. Bike advocates regularly impress the importance of this corridor and have advocated for more intensive bike infrastructure interventions in recent months (Rudick 2017). The corridor features three travel lanes and metered on-street parking. There is no transit service directly on Valencia, but the corridor is one block from Mission Street, which has a high transit level of service and regional connections via BART.

Figure 12: Valencia Street

Image source: http://www.missionmission.org/tag/valencia-street/

24th Street

Valencia Street's matched pair is 24th Street. 24th Street is located in the southern portion of the Mission District neighborhood and intersects with Valencia in the west. The study area for 24th Street is the dense commercial portion to the east of Folsom Street, roughly a quarter mile from Valencia Street. 24th Street has one lane of traffic in each direction and metered parking on either side of the street. The corridor is served by Muni bus routes 48 and 67 and does not currently include any bicycle infrastructure. Development along 24th Street is medium density mixed commercial and residential uses.

Figure 13: 24th Street

Image source: https://www.sfgate.com/style/article/Welcome-to-Top-Shops-2015-6504145.php#next

Survey protocol

Surveys were conducted from November 2017 to February 2018. Surveyors were in the field during high yield periods – evening commute hours (4pm-6pm) during weekdays and weekend mornings (11am-1pm) and evenings (4pm-6pm). Surveyors were dispatched in teams of two to survey at the same site. The survey was conducted using the Qualtrics survey platform loaded onto iPads and was available in English and in Spanish.

In the interest of respondent time, questions generally pertained to the trip the person was currently undertaking. As such, people who were intercepted in the middle of a trip for a purpose other than shopping were excluded from the sample. Respondents coming from outside the Bay Area were also excluded in the survey data cleaning phase.

Questionnaire

The survey consisted of 20 questions regarding the respondent's current shopping trip, travel to the corridor, and general demographic information. Respondents answered questions on the mode they used to arrive to the corridor, the frequency with which they traveled to the corridor, and the frequency with which they traveled to the corridor by bike. In terms of questions about the shopping trip, respondents were asked the type of business they intended to patronize (eating and drinking place, service, entertainment, etc.) and were asked to project the amount of money they would spend on the corridor that day. Information about the respondent, including access to a car or bicycle, income, and home location were also collected.

Overall, the survey took an average of 5 minutes to complete and was completed by just over 300 respondents. This translated to roughly 250 valid responses after the data cleaning process was complete and non-shoppers and non-Bay Area residents had been excluded. Corridors with bike infrastructure were purposefully oversampled to bolster the share of cyclists in the sample.

Results

Table 15 summarizes the number of responses collected at each survey location. The corridors with bike infrastructure, Valencia and Broadway, were both oversampled in an attempt to over-represent cyclists in the sample and better understand their decisions. There were a relatively small number of responses for 24th Street. In total, there were 241 completed surveys, though not every respondent completed each question.

Table 15: Responses per survey location

	Responses
24th	19
Valencia	56
University	65
Broadway	110
Total	**250**

The survey seeks to tease out differences in shopper behavior at the different matched pair locations. To begin, respondents were asked what mode they used to arrive at the corridor that day. Respondents who used more than one mode, a transportation network company, or selected a fill in the blank "other" response were condensed into the category "other." Overall, they represent a small fraction of the sample as a whole. Table 16 presents the breakdown of various modes used by shoppers intercepted on the corridors. Of note is the relative prominence of users of "other" modes on University Avenue and Valencia Street. Many respondents combined transit with another mode (drive or walk) to arrive at University, while there was a higher presence of users of TNCs on Valencia.

Table 16: Mode share at survey locations

		Bike	Walk	Transit	Car	Other	**Total**
24th	N	0	13	2	3	1	**19**
	%	0%	68%	11%	16%	5%	**100%**
Valencia	N	2	25	3	18	8	**56**
	%	4%	45%	5%	32%	14%	**100%**
University	N	12	26	4	5	9	**56**
	%	21%	46%	7%	9%	16%	**100%**
Broadway	N	22	30	1	53	4	**110**
	%	20%	27%	1%	48%	4%	**100%**
Total		**36**	**94**	**10**	**79**	**22**	**241**

Roughly the same share of shoppers biked to Broadway and University Avenue at 20% and 21% respectively. No respondents on 24th Street had biked that day, while 2 respondents were intercepted after biking to Valencia, representing 4%. The small number of bike shoppers on Valencia and 24th Street when compared against Broadway and University could be due to the higher degree of walkability and transit access provided by both San Francisco survey sites. Located in a dense, transit-rich neighborhood like the Mission, biking may be a relatively poor match to respondents' transportation needs. Nearly half of respondents drove to Broadway, perhaps encouraged by the availability of a large parking structure near the survey site. Walking was a popular mode for all survey sites.

Research suggests that cyclists are more frequent shoppers (Clifton 2012). A question remains as to whether or not bike infrastructure encourages people to bike more frequently for various trip modes, including shopping. The survey asked respondents to report the frequency with which they traveled to the corridor by bike to make purchases. Table 17 summarizes the responses. Weekly biking was higher on the control streets, 24th Street and University, Avenue, than on Valencia and Broadway. This suggests that the presence of bike infrastructure may matter less than the demographic and behavioral characteristics of a street's shoppers. Shoppers in San Francisco were more likely to never bike than people intercepted in the East Bay. This could be due to the Mission District, where both San Francisco survey sites are located, being considered a regional destination attracting people from beyond a reasonable biking distance to shop. The East Bay survey sites indicated large shares of monthly riders.

Interestingly, a slightly higher share of respondents said they never bike on both corridors with bike infrastructure. However, a larger share of respondents said they travel to the corridor by bike monthly to shop. Overall, these findings could suggest preferences in different kinds of cyclists. Perhaps infrequent bike shoppers are generally less comfortable biking, and prefer the added feeling of safety and comfort that the bike lanes provide. Conversely, weekly bike shoppers who may feel more comfortable riding in mixed traffic may feel fine biking to corridors without infrastructure to shop.

Table 17: Frequency of bike trips by corridor

		Weekly	Monthly	Never	**Total**
24th	N	6	1	12	**19**
	%	31%	5%	63%	**99%**
Valencia	N	9	6	41	**56**
	%	16%	11%	73%	**100%**
University	N	13	10	32	**55**
	%	24%	58%	18%	**100%**
Broadway	N	11	26	73	**110**
	%	10%	66%	24%	**100%**
Total		**30**	**43**	**158**	**240**

Research has also shown that while cyclists have lower spending per trip, the increased frequency of shopping trips actually puts them among the biggest spenders of users of all modes (Clifton 2012, Bent and Singa 2009). As such, respondents were asked to estimate the amount of money they would spend during the day's shopping trip on the corridor. Table 18 summarizes the average expected expenditure by users of each mode. Cyclists on Broadway expected to spend twice what the cyclists on University expected, suggesting that more affluent cyclists may seek to patronize businesses on corridors with bike lanes. Such a comparison is not possible for 24th and Valencia since no bike shoppers were intercepted on 24th. That spending is expected to be relatively high on the streets with bike infrastructure may be due to a couple different factors. Bike infrastructure may attract more boutique, high-end businesses. Alternatively, or in addition, planners may choose to locate bike lanes in areas with more expensive businesses.

Also of note is the trends in spending for users of other modes. On Broadway, transit users expected to spend almost $100, an average larger than that for users of any other mode on the corridor by a factor of 3. On Valencia, users of cars and other modes had the highest estimated spending, while cyclists had the lowest. This pattern was reversed on 24th, with transit users having the highest expected spending, followed by pedestrians. 24th Street's easy accessibility to BART via the 24th Street station could have an effect here, bringing in consumers from around the region looking to spend more.

Table 18: Estimated expenditure by mode and survey location

	Bike	Walk	Transit	Car	Other	**Average**
24th	-	$36	$60	$28	$20	**$26**
Valencia	$20	$35	$53	$59	$67	**$49**
University	$15	$32	$15	$23	$78	**$27**
Broadway	$33	$23	$96	$38	$25	**$33**
Average	**$25**	**$30**	**$43**	**$41**	**$52**	**$35**

To test the relationship between frequency of trips and spending, we also calculated average expenditure at the survey sites broken down by frequency of biking. Table 19 shows averages for each survey site broken down by how frequently the respondent comes to the corridor by bike to make purchases. Shoppers who biked to University weekly to make purchases had the highest estimated expenditure by nearly a factor of two, with never bikers having the lowest. On Broadway, monthly bike shoppers had the highest expenditure, followed by weekly bikers and then never bikers. In San Francisco, shoppers who bike to Valencia weekly to make purchases estimated that they would spend $38, while shoppers who never biked had the highest estimated spending at $55. On 24th Street, shoppers who bike weekly estimated that they would spend $48, followed by monthly and then never bikers. On both corridors without bicycle infrastructure, regular bike shoppers had the highest estimated spending.

Generally, Table 19 suggests that more frequent bikers are more likely to spend more, though this pattern was not seen on 24th Street. Never bikers had the lowest average spending on three of the corridors, with the exception being Valencia where they reported the highest estimated spending.

Table 19: Estimated expenditure by frequency of biking

Survey site		Estimated expenditure
Broadway	Weekly	$33
	Monthly	$46
	Never	$27
University	Weekly	$40
	Monthly	$24
	Never	$22
Valencia	Weekly	$38
	Monthly	$30
	Never	$55
24th	Weekly	$48
	Monthly	$40
	Never	$31
Average		**$35**

Summary

The survey results explore the complex relationship between built environment and consumer behavior. By surveying on matched pair corridors with and without bike lanes, the data represent how behavior differs when consumers are presented with a commercial corridor that includes bike infrastructure. Shopper behavior is analyzed along four primary definitions: mode share, frequency of trips, estimated expenditure, and estimated expenditure by frequency of trips.

In terms of mode share, corridors with and without bike infrastructure featured similar shares of customers arriving by bike. Survey locations in the East Bay saw substantially higher shares of shoppers arriving by bike in the survey sample. However, in terms of frequency, corridors without bicycle infrastructure registered higher rates of respondents regularly shopping by bicycle. Counterintuitively, corridors with bike infrastructure saw larger shares of shoppers who never bike.

Shoppers were also asked to estimate the amount of money they would spend on the corridor that day. Findings were mixed, with more spent on corridors with bike infrastructure – but not necessarily by bikers. More frequent bikers tended to spend more.

In sum, the analysis examining differences in consumer behavior on corridors with and without bike infrastructure did find some interesting differences. However, the survey findings do not establish that bike infrastructure itself makes a difference;

rather, it seems like shoppers travelling via bike may be more affluent, with greater expenditures at local businesses.

The question of cyclist comfort was not answered using this survey, though the differences in usage patterns on corridors with and without bike infrastructure point to comfort having an influence with infrequent riders. Future survey research should seek to quantify comfort, though this is an admittedly personal definition that may be hard to measure objectively across respondents.

Discussion

This research was ultimately motivated by the perceived conflict between the business community and cycling advocates. Business owners have been some of the most vocal opponents to bicycle infrastructure projects, and their opposition carries substantial weight with planners and elected officials. However, there is a relative paucity of research that provides an empirical look into the relationship between bicycle infrastructure and business performance.

Our research found that location on bicycle infrastructure has a mixed effect on business performance. In terms of change in sales, location on Class II facilities was not associated with a change in sales, while location on Class III facilities was either neutral in San Francisco or mixed in Alameda County. Interaction terms provided additional insights, with automobile-oriented businesses located on corridors with Class II facilities seeing a significant decline in sales. Class II facilities also had significant positive effects on sales for businesses on lower volume roads (neighborhood roads in San Francisco and tertiary roads in Alameda County). The models of the likelihood of business turnover showed that location on bicycle infrastructure either had no significant effect in the case of Class II and III facilities in San Francisco, or a reduction in the likelihood of turnover for Class II and III facilities in Alameda County.

Through a survey of shoppers on matched pair corridors in San Francisco and Alameda Counties, we failed to find a coherent distinction in shopper behavior on corridors with and without bicycle infrastructure. Similar rates of shoppers arriving by bike were registered for corridors with and without bicycle infrastructure. When asked about the general frequency with which they visit the corridor by bike for shopping trips, all respondents, those who arrived by bike and otherwise, reported coming to corridors without bicycle infrastructure more frequently to shop. It appears that cyclists in the survey sample were wealthier on the whole than shoppers who arrived by other modes and that any differences in shopping patterns were likely due to that difference, rather than the mode used or the presence of bicycle infrastructure.

Limitations and future research

This research was bounded in part by information that was publicly available, and the incompleteness of that information. The analysis focuses on two counties, San Francisco and Alameda, rather than being able to speak comprehensively about patterns throughout the region. This is due in large part due to the lack of complete information about bicycle infrastructure in the Bay Area. The most comprehensive dataset with information about regional bike facilities is the MTC Regional Bike Facilities dataset. This dataset includes the location and class of all infrastructure throughout the Bay Area through the year 2014. Unfortunately, it does not include installation dates. San Francisco is a model for bike infrastructure data, publishing a comprehensive and regularly updated dataset with information on every bicycle facility in its bounds, including data points on the month and year of installation, facility type, and other special considerations. Contingent on available resources, more public agencies should seek to achieve the same level of transparency. Without a reliable source for this data, installation dates were assigned manually using satellite imagery. However, the manual process is susceptible to human error, grainy historic satellite imagery, and limited imagery for years before the 2000s. Another limitation to this research regards the intercept survey of shoppers. The overall sample size is smaller than would have been ideal, making it difficult to reliably generalize to the entire population. Future research should devote more resources to gathering a large sample of shoppers to further illuminate the patterns related to bicycle infrastructure and shopping behavior.

In a similar vein, historical parking count data was also gathered manually using Google Street View. This process is also prone to human error, particularly when parking spaces do not have clear curb markings or meters and the research assistants had to make a judgment call on the number of parking spaces on a block. This is a somewhat subjective process, which introduces some irregularity into the parking count dataset. Furthermore, the counts were only conducted on corridors with bicycle infrastructure in the interest of time. However, parking could also have been removed for a number of other reasons on blocks without Class II bicycle infrastructure, including for purposes such as parklets, bus bulbs, or transit only lanes. The model oversimplifies the change in parking on corridors without bicycle infrastructure by assuming that these blocks saw no change in parking.

This research also doesn't touch on another issue that is likely key to business owners: the question of rents for storefront establishments. Future research should use hedonic regression to investigate whether distance to bicycle infrastructure or location immediately on bicycle infrastructure have a statistically significant association with increases in rent. A common implication in opposition to bicycle infrastructure projects from business owners and communities alike is that bicycle infrastructure projects will attract outside residents to the neighborhood, initiating or intensifying gentrification pressures (Levin 2017).

Future research should also investigate how businesses that open after the installation of bicycle infrastructure differ from businesses that were there in years prior. Research into the ways in which businesses differ in terms of average sales and industry could serve as a contirbution to the discussion surrounding bike infrastructure and gentrification.

A final conceptual limitation to this research is that it assumes that location immediately adjacent to bicycle infrastructure has a distinct impact from being located one block away from a corridor with bicycle infrastructure. The dichotomy between abutting and non-abutting businesses is almost certainly not so black and white in the real world. Rather, a more nuanced representation of this relationship would incorporate some sort of bicycle accessibility measure to assign a weighted accessibility bonus to businesses based on their distance from bicycle infrastructure.

Implications for planning and policy

This research sought to explore the narrative emerging from the business community that bicycle infrastructure has a negative effect on businesses. Through an empirical analysis of secondary data and primary intercept survey data, we find a mixed association between bicycle infrastructure and business performance. Bicycle infrastructure was associated with a generally neutral effect in terms of change in sales and a positive or neutral effect in terms of turnover. These findings make it difficult to generalize bike infrastructure as being overall good or bad for the business community. Bicycle infrastructure was associated with no significant effect in many of the models produced for this report.

Models of sales change for Alameda and San Francisco counties indicated that bicycle infrastructure alone has no significant effect on business sales, but roadway type matters. There is some evidence to support planning new bike facilities on neighborhood roads, but planners should carefully assess potential impacts when placing lanes on other roadway types.

The models of turnover suggest that businesses on Class II infrastructure in Alameda County could benefit from infrastructure projects in terms of a reduced likelihood of turnover. Class III facilities were also associated with a reduction in the likelihood of turnover for Alameda County. This could be interpreted as a reason to promote the expansion of bike infrastructure projects in commercial zones. With mixed findings cropping up, it becomes difficult to conclusively rule on the relationship between bike infrastructure and business performance.

Another salient issue related to bicycle infrastructure and business performance is the issue of parking removal. While only the models for San Francisco Class II facilities are able to address this issue, the results indicate no significant effect in terms of change in sales or turnover. Additionally, the presence of other curb management zones, including passenger and/or commercial loading zones, did not appear to have a significant effect. This information is also important for planners to know as they negotiate between the need for dedicated road space for all users and car owners and business owners' desire to maintain on-street parking.

In sum, the positive effects of bicycle infrastructure on bicycle mode share, cyclist safety, car usage, and population physical activity levels have been well-documented, but the same amount of attention has not been paid to the interaction between bike infrastructure and business performance. A prevailing assumption has been that business owners will oppose any change to the status quo when it comes to the road space outside their front door. While the relationship between business owners and bicycle advocates has been fraught for some time, this need not be the case. This research indicates that overall, bike infrastructure does not have a definitively positive or negative effect on business performance. Instead, there are a multitude of other factors outside of planners' control that determine sales or the likelihood that a business closes, our two measures of business performance. This research can inform future conversations around the relationship between bikes and business, and will hopefully inspire further research into this complex relationship.

Appendix 1: List of storefront NAICS codes

NAICS Code	2012 NAICS US Title
31212	Breweries
31213	Wineries
31214	Distilleries
44111	New Car Dealers
44112	Used Car Dealers
44122	Motorcycle, Boat, and Other Motor Vehicle Dealers
44131	Automotive Parts and Accessories Stores
44132	Tire Dealers
44211	Furniture Stores
44221	Floor Covering Stores
44229	Other Home Furnishings Stores
44314	Electronics and Appliance Stores
44412	Paint and Wallpaper Stores
44413	Hardware Stores
44422	Nursery, Garden Center, and Farm Supply Stores
44511	Supermarkets and Other Grocery (except Convenience) Stores
44512	Convenience Stores
44521	Meat Markets
44522	Fish and Seafood Markets
44523	Fruit and Vegetable Markets
44529	Other Specialty Food Stores
44531	Beer, Wine, and Liquor Stores
44611	Pharmacies and Drug Stores
44612	Cosmetics, Beauty Supplies, and Perfume Stores
44613	Optical Goods Stores
44619	Other Health and Personal Care Stores
44711	Gasoline Stations with Convenience Stores
44719	Other Gasoline Stations
44811	Men's Clothing Stores
44812	Women's Clothing Stores
44813	Children's and Infants' Clothing Stores
44814	Family Clothing Stores
44815	Clothing Accessories Stores
44819	Other Clothing Stores
44821	Shoe Stores

44831	Jewelry Stores
44832	Luggage and Leather Goods Stores
45111	Sporting Goods Stores
45112	Hobby, Toy, and Game Stores
45113	Sewing, Needlework, and Piece Goods Stores
45114	Musical Instrument and Supplies Stores
45121	Book Stores and News Dealers
45211	Department Stores
45291	Warehouse Clubs and Supercenters
45299	All Other General Merchandise Stores
45311	Florists
45321	Office Supplies and Stationery Stores
45322	Gift, Novelty, and Souvenir Stores
45331	Used Merchandise Stores
45391	Pet and Pet Supplies Stores
45392	Art Dealers
45399	All Other Miscellaneous Store Retailers
51213	Motion Picture and Video Exhibition
52211	Commercial Banking
52212	Savings Institutions
52213	Credit Unions
53221	Consumer Electronics and Appliances Rental
53222	Formal Wear and Costume Rental
53223	Video Tape and Disc Rental
53229	Other Consumer Goods Rental
53231	General Rental Centers
54121	Accounting, Tax Preparation, Bookkeeping, and Payroll Services
54192	Photographic Services
54193	Translation and Interpretation Services
54194	Veterinary Services
56141	Document Preparation Services
56151	Travel Agencies
56174	Carpet and Upholstery Cleaning Services
62111	Offices of Physicians
62121	Offices of Dentists
62131	Offices of Chiropractors
62132	Offices of Optometrists
62133	Offices of Mental Health Practitioners (except Physicians)
62134	Offices of Physical, Occupational and Speech Therapists, and Audiologists

62139	Offices of All Other Health Practitioners
	Family Planning Centers
	Outpatient Mental Health and Substance Abuse Centers
	Other Outpatient Care Centers
	Theater Companies and Dinner Theaters
	Dance Companies
	Musical Groups and Artists
	Other Performing Arts Companies
	Spectator Sports
	Museums
	Amusement Arcades
	Casinos (except Casino Hotels)
	Other Gambling Industries
	Fitness and Recreational Sports Centers
	Bowling Centers
	Mobile Food Services
	Drinking Places (Alcoholic Beverages)
	Restaurants and Other Eating Places
	Automotive Mechanical and Electrical Repair and Maintenance
	Automotive Body, Paint, Interior, and Glass Repair
	Other Automotive Repair and Maintenance
	Home and Garden Equipment and Appliance Repair and Maintenance
	Reupholstery and Furniture Repair
	Footwear and Leather Goods Repair
	Other Personal and Household Goods Repair and Maintenance
	Hair, Nail, and Skin Care Services
	Other Personal Care Services
	Coin-Operated Laundries and Drycleaners
	Drycleaning and Laundry Services (except Coin-Operated)
	Linen and Uniform Supply
	Pet Care (except Veterinary) Services
	Photofinishing

Appendix 2: Industry groupings

Industry	Number	Description
Auto-oriented	44111	New Car Dealers
	44112	Used Car Dealers
	44122	Motorcycle, Boat, and Other Motor Vehicle Deal...
	44131	Automotive Parts and Accessories Stores
	44132	Tire Dealers
	44711	Gasoline Stations with Convenience Stores
	44719	Other Gasoline Stations
	81111	Automotive Mechanical and Electrical Repair an...
	81112	Automotive Body, Paint, Interior, and Glass Re...
	81119	Other Automotive Repair and Maintenance
Bar	7224	Drinking Places (Alcoholic Beverages)
Entertainment	711	Performing Arts, Spectator Sports, and Related Industries
	712	Museums, Historical Sites, and Similar Institutions
	713	Amusement, Gambling, and Recreation Industries
	51213	Motion Picture and Video Exhibition
Financial	52211	Commercial Banking
	52212	Savings Institutions
	52213	Credit Unions
	52219	Other Depository Credit Intermediation
	54121	Accounting, Tax Preparation, Bookkeeping, and Payroll Services
	522291	Consumer Lending
Grocery	445	Grocery Stores
Health	621	Ambulatory Health Care Services
Home goods	44221	Floor Covering Stores
	44229	Other Home Furnishings Stores
	44314	Electronics and Appliance Stores
	44412	Paint and Wallpaper Stores
	44413	Hardware Stores
	44422	Nursery, Garden Center, and Farm Supply Stores
	81142	Reupholstery and Furniture Repair
	443142	Electronics Stores
Personal shopping	446	Health and Personal Care Stores
	448	Clothing Stores
	4511	Sporting Goods, Hobby, and Musical Instrument Stores

	4512	Book Stores and News Dealers
	4521	Department Stores
	45391	All Other Miscellaneous Store Retailers
Restaurant	7225	Restaurants and Other Eating Places
Service	8121	Personal Care Services
	8123	Drycleaning and Laundry Services
	8129	Other Personal Services
	54192	Photographic Services
	54193	Translation and Interpretation Services
	81143	Footwear and Leather Goods Repair
	81211	Hair, Nail, and Skin Care Services
	81219	Other Personal Care Services
	81231	Coin-Operated Laundries and Drycleaners
	81233	Linen and Uniform Supply
	81291	Pet Care (except Veterinary) Services
	81292	Other Personal Care Services
	811213	Communication Equipment Repair and Maintenance

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