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# Bikes or Bust? Analyzing the Impact of Bicycle Infrastructure on Business Performance in San Francisco

**Raleigh McCoy[1], Joseph A. Poirier[2], and Karen Chapple[3]**

**Abstract**

Transportation agencies at the local, state, and federal levels in the United States (U.S.) have shown a growing interest in expanding bicycle infrastructure, given its link to mode shift and safety goals. These projects, however, are far from universally accepted. Business owners have been particularly vocal opponents, claiming that bicycle infrastructure will diminish sales or fundamentally change the character of their neighborhoods. This research explores the relationship between bicycle infrastructure and business performance in two ways: change in sales over time, and a comparison of sales for new and existing businesses. An ordinary least squares regression is used to model the change in sales over time, isolating the effect of location on bicycle infrastructure while controlling for characteristics of the business, corridor, and surrounding neighborhood. Through a series of t-tests, average sales for businesses that pre-date bicycle infrastructure and for those that opened after the installation of such projects are compared. Ultimately, the research suggests that location on bicycle infrastructure and changes in on-street parking supply generally did not have a significant effect on the change in sales, with a few exceptions. Businesses that sell goods for the home or auto-related goods and services saw a significant decline in sales when located on corridors with bike lanes. New and existing businesses generally had similar sales, though not across the board. New restaurants and grocery stores had significantly higher sales than their existing counterparts, suggesting bicycle infrastructure may attract more upmarket businesses in those industries.

Increasing the use of active modes of transportation, including cycling, can have many positive public health and environmental benefits (*1–6*). Providing bicycle infrastructure is one action that jurisdictions can undertake to increase bicycle mode share (*7–9*). While interest in bicycle infrastructure has steadily increased over time, acceptance of these projects has been far from universal. Bicycle infrastructure has come under attack from a number of constituencies, including the business community. There are many justifications for merchant opposition to bicycle infrastructure, including concerns about parking removal, commercial loading zone obstruction, or general hassles for customers arriving by car. Given that planners and policymakers do not want to appear anti-business, merchant opposition has been particularly effective (*10*).

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 secondary data, will enable more effective public outreach. Given the uncertainty surrounding the impacts of bicycle infrastructure projects, equipping planners with quantitative evidence could go a long way towards building consensus in favor of bicycle infrastructure.

Furthermore, it is likely that bicycle infrastructure will create winners and losers. Identifying certain vulnerable industries is a key first step in designing mitigation measures to help businesses avoid adverse outcomes. Knowing more about vulnerable businesses could inform the design and siting of bicycle infrastructure, allowing planners to bypass concentrations of vulnerable businesses. At the same time, understanding which types of businesses benefit from bicycle infrastructure will help economic development planners identify corridors where businesses could benefit from such projects.

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## Literature Review

While the effect of bicycle infrastructure on residential property values has been the subject of many studies, the relationship between bicycle infrastructure and business performance has received relatively little attention (*11–13*). Literature examining the connection between bicycle infrastructure and business performance can be placed in the following categories: 1) surveys on shopper behavior and perceptions, 2) surveys of merchants on perceived effects, support, or opposition, and 3) secondary data analysis conducted on tax receipts or other third-party sources. Some studies also examine the nature of opposition to bike lanes and the relationship between bicycle infrastructure and gentrification, which are beyond the scope of this study.

### Shopper Behavior: Evidence on Sales

One intercept survey-based analysis of various travel mode users in Portland, Oregon showed that—on average—cyclists spent more at certain business types and patronized them more frequently than shoppers using other modes (*14*). This research has since been widely implemented as a policy tool in bicycle advocacy circles (*15–17*). These findings, however, addressed a limited sampling frame, surveying only patrons of eating and drinking establishments, and 24-hour convenience stores. 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 public agencies in the United States (U.S.) In 2008, the San Francisco County Transportation Authority (SFCTA) conducted a shopper survey on the Columbus Avenue corridor, finding that those who bicycled, rode in a taxi, or used "other" modes of transportation spent more in the corridor than those who drove or took transit (*18*). The following year, SFCTA conducted another, similar study at several downtown San Francisco sites, finding that while people who drove to shopping destinations spent the most money per trip, they visited businesses less frequently than those arriving by transit, walking, or biking (*19*). When the average amount spent was multiplied by the average number of visits per month, drivers spent the least on average and walkers spent the most (*19*). A similar study in Davis, California examined spending and mode choice decisions for shoppers, finding no significant difference in spending between cyclists and drivers (*20*).

### Merchant Perspectives: Evidence on Sales

Interviews with merchants before and after the installation of a segregated bike path in Sydney, Australia showed initial worry over the infrastructure that subsided after installation was complete (*21*). When pressed, some merchants admitted their fears might have been overblown. Researchers also interviewed three business owners who had moved to the cycleway after construction was complete, all of whom viewed the bicycle infrastructure as a positive aspect of the location. This analysis highlights the divergent narratives that business owners express before and after installation of bicycle infrastructure, further underscoring the importance of information to help business owners understand what to expect from these projects.

There are several studies that investigate the effect of bicycle infrastructure via self-reported data on sales and profit collected through business owner surveys. A survey of restaurateurs and their patrons in downtown Brisbane, Australia revealed that restaurateurs underestimated the amount of money spent by users of active modes and transit (*21*). In 2011, 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 profits, though it is difficult to verify the veracity of this finding without reliable secondary data (*21*).

Two survey-based studies conducted on Bloor Street 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 (*22*). The analysis 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" (*23*). In 2010, a similar survey-based study conducted in the area found more than half of merchants believed reducing parking and adding a bike lane would increase or have no impact on their number of customers (*23*). The same study found that "[t]he 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%" (*23*).

### Secondary Data Analysis of Sales

Analysis of secondary data to discern impacts of bicycle infrastructure on business outcomes has generally used taxable sales receipt data to gather a more objective picture of trends in business performance before and after the implementation of bicycle infrastructure.

Poirier 2018 used National Establishment Time Series (NETS) data to examine trends on three corridors with bicycle infrastructure in San Francisco (*24*). The study compared trends over time leading up to and following the installation of bicycle infrastructure, finding that changes in business outcomes were generally neutral or positive, and rarely negative. The study found that different types of businesses responded differently to bicycle infrastructure, with local-serving businesses typically faring better.

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 with increases of 3% borough-wide (*25*). Similarly, a 2017 Oakland DOT report using sales tax data stated that retail sales in the Telegraph Avenue corridor had increased 9% year-over-year after a protected bicycle lane intervention (*26*). However, in neither DOT study were the bicycle lane corridors compared with control corridors or nearby small geographies, making it difficult to separate the effect of bicycle infrastructure from general economic trends or neighborhood-wide changes.

A taxable retail sales-based study of two bicycle lane interventions in Seattle, Washington, included dual control areas for each of the two study corridors, showing no negative sales impact on businesses resulting from either bike lane (*27*). The study suggested the possibility of a wildly successful economic impact produced by a climbing lane installed on NE 65th Street that removed 12 parking spots, with an observed 400% increase in sales in the district (*27*).

## Methodology

The following section discusses this study's overarching analytic framework and data sources. The City and County of San Francisco is selected as the study area because of its extensive network of bicycle infrastructure, implemented over a long period of time, and high density of business establishments. Only by using an extreme case study like this can research uncover complicated relationships (*28*).

### *Defining Bicycle Infrastructure*

Bicycle infrastructure refers to a broad set of facilities that encourage and allow cycling as a mode of transportation (*29*). For the purposes of this paper, the focus is on right-of-way, with bicycle infrastructure broken down into two distinct classifications, defined by the California Department of Transportation (Caltrans) and described below (*30*). (Note: Class I and IV facilities are not included here because of their small sample size in San Francisco. Class I facilities are shared-use or bike paths. Class IV infrastructure runs parallel to automobile traffic in the same road space, featuring vertical physical separation.) [AQ: 2]

*Class II Facilities.* These facilities are frequently referred to as bike lanes and are denoted by a striped line indicating a certain portion of the road is reserved for cyclists. Bike lanes can be painted solid green to maximize visibility. They can also feature a striped buffer zone, which improves cyclist comfort by increasing their distance from moving cars or parking spaces.

*Class III Facilities.* Class III facilities are low-speed and low-traffic-volume roadways specifically designated as shared-use facilities. Class III bikeways are often distinguished into two categories: bicycle routes and bicycle boulevards. They commonly feature road markings called sharrows, along with posted signage. For the purposes of this analysis, both sub-types of Class III facilities are analyzed together.

### *Analytical Framework*

There are two primary outcomes of interest in determining the relationship between bicycle infrastructure and business performance: change in sales and difference in sales between new and existing businesses. Businesses on Class II and Class III facilities are compared against non-abutting businesses separately to further explore any differing effects that may exist between facility types.

Change in sales is examined using an ordinary least squares (OLS) regression on the dependent variable, change in sales. Change in sales is calculated as the average sales for a business in the years prior to the installation of bicycle infrastructure subtracted from the average sales for a business after the installation of bicycle infrastructure, with all figures in 2014 U.S. dollars.

The second analysis examines only businesses on corridors with bicycle infrastructure. Sales in 2014—the most recent year for which data are available—is compared for businesses that opened any time before the installation of bicycle infrastructure and any time after the installation of bicycle infrastructure. Sales are compared for just one year to control for temporal market fluctuations, though this does introduce a survivorship bias, as only businesses that have succeeded in remaining open are included in this analysis.

### *Data*

*Bicycle Infrastructure.* Bicycle infrastructure data are from the San Francisco Municipal Transportation Agency (SFMTA) Bike Network dataset. This dataset includes

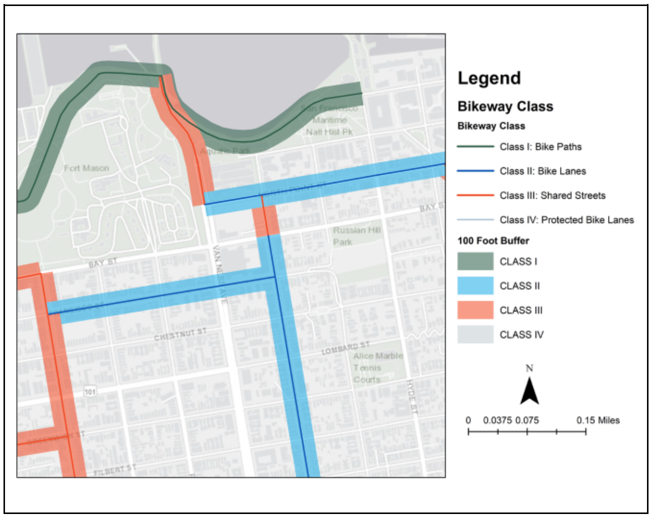


**Figure 1.** Bicycle infrastructure buffer process.

the location, facility type, and installation date of all bicycle infrastructure in San Francisco. Bicycle infrastructure is concentrated in the heavily commercial northeastern section of the city, though there are corridors with Class II and Class III facilities throughout the city.

Throughout this paper, businesses that abut bicycle infrastructure will be compared against businesses that do not. To classify abutting businesses, a 100-ft buffer was drawn around linear bicycle infrastructure features. Business point features that fell within the buffer were designated as abutting businesses (Figure 1). Businesses that fell within multiple buffer zones were dropped from analysis, as there was no way to systematically determine whether the business's entryway was on the Class II or Class III corridor. For non-abutting businesses, the intervention year around which the before-and-after change was calculated comes from the installation year of the nearest bicycle infrastructure. This way, abutting businesses are compared against neighboring non-abutting businesses. Roughly 10% of businesses in the sample abut Class II facilities and 15% of businesses abut Class III facilities.

*Business Performance.* Business performance data come from the National Establishment Time Series (NETS) database, a proprietary database of annual data from 1996 through 2014 at the individual business level, with 99% of California businesses reporting (*31*). Businesses of all sizes are included in the dataset, from freelancers to major corporations. The primary variables of interest were the annual sales and other characteristics of the business, including industry [six-digit North American Industry Classification System (NAICS) code], years of operation, and location. As is typical of business data, NETS has shortcomings, including some inaccuracy and infrequency of updates (*31–33*).

Businesses that closed before or opened after bicycle infrastructure was installed were excluded from the regression analysis. The 159 businesses with sales larger than the $99^{th}$ percentile for the given year were deemed outliers and dropped. The 3,615 businesses with only one employee were also dropped.

Using six-digit NAICS codes, the data were subset to include only businesses of interest: storefront retail, food service, and other service-providing businesses. Businesses that aren't dependent on consumer access, such as office-based workplaces, were dropped. The remaining businesses were then classified into 10 industry classifications of particular interest—though not every business falls within one of the ten categories—which are: bar, restaurant, grocery, personal goods, home goods, services, entertainment, financial, health, and automobile-oriented. These industry classifications were used as independent variables in the model and were the categories in which sales were compared for new and existing businesses.

Other variables that were used to estimate the models include the number of years in operation and a dummy variable indicating if the business is part of a chain.

*On-Street Parking.* On-street parking counts before and after bicycle lane installation were conducted using Google Street View imagery, which covers 2007 to 2018. On-street parking counts were conducted for the most recent imagery (post-bicycle infrastructure installation) and for the most recent date preceding bicycle infrastructure installation for which imagery was available. Parking counts were conducted at the block level as the sums of on-street stalls on both sides of the street.

In total, there were 459 block-level street segments with Class II facilities. Of these, 167 did not have pre-installation imagery, meaning change in parking could not be calculated. 174 segments saw no change in parking and 14 segments increased the number of spaces, usually because of replacing parallel parking with perpendicular parking. The average change in parking was minus three (–3) spaces per block.

During the parking counts, the number of spaces dedicated to passenger or commercial loading was also noted. Dummy variables indicating the presence of at least one passenger or commercial loading zone were used in the models.

Parking counts were conducted for corridors with Class II facilities, as Class III facilities generally do not affect the number of parking spaces. Change in parking was assumed to be zero for other blocks.

**Table 1.** Average Sales and Change in Sales

| | Sales in intervention year | | Average sales change | |
|---|---|---|---|---|
| | Median | Mean | Median | Mean |
| All businesses | 142,500 | 183,345 | –24,295 | –46,418 |
| All non-abutting businesses | 142,700 | 183,827 | –25,296 | –47,414 |
| All abutting businesses | 140,000 | 181,868 | –21,553 | –43,365 |
| Businesses abutting Class II | 150,000 | 207,884 | –27,921 | –68,130 |
| Businesses abutting Class III | 125,700 | 165,478 | –19,390 | –27,762 |

*Data sources*: NETS, San Francisco Bike Network.

*Corridor Characteristics.* To compare across corridors that see similar traffic volumes and offer similar degrees of local, regional, or statewide connectivity, a four-tiered roadway classification system was created by condensing OpenStreetMap's road classification types (*32*). The highest volume roads, designated "trunk" or "primary" by OpenStreetMap, were classified as primary roads. Roads classified as "secondary" or "tertiary" were classified as such in the model. Roads classified as "residential" or "living streets" were classified as neighborhood roads. Interstates were not included.

The number of businesses on each of the four road types was: approximately 190 businesses each located on primary and secondary roads, 430 businesses on tertiary roads, and 1,000 businesses on neighborhood roads. Between 22% and 39% of businesses abutted bicycle infrastructure for each of the four classes.

*Neighborhood Characteristics.* Information on the neighborhood in which a business was located was also included in the model. Neighborhood data correspond to the intervention year, providing a snapshot of neighborhood dynamics at the time bicycle infrastructure was installed. Data from 2009 to 2014 come from the U.S. Census Bureau's American Community Survey (ACS). Prior to 2009, Census data were released once very 10 years. Therefore, when bicycle infrastructure was installed before 2004, data from the 2000 Census were used. Businesses on corridors with infrastructure installed between 2004 and 2009 were assigned 2009 ACS data.

Neighborhood demographic variables include median household income (2014 U.S. dollars), percent of housing occupied by renters, and shares of residents who are Hispanic or non-Hispanic black. Population density showed a highly non-normal distribution, so a dummy variable representing the top 50th percentile of population density (25 people per acre) was included to capture denser environments. Finally, the density of business establishments in each census tract was derived from NETS data.

*Interactions.* The models also include interactions between bicycle infrastructure and industry or roadway type to quantify differing effects that bicycle infrastructure may have based on automobile traffic volume and industry.

## Findings

### *Sales Change*

This section presents the findings from an OLS model of the change in sales before and after the intervention, defined as the year of bicycle infrastructure installation or the year of installation of the nearest bicycle infrastructure (in the case of non-abutting businesses). Change in sales is perhaps the most easily interpretable metric of business performance; an increase in sales suggests a business is doing well, while declining sales suggests it is not.

*Descriptive Statistics.* Businesses across the board experienced a decline in sales over time, likely because of an overall market shift away from storefront retail and toward e-commerce (Table 1). Non-abutting businesses saw a median decline in sales of around $25,000, while abutting businesses exhibited a divergent pattern. Businesses abutting Class II facilities saw the largest decline in sales over time, while businesses on Class III facilities saw the smallest. Mean values for average sales change were nearly double the median, indicating right-skewed distribution of the data.

To provide context for the change in sales, mean and median sales in the year of intervention are given. Median sales were roughly equivalent across categories, though mean sales are slightly more spread. Businesses abutting Class II facilities saw the largest average sales, while businesses abutting Class III facilities reported the lowest mean sales.

*Model Results.* Two OLS models were estimated on the dependent variable of change in sales. The first model compares businesses abutting Class II facilities with all

**Table 2.** Sales Change Model for Class II Facilities

| | Coefficient | Sig. | T-statistic |
|---|---|---|---|
| **Corridor characteristics** | | | |
| Class II | 2,642 | | 0.15 |
| Primary road | –18,780 | * | –1.93 |
| Secondary road | –31,630 | *** | –2.98 |
| Tertiary road | –165 | | –0.02 |
| Change in on-street parking | 194 | | 0.08 |
| Commercial loading zone | 53,200 | | 0.88 |
| Passenger loading zone | 4,686 | | 0.17 |
| **Business characteristics** | | | |
| Years old | –2,094 | *** | –10.34 |
| Chain | –18,280 | | –1.50 |
| Bar | 57,940 | *** | 3.28 |
| Restaurant | 15,720 | | 1.48 |
| Grocery | 1,400 | | 0.10 |
| Personal goods | 287 | | 0.03 |
| Home goods | –10,250 | | –0.69 |
| Services | 40,050 | *** | 3.92 |
| Entertainment | 39,860 | | 0.58 |
| Financial services | 42,630 | ** | 2.20 |
| Health services | –12,660 | | –1.27 |
| Automobile-oriented | –26,520 | | –1.54 |
| **Bicycle infrastructure and road class interactions** | | | |
| Class II x primary roads | 10,470 | | 0.50 |
| Class II x secondary roads | –17,200 | | –0.70 |
| Class II x tertiary roads | –19,690 | | –1.20 |
| Class II x neighborhood roads | 29,060 | ** | 2.04 |
| **Bicycle infrastructure and industry interactions** | | | |
| Class II x bar | –16,740 | | –0.28 |
| Class II x restaurant | –25,580 | | –0.81 |
| Class II x grocery | –10,440 | | –0.30 |
| Class II x personal goods | –956 | | –0.03 |
| Class II x home goods | –94,250 | ** | –2.19 |
| Class II x services | –17,080 | | –0.56 |
| Class II x health services | –14,500 | | –0.50 |
| Class II x automobile-oriented | –162,800 | *** | –3.92 |
| **Neighborhood characteristics** | | | |
| Business density (est./acre) | –414 | | –0.92 |
| Urban | 16,040 | | 1.58 |
| Median household income ($1,000) | –212 | | –1.34 |
| Percent housing renter-occupied | 40 | | 0.17 |
| Percent Latino | 199 | | 0.76 |
| Percent Black | –279 | | –0.56 |
| **Intervention year** | | | |
| 1996 | –5,685 | | –0.26 |
| 1997 | 2,892 | | 0.19 |
| 1998 | –4,023 | | –0.08 |
| 1999 | –29,730 | | –1.26 |
| 2000 | 4,936 | | 0.23 |
| 2002 | 2,532 | | 0.12 |
| 2003 | –13,240 | | –0.89 |
| 2004 | 35,090 | | 1.45 |
| 2005 | –2,581 | | –0.27 |
| 2006 | –14,390 | | –1.25 |
| 2008 | 6,881 | | 0.18 |
| 2009 | 22,660 | * | 1.72 |
| 2011 | 21,860 | ** | 2.11 |
| 2012 | 30,580 | ** | 2.46 |
| 2013 | 1,648 | | 0.08 |
| Constant | –11,230 | | –0.37 |

*Note*: * = $p$ <0.10, ** = $p$ < 0.05, *** = $p$ < 0.00.
N = 1,536, Adjusted R-squared = 0.11.
Abutting = 172, Non-abutting = 1,364.
*Data sources*: NETS, ACS Tables B01003, DP05, B19013, Census tables P001, QTP3, HCT012, OSM, San Francisco Bike Network.[AQ: 3]

non-abutting businesses, while the second compares businesses abutting Class III facilities with all non-abutting businesses. Independent variables representing characteristics of the business, corridor, and surrounding neighborhood are included to isolate the effect of bicycle infrastructure.

The Class II model suggests that location on Class II facilities was not associated with a significant change in sales before and after installation of bicycle infrastructure, indicating the initial finding observed in the descriptive statistics disappears when controlling for other factors (Table 2). Additionally, there was no significant relationship between the change in on-street parking and change in sales. Curb management variables representing availability of a commercial or passenger loading zone were also not significant.

The model did, however, identify other predictors that had a significant association with change in sales. Businesses located on higher-volume primary or secondary roads saw sales decline over time when compared with the reference category of neighborhood roads.

Perhaps unsurprisingly, characteristics of the individual business proved to be some of the most powerful predictors of business performance. Industry was a reliably predictive variable, though not across the board. Bars, service-providing businesses, and financial businesses all

**Table 3.** Sales Change Model for Class III Facilities

| | Coefficient | Sig. | T-statistic |
|---|---|---|---|
| **Corridor characteristics** | | | |
| Class III | 52,060 | | 0.98 |
| Primary road | −18,500 | ** | −2.02 |
| Secondary road | −32,460 | *** | −3.25 |
| Tertiary road | −4,901 | | −0.65 |
| **Business characteristics** | | | |
| Years old | −1,896 | *** | −10.72 |
| Chain | −32,870 | *** | −2.89 |
| Bar | 57,930 | *** | 3.48 |
| Restaurant | 16,250 | | 1.62 |
| Grocery | 560 | | 0.04 |
| Personal goods | 2,031 | | 0.2 |
| Home goods | −10,260 | | −0.73 |
| Services | 39,790 | *** | 4.13 |
| Entertainment | 42,630 | | 0.66 |
| Financial services | 40,200 | ** | 2.2 |
| Health services | −13,020 | | −1.38 |
| Automobile-oriented | −26,030 | | −1.61 |
| **Bicycle infrastructure and road class interactions** | | | |
| Class III x primary roads | −17,580 | | −0.31 |
| Class III x secondary roads | −9,272 | | −0.17 |
| Class III x tertiary roads | −63,840 | | −1.22 |
| Class III x neighborhood roads | −40,480 | | −0.8 |
| **Bicycle infrastructure and industry interactions** | | | |
| Class III x bar | −12,190 | | −0.33 |
| Class III x restaurant | −5,681 | | −0.23 |
| Class III x grocery | −21,840 | | −0.75 |
| Class III x personal goods | −3,235 | | −0.12 |
| Class III x home goods | 28,120 | | 0.9 |
| Class III x services | −7,993 | | −0.33 |
| Class III x entertainment | 17,500 | | 0.7 |
| Class III x financial services | −18,020 | | −0.49 |
| Class III x health services | −103,200 | | −0.79 |
| Class III x automobile-oriented | 40,990 | | 1.02 |
| **Neighborhood characteristics** | | | |
| Business density (est./ acre) | −251 | | −0.63 |
| Urban | 0 | | 0.21 |
| Median household income ($1,000) | −54 | | −0.37 |
| Percent housing renter-occupied | 156 | | 0.76 |
| Percent Latino | 170 | | 0.69 |
| Percent Black | −213 | | −0.5 |
| **Intervention year** | | | |
| 1996 | −7,849 | | −0.36 |
| 1997 | 13,190 | | 0.89 |
| 1998 | −4,168 | | −0.09 |
| 1999 | 14,850 | | 0.55 |
| 2000 | −19,140 | | −0.82 |
| 2002 | 11,120 | | 0.44 |
| 2003 | −18,820 | | −1.16 |
| 2004 | 22,620 | | 1.06 |
| 2005 | −13,030 | | −1.55 |
| 2006 | −8,434 | | −0.87 |
| 2008 | 7,199 | | 0.2 |
| 2009 | 15,500 | | 1.32 |
| 2011 | 17,290 | * | 1.75 |
| 2012 | 30,790 | *** | 2.89 |
| 2013 | 1,823 | | 0.09 |
| Constant | −35,640 | | −1.28 |

*(continued)*

**Table 3.** (continued)

*Note:* * = $p < 0.10$, ** = $p < 0.05$, *** = $p < 0.00$.
N = 1,637, Adjusted R-squared = 0.1.
Abutting = 273, Non-abutting = 1,364.
*Data sources*: NETS, ACS Tables B01003, DP05, B19013, Census tables P001, QTP3, HCT012, OSM, San Francisco Bike Network.[AQ: 4]

saw increases in sales. These trends generally match observed trends in the market, with service-based businesses growing in prominence while traditional brick-and-mortar retail recedes. Business age was associated with a decline in sales, indicating that older businesses observed a slightly smaller change in sales on average than their newer counterparts, perhaps because of these businesses being more established and less likely to experience sudden, skyrocketing sales. Neighborhood characteristics were generally insignificant, indicating that the surrounding population is a poor predictor of business success.

Interactions between the presence of Class II facilities and road classification were generally not significant, except for the interaction between Class II facilities and neighborhood roads, which indicated a positive change in sales. When the Class II variable was interacted with 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 suggests that Class II infrastructure has a distinct negative effect on these industries.

Finally, dummy variables indicating the intervention year around which the change in sales was calculated were also included within the model for time-fixed effects. These variables do not have a strong policy connection but serve to control for temporal market fluctuations.

Like Class II infrastructure, location on Class III facilities was not associated with significant change in sales over time (Table 3). The Class III model shows many of the same associations as the Class II model. Location on primary and secondary roads demonstrated a negative association with change in sales, as did business age. Services, financial services, and bars saw significant growth in sales. Unlike in the previous model, chain stores saw a significant decline in sales. This model also

**Table 4.** Sales for New and Existing Businesses on Class II Facilities

| Industry | | N | Average sales | Difference | Sig. | T Statistic |
|---|---|---|---|---|---|---|
| Bar | Existing | 22 | 185,936 | | | |
| | New | 26 | 233,700 | 47,764 | | −1.7 |
| Restaurant | Existing | 158 | 251,427 | | | |
| | New | 145 | 285,783 | 34,356 | ** | 2.1 |
| Grocery | Existing | 69 | 225,607 | | | |
| | New | 48 | 282,490 | 56,883 | * | 1.9 |
| Personal goods | Existing | 60 | 192,300 | | | |
| | New | 72 | 163,129 | −29,171 | | −1.2 |
| Home goods | Existing | 47 | 247,681 | | | |
| | New | 34 | 222,976 | −24,705 | | 0.7 |
| Services | Existing | 90 | 80,213 | | | |
| | New | 83 | 54,086 | −26,127 | ** | −2.5 |
| Entertainment | Existing | 1 | 75,000 | | | |
| | New | 0 | – | – | | – |
| Financial services | Existing | 28 | 174,027 | | | |
| | New | 16 | 98,455 | −75,572 | * | −1.8 |
| Health services | Existing | 129 | 203,436 | | | |
| | New | 208 | 215,792 | 12,356 | | 0.9 |
| Auto-oriented | Existing | 69 | 247,712 | | | |
| | New | 42 | 185,094 | −62,618 | ** | −2.2 |
| Uncategorized | Existing | 130 | 199,929 | | | |
| | New | 121 | 140,434 | −59,495 | *** | −3.0 |
| All | Existing | 803 | 205,070 | | | |
| | New | 795 | 196,380 | −8,690 | | −1.2 |

[AQ: 5][AQ: 6]
*Data sources*: NETS, San Francisco Bike Network.

shows a significant positive association between dense populations and change in sales.

None of the interactions between Class III infrastructure and roadway classification or industry were statistically significant. The lack of significant associations between interactions could be because of the relatively low intensity of the change to street dynamics presented by Class III projects. It appears that, on the whole, Class III facilities do little to affect business dynamics in one way or another.

Overall, the sales change models suggest that location on bicycle infrastructure has a neutral effect on change in sales, particularly for Class III facilities. There are a few cases where Class II infrastructure may benefit businesses and a few cases where it may have a detrimental effect. These findings generally don't support business owners' claims that bicycle infrastructure is bad for business, though they don't confirm advocates' claims that bicycle infrastructure is good for business, either. Instead, it appears that for businesses in San Francisco, there are a multitude of other factors that affect the change in sales a business sees over time.

## *Comparing New and Existing Businesses*

Another dimension of the relationship between bicycle infrastructure and business performance involves the difference between businesses that existed on the corridor before the installation of bicycle infrastructure and businesses that opened after these projects were installed. Contrasting the performance of existing and new businesses further explains trends in types of businesses and the markets they target.

A series of two-sample t-tests of means were performed to contrast average sales in 2014 for new and existing businesses, broken down by industry. New businesses were defined as businesses that opened after the installation of bicycle infrastructure and existing businesses were defined as businesses that opened before the year of installation of bicycle infrastructure. Businesses that opened in the year of installation were excluded because there was no way to verify if the business opened before or after the installation of bicycle infrastructure.

As a whole, sales were not significantly different between new and existing businesses on Class II corridors (Table 4). However, there were a few exceptions. New restaurants and grocery stores showed significantly higher sales than existing businesses in these industries. Auto-oriented businesses and businesses providing services or financial services showed significantly lower sales for new businesses. Businesses that did not fit into one of the ten categories of interest also showed lower sales for new businesses. This category can be considered a catch-all for all other storefront businesses. The remaining

**Table 5.** Sales for New and Existing Businesses on Class III Facilities

| Industry | | N | Average Sales | Difference | Sig. | T Statistic |
|---|---|---|---|---|---|---|
| Bar | Existing | 54 | 225,181 | | | |
| | New | 19 | 186,832 | –38,349 | | –1.2 |
| Restaurant | Existing | 357 | 267,653 | | | |
| | New | 145 | 304,765 | 37,112 | *** | 2.6 |
| Grocery | Existing | 131 | 261,567 | | | |
| | New | 46 | 256,254 | –5,313 | | –0.2 |
| Personal goods | Existing | 252 | 212,940 | | | |
| | New | 132 | 209,342 | –3,598 | | –0.2 |
| Home goods | Existing | 93 | 269,674 | | | |
| | New | 32 | 181,944 | –87,730 | ** | –2.5 |
| Services | Existing | 387 | 83,314 | | | |
| | New | 97 | 55,814 | –27,500 | ** | –2.3 |
| Entertainment | Existing | 2 | 338,700 | | | |
| | New | 3 | 373,433 | 34,733 | | 0.2 |
| Financial services | Existing | 122 | 168,976 | | | |
| | New | 37 | 98,300 | –70,676 | *** | –2.7 |
| Health services | Existing | 726 | 250,219 | | | |
| | New | 427 | 216,493 | –33,726 | *** | –4.3 |
| Auto-oriented | Existing | 49 | 243,686 | | | |
| | New | 14 | 158,736 | –84,950 | * | –1.7 |
| Uncategorized | Existing | 334 | 195,701 | | | |
| | New | 133 | 157,077 | –38,624 | ** | –2.2 |
| All | Existing | 2,507 | 212,691 | | | |
| | New | 1,085 | 201,577 | –11,114 | * | –1.9 |

[AQ: 7][AQ: 8]
*Data sources*: NETS, San Francisco Bike Network.

industries showed no significant difference in sales between new and existing businesses.

The trends between new and existing businesses on Class III corridors were similar to those on Class II corridors (Table 5). Businesses that sell home goods, auto-oriented businesses, and businesses providing services, healthcare, or financial services all showed significantly lower sales for new businesses. Again, restaurants reported higher sales for new businesses, though unlike Class II corridors, there was no significant difference in sales for new and existing grocery stores.

To summarize, new businesses in many industries underperformed existing businesses, and in others were about equal. This could be explained by business maturity, as new businesses are at least slightly less established than businesses that existed before the installation of bicycle infrastructure. Less-established businesses could still be building a clientele or honing their product and service offerings. Although nearly all retail businesses face competition from e-commerce, new businesses may be at a disadvantage because they don't have the same customer base that existing businesses can call on to weather this competition.

This general trend of lower sales for new businesses on corridors with bicycle infrastructure provides an interesting context for the finding of higher sales for new restaurants and grocery stores. New restaurants on both Class II and Class III corridors saw higher sales, suggesting that restaurants that open after the installation of bicycle infrastructure projects could be catering to more affluent clients.

Grocery stores reported higher sales when located on Class II corridors, though the difference in sales for groceries on Class III facilities was not significant. This reveals some heterogeneity in the locational preferences of upscale groceries, suggesting that higher-revenue-generating groceries may prefer sites on corridors with bike lanes, but do not necessarily choose to locate on Class III corridors.

These findings provide some support for claims of a relationship between bicycle infrastructure and the attraction of higher-end businesses, though the results are not conclusive. Regardless, the findings present some concerns to restaurateurs and grocery store owners along corridors with bicycle infrastructure currently installed or in the pipeline. These industries could face challenges from more upscale (or larger) competitors, in turning leading to increased rents. Furthermore, there is some concern that businesses in these industries could be pushed out in favor of businesses that cater to a different market. In the case of grocery stores, this could be problematic, particularly if there are no other grocery stores at equivalent price points within reach of the community. If a neighborhood loses its affordable grocery stores in favor of more upscale providers, this could have a substantial negative effect on access to fresh and healthy food for residents.

## Discussion

### Summary of Findings

This research defined the relationship between bicycle infrastructure and business performance in two ways: change in sales over time, and differences between new and existing businesses. With an average decline in sales of $46,000 across all businesses, businesses abutting Class II corridors showed an average decline in sales of $68,000 and businesses abutting Class III corridors showed an average decline in sales of $28,000.

The divergent results between businesses abutting Class II and Class III corridors inspired further investigation that controlled for characteristics of the business, the corridor, and the neighborhood in which the business was located. Models estimating the change in sales showed that, controlling for these factors, there was no significant association between location on a Class II or Class III corridor and change in sales, suggesting that the significant relationship found in the initial stages of research was likely spurious.

Bicycle infrastructure was interacted with corridor volume and industry to identify vulnerable industries or corridor types. While there were no significant associations between interactions of Class III infrastructure and industry or roadway classification, several interesting findings did emerge from the Class II model. Businesses located on Class II infrastructure installed on low-volume neighborhood roads saw significant increases in sales. On the other hand, auto-oriented businesses and businesses that sell home goods that were located on Class II infrastructure saw significant declines in sales.

Also of interest in the conversation around bicycle infrastructure and business performance is the issue of on-street parking. The model for Class II facilities showed no significant association between change in on-street parking and change in sales.

Most industries observed either no significant difference between sales for new and existing businesses or lower sales for new businesses, though there were notable exceptions. New restaurants on Class II and Class III corridors both experienced higher sales than existing restaurants (for the purposes of this research, the restaurants category includes cafés).

The second exception was grocery stores that opened after the installation of Class II facilities, which reported significantly higher sales than their existing peers. This pattern was not observed for groceries on Class III corridors, indicating that upscale groceries may choose to locate on corridors with bike lanes over shared-use facilities. Upscale groceries like Whole Foods are also seen by many as signals of gentrification (*36*, *37*).

Altogether, these findings suggest bicycle infrastructure in general is not conclusively associated with business performance. Location on bicycle infrastructure demonstrated a neutral association with change in sales across infrastructure types. While there are exceptions, these are relatively few and far between. Instead, the models demonstrate how other characteristics of a business are more reliable and powerful predictors of business performance. When examining how new businesses differ from existing businesses on corridors with bicycle infrastructure, most new businesses experienced lower sales than their existing counterparts, with the exception of restaurants and groceries.

### Limitations and Future Research

This analysis is limited to San Francisco, a city whose unique economic situation and relatively high population density makes it a poor case for generalization to other cities, but a good case for discerning the potential impacts of bicycle infrastructure: if facilities don't boost sales in a city like San Francisco, they are not likely to do so elsewhere. However, the data to complete this analysis at a regional level were not available, with few public agencies publishing comprehensive information about bicycle infrastructure. In this regard, San Francisco serves as a model for bicycle infrastructure data.

Historical parking count data were gathered manually using Google Street View. This is a subjective exercise prone to human error. Furthermore, in the interest of time, the counts were only conducted on corridors with bike lanes. However, parking could also have been removed for a number of other reasons on street segments without Class II bicycle infrastructure, for purposes such as parklets, bus boarding islands, 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. City departments of transportation or public works could record on-street parking count data during street maintenance and make them publicly available with minimal additional data collection effort involved, providing a valuable resource to planners and researchers.

Data on privately owned off-street parking were not available for use in this analysis. Businesses that provide customers with access to a parking lot may not have been as negatively affected by the removal of on-street parking as businesses without such facilities, though it is impossible to tease out this disparity at present.

A final methodological limitation is that this research assumes that location immediately adjacent to bicycle infrastructure has an impact distinct from being blocks away from a corridor with bicycle infrastructure. The dichotomy between abutting and non-abutting businesses is almost certainly not so black and white. A more nuanced representation of this relationship would incorporate a bicycle accessibility measure to assign a score to businesses based on their distance from bicycle infrastructure.

Future research should examine more directly the idea that bicycle infrastructure may lead to gentrification and displacement, ideally through surveys and interviews. Activists have rallied around the idea that "bike lanes are white lanes" and that bicycle infrastructure only serves to attract outside residents, intensifying gentrification pressures by catering to the preferences of "creative" types (*39*, *40*). If an association between bicycle infrastructure and commercial displacement is evident, planners may need to rethink strategies to help legacy businesses remain in place. Future research should develop a better understanding of what goes on inside the business: how existing businesses are adapting to new clientele, and even how the introduction of bicycle infrastructure can induce new delivery-based businesses.

## *Implications for Planning and Policy*

Our models of change in sales suggest there is a minimal relationship between bicycle infrastructure and business performance. While there are a few cases where businesses on certain types of corridors or of a certain industry stand to benefit or lose out, generally speaking, the association between infrastructure and sales was rarely significant. As such, it is difficult to generalize bicycle infrastructure as being an overall benefit or burden to businesses.

Findings from the model can be used to determine corridors where bicycle infrastructure could be beneficial or detrimental to businesses. Given that businesses of all types reported an increase in sales over time when bicycle infrastructure was located on neighborhood roads, planners should prioritize planning infrastructure on corridors with low automobile traffic. The increase in sales in this setting could suggest that bicycle infrastructure has the ability to incentivize new customers to come to the corridor by bike only when located on the lowest-traffic, most bike-friendly roads. Conversely, infrastructure may not be able to change the volume of shoppers on high-traffic streets.

On the other hand, the models suggest that planners should avoid routing bicycle infrastructure through corridors with high concentrations of automobile-oriented businesses or businesses that sell home goods. Both of these industries have a clear relationship with—and to a point, dependency on—customer access by automobile. Similarly, there are limited opportunities for shoppers arriving by bike to engage with the goods and services these businesses provide. Many automobile-oriented businesses perform vehicle maintenance, while home goods stores tend to sell bulky, fragile, or heavy items that would not be easily transported by bike. Patrons could potentially perceive bike lanes as an impediment to access, finding the infrastructure and additional cyclists on the road a frustration that could be avoided by shopping elsewhere. A compromise for planners would be to install Class III facilities on these corridors, as these facilities did not have a significant association with change in sales and therefore may be more compatible.

A salient secondary issue related to bicycle infrastructure and business performance is parking removal. While this issue receives much attention, the model revealed that changing the number of on-street spaces did not affect change in sales. This information is relevant for planners as they negotiate between the need for non-auto road space and business owners' desire to maintain on-street parking.

This paper finds mixed evidence in support of a relationship between bike lanes and the attraction of upscale businesses. The comparison of outcomes for new and existing businesses finds that, on the whole, new businesses have lower or equivalent sales, though sales are higher for new grocery stores and restaurants. This could suggest that some industries are more responsive to the changes brought about by bicycle infrastructure than others, and there may be a role for planners in helping existing grocery stores and restaurants adjust to new clientele.

In sum, the positive effects of bicycle infrastructure on bicycle mode share, cyclist safety, pollution reduction, car usage, and population physical activity levels have been well documented, but the same attention has not been paid to the interaction between infrastructure and business. While the relationship between business owners and bicycle advocates has been contentious for some time, this research suggests that this need not be the case. Generally speaking, bicycle infrastructure does not have a definitively positive or negative effect on business performance. As such, while there are many reasons to promote bicycle infrastructure, economic development alone may not be sufficient justification.

## Author Contributions

The authors confirm contribution to the paper as follows—study conception and design: JAP; data collection: RM, KC, JAP; analysis and interpretation of results: RM, KC; draft manuscript preparation: RM, KC, JAP. All authors reviewed the results and approved the final version of the manuscript.

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