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Cycling into the Future: Implementation of Enhanced Bikeways Along San Fernando Street in Downtown San Jose

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CYCLING INTO THE FUTURE:

Implementation of Enhanced Bikeways

Along San Fernando Street in Downtown San Jose

by

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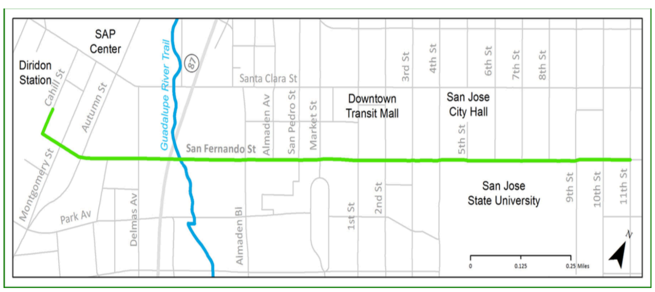
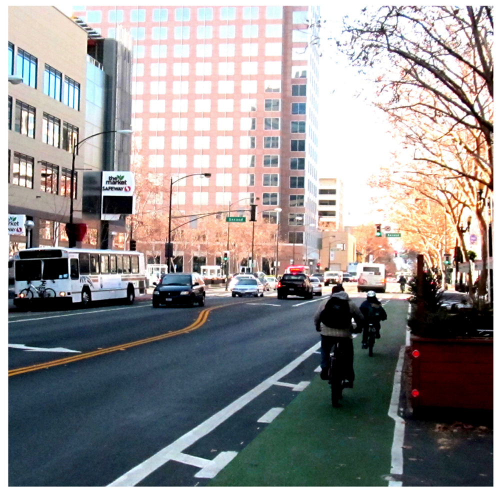
BACKGROUND

In 2012, the City of San Jose acquired funding from the Transportation for Livable Communities Grant Program and began installing "green striped" enhanced bicycle lanes on a 1.5 mile stretch San Fernando Street between Diridon Station and 10th Street connecting San Jose's Downtown Train Station to San Jose State University (City of San Jose, 2014) (Fig 1). According to city documents, these enhanced bikeways are intended

Fig 1: Map and photograph highlighting the San Fernando Street Improvement Project.





Source: City of San Jose, 2014.

to "enhance the visibility and safety of this route as a primary bikeway" (Larsen, 2012). An important element of the project was the installation of LED streetlights to improve nighttime visibility (City of San Jose, 2014). This specific project undertaken by the city falls under the umbrella of its Bike Plan 2020, intended to transform San Jose into "a city where bicycling is safe, convenient, and commonplace" (City of San Jose, 2009, i). One of the Bike Plan's primary goals is to reduce bicycle collision rates by 50% before the year 2020. The San Fernando Street Improvement Project and others like it will be validated by "reach[ing] a Gold-level Bicycle Friendly Community status by 2020" (City of San Jose, 2009, i). The purpose of this research is to determine whether this project has successfully reduced rates of injuries and fatalities.

The significance of this infrastructure lies in the way much of the United States developed in the 20th century. The emergence of mass production and low gasoline costs in the United States allowed the automobile to flourish during the 20th century. This newly found symbol of individual independence and power had the public lusting for personal transportation. Mass automobile ownership quickly led to changes in the way cities and greater metropolitan areas were developed. Generally, cities prioritized the automobile and did not plan for much bicycle use or other means of what is now considered "sustainable transportation" (Volti, 1996). The original design of San Fernando Street is representative of how many 20th century roadways were designed (Fig 2).

Fig 2: San Fernando Street before the installation of bicycle lanes.
Source: City of San Jose, 2014.

Another example of the automobile's influence is the creation of the interstate highway system. According to Volti (1996), "This system has brought with it many of the most evident features of the built environment: strip development, shopping malls, motels, and fast food, to name only the most obvious manifestations", and that "the building and maintenance of the system represented a political and financial commitment to a car- and truck-based land transportation system and for many years the foreclosure of alternative modes of transportation" (Volti, 1996). In essence, all of these factors helped contribute to low rates of sustainable transportation that are far from desirable under the constraints of the modern, 21st century cityscape.

Although the automobile has revolutionized the way people travel, their use, and the development of cities based on their predominance has resulted in many unintended consequences. The most considerable negative externality is the pollution created by internal combustion engines. Beginning in the early 1950's, scientists began correlating automobiles with increased pollution throughout the United States (Volti, 1996). Until the mid 1960's there were no emission control systems on vehicles that were manufactured in or imported into the United States. In Southern California, the pollution became so notorious that the State of California took it upon itself to mandate PCV systems on all vehicles produced there, starting in 1963 (Volti, 1996). In the following years, the federal government began to take action and enacted The Clean Air Act in 1970. Eventually this legislation led to vehicles producing just 10% of the emissions by the mid 1990s. Although significant, these changes were the results of major government intervention (Volti, 1996).

Another negative externality motorists face in urban areas is congestion. According to the Urban Mobility Report, by 2020 motorists across the United States will waste 3.2 billion gallons of fuel while sitting in traffic (Schrank, Eisele, Lomax, & Bak, 2015). Aside from the microeconomic impacts, such as fuel and opportunity costs that the individual will face, each gallon of gasoline and diesel creates 19.64 and 22.38 pounds of carbon dioxide (CO_2) respectively after combustion (U.S. Energy Information Administration, n.d.). The San Francisco Bay Area has the 7th worst congestion across the country, and the average commuter spends 50 hours per year sitting in traffic (Schrank, Eisele, Lomax, & Bak, 2015). Planners are looking for ways to help alleviate the congestion and its environmental impacts. One of The Urban Mobility Report's many recommendations is to incorporate bicycle and pedestrian strategies into urban planning (Schrank, Eisele, Lomax, & Bak, 2015).

Elements of San Jose's Bike Plan 2020 were inspired from successful projects completed by other bicycle friendly cities, such as Portland, San Francisco, Seattle and other locations around the world. Some examples of other bicycle oriented developments are installing exclusive bicycle trails and sidewalks (Fig 3), designing bus stops with designated turnouts that allow for a bus to completely exit the roadway that leaves room for bicycles to safely pass (Fig 4), having bike lanes that flow the opposite direction of one-way streets, other variations of green striped lanes, and combinations of alternatives listed in the brochure. (City of San Jose, 2009). All of these options are excellent alternatives, however, due to existing development and space restrictions, the green stripe selected for the majority of San Fernando Street was determined to be the most fitting.

Fig 3: Designated bike trail in Boulder, CO.
Source: City of San Jose, 6-3, 2009.

Fig 4: Bus stop designed to leave room for cyclists in Boulder, CO.
Source: City of San Jose, 6-3, 2009.

According to the 2016 Benchmarking Report, San Jose's population density per square mile is 5,558.1 and is closest to Cleveland (5,016.9) and Detroit (5,013.8) (Milne and Melin, 2016). Overall, the percentages of bicycle commuters among the three cities are: 0.9% for San Jose, 0.5% for Cleveland and 0.4% for Detroit (Miline and Melin, 128, 2016). The Benchmarking Report does not make assumptions about why this is the case, but it does show the reader that there is something about San Jose, whether its infrastructure, economic conditions, weather, personal preference, other outside factors, or some combination of influences, that leads to a higher rate of bicycle use. The Benchmarking Report also found that the injury rate for 10,000 bicycle commuters for San Jose is 5, while Cleveland is 8 and Detroit is 35 (Miline and Melin, 137, 2016). The latter data shows that San Jose's infrastructure is safer for bicyclists when compared to other cities with similar population densities.

A Canadian study (Teschke et al., 2010) found a strong correlation between bicycle infrastructure and the safety of bicycle users. The study interviewed qualified accident victims from hospitals in both Toronto and Vancouver, Canada. The injured cyclists were asked to map out their "injury trip" for the study, which then "compared [the] route infrastructure at each injury site to that of a randomly selected control site from the same trip" (Teschke et al., 2012). Using an odds of incident ratio, it was determined that dedicated bicycle lanes reduced injury rates by almost 50% (OR = .54) and that cycle tracks reduced injuries by almost 90% (OR=.11) (Teschke et al, 2010). An outside analysis discussing this study (Badger, 2012) argues that studies in previous decades did not yield the same results because "we had little of the dedicated commuter bike infrastructure many cities are just creating now" (Badger, 2012).

A study from the Mineta Transportation Institute has found that among riders "a large majority is 'traffic-intolerant,' willing to tolerate only a small degree of traffic stress." (Furth, Mekuria & Nixon, 8, 2012). This 2012 report used data from San Jose prior to the San Fernando Street improvement project and found stress levels between Diridon Station and San Jose State University ranged from "lowest" to "high". (Furth, Mekuria & Nixon, 31-32, 2012). The San Fernando Street Improvement Project can be seen as the beginning of a low stress bicycle network. This may help eliminate "medium" or "high" risk areas. Although this study will not analyze whether the San Fernando Street improvement project decreased traffic stress for its bicycle users as a primary measure, it is important to note that this network may have had an effect on ridership, simply because it was perceived to increase safety.

A study that set out to determine the practicality of using bicycles to meet exercise requirements in Portland, Oregon (Dill, 2009) found that "59% of the participants were able to meet the recommended 150 minutes of activity per week through the bicycling recorded by the GPS units" (Dill, 2009, 104). It also determined that of the trips taken by participants, 33% were to home, 25% were to work, 13% were for social & recreation purposes, 8% were for personal reasons, 7% were for shopping, 5% were for exercise, 3% were for dining, 3% were for work, 2% for other, and 1% to school (Dill, 2009, 101). These findings show that a large majority of trips taken by the participants were for utilitarian purposes (Dill, 2009, 100).

According to a study conducted by Hartog, Boogaard, Nijland, and Hoek (2011), the benefits of cycling need to outweigh the risks for it to be considered a long-term alternative to the automobile. Their study looked at the overall benefit between exercise, safety, and pollution from cars on local commutes, and that bicycles and cars can be considered substitutes. It was found that bicycle commuters breathe between 2.3 and 2.1 times the amount of air, and therefore pollution, over vehicle commuters. It was also found that the risk of a fatal accident on a bicycle is 4.3 times greater than for commuters by car over the same distance. Lastly, when analyzing the impacts of physical activity, it was determined that regular physical activity can be expected to increase the average person's life by 3-14 months. Overall, "For the people who shift from car to bicycle, we estimated that the well-documented beneficial effect of increased physical activity due to cycling resulted in about 9 times more gains in life-years than the losses in life years due to increased inhaled air pollution doses and traffic accidents" (Hartog, Boogaard, Nijland, and Hoek, 2011).

To compliment the projects like the San Fernando Street Improvement Project, a bike share network has been constructed throughout Downtown San Jose. There are five stations located along San Fernando Street between Diridon Station and San Jose State University (Find a Station, n.d.). This network gives those who do not possess a bicycle access to the downtown cycling network. Research has shown that bike share networks act as a theft deterrent (Fishman, Washington & Haworth, 2014, 14) and have facilitated a vehicle substitution rate of up to 21% (Gishman, Washington & Haworth, 2014, 16).

In 2019, the City of San Jose will convert the existing enhanced bicycle lanes on San Fernando Street into protected bikeways. Protected bikeways have been shown to increase ridership and reduce accidents in other cities around the world. (City of San Jose, n.d.(c)). The studies referenced in the *Better Bikeways* brochure yielded similar findings to *Low-Stress Bicycling and Network* (Furth, Mekuria & Nixon, 2012) because the barriers used in protected bikeways were perceived as safer, and “provide a trail-like level of comfort and safety on urban streets” (City of San Jose, n.d.(c)).

METHODOLOGY

The methodology used in this study was based on Ronald & Kathleen Sylvia's ideas for conducting an outcome evaluation as described in *Program Planning and Evaluation for the Public Manager*. In their description of policy analysis for start up programs, the authors state, "policy makers want to know whether a new program idea will work before undertaking it on a larger scale" (Sylvia and Sylvia, 2012, 116). That logic is important when analyzing San Jose's "Green-Stripe" enhanced bike lanes, because they are a relatively new implementation throughout the city and the extent of their benefits is not entirely known. Since the city has limited resources, it is important to ensure that these bicycle lanes are creating safer modes of travel for their users before further expansion. The ideal result of this analysis was to eliminate any "wrinkles" in these roadway improvements, and to determine whether the benefits received by bicyclists around Downtown San Jose outweigh the cost of the improvements (Sylvia and Sylvia, 2012, 116). This study was an external evaluation and provided a fresh and objective perspective to the project (Sylvia and Sylvia, 2012, 119).

Table 1: Outcome Analysis of San Fernando Street Improvement Project

Program	Theoretical Goals	Program Goals	Selected Proximate Indicators	Selected Program Measures	Program Outcomes	Outcome Valence
San Fernando Street Improvement Project	T1: Reduce traffic congestion T2: Reduce total incidents T3: Reduce total injuries T4: Create a safer rider experience in Downtown San Jose by reducing the amount of accidents involving a bicycle T5: Create a safer rider experience in Downtown San Jose by reducing the amount of accidents in which a bicycle was involved and injury occurred T5: Promote healthier lifestyles for Downtown San Jose's residents and commuters T6: Improve air quality in Downtown San Jose	G1: Increase bicycle commuting to work (T1) G2: Increase bicycle use for misc. other downtown trips (T1) G3: Reduce accidents among all roadway users (T2) G4: Reduce total number of injury accidents (T3) G5: Reduce number of bicycle related accidents (T4) G6: Reduce number of bicycle related accidents in which an injury occurred (T5)	I1: Total Number of accidents (G3) I2: Number of Injury Accidents (G5) I3: Number of accidents with bicycles involved (G4) I4: Number of accidents involving a bicycle and injury	M1: Comparing total accidents for all users before and after installation of enhanced bikeways (I1) M2: Comparing injury accident rates before and after installation of enhanced bikeways (I2) M3: Comparing bicycle involved accident rates before and after installation of enhanced bikeways (I3) M4: Comparing bicycle involved injury rates before and after installation of enhanced bikeways. (I4)	O1: Primary outcomes/ direct impact (M1, M2, M3, M4)	±

The first step in this outcome evaluation was to define the program goals. Sylvia and Sylvia state that generally there are two goals of public policy: theoretical and program goals. Theoretical goals are what the program is intending to do, while program goals are the vehicle that the organization creates to achieve its theoretical goals. In essence, this study attempted to confirm that the "Green-Stripe" bike lane had an impact that is consistent with its goals. (Sylvia and Sylvia, 2012, 122). These goals were determined by reviewing official literature and brochures distributed by the City of San Jose.

After determining San Jose's goals, the study looked at the proximate indicators. The proximate indicators in this study were generic indicators, which were gathered from data collection. (Sylvia and Sylvia, 2012, 128). The data in this study was gathered from San Jose's Department of Transportation. Next, the study determined the program measures by synthesizing the proximate indicators into formal measures (Sylvia and Sylvia, 2012, 129). As this analysis was outcome based, the data was compared during years before and after the bike lanes implementation and not with other cities. After establishing the program measures, the study determined program outcomes, which looked at how the project impacted stakeholders (Sylvia and Sylvia, 2012, 126). The primary outcomes were considered the direct impacts of the project. (Sylvia and Sylvia, 2012, 129). Lastly, this study determined the outcome valance, which is a simple connotation as to whether this project had a positive or negative overall effect for bicyclists in Downtown San Jose (Sylvia and Sylvia, 2012, 130).

In addition to the outcome evaluation, this study attempted to determine factors involved in bicycle accidents along San Fernando Street using a linear regression. The purpose of determining the factors involved was to contribute to the body of knowledge surrounding bicycle use. This contribution may help plan future projects by providing a more complete understanding of why these accidents are occurring. The variables used in the linear regression were provided by the San Jose Department of Transportation in the same data set used to complete the outcome evaluation.

LITERATURE REVIEW

One reason the findings in *Bicycling for Transportation and Health: The Role of Infrastructure* (Dill, 2009) are important is because the research took place in Portland, Oregon, an early adopter of these strategies. As stated in the background, many of San Jose's bicycle improvement projects were inspired by the infrastructure improvements undertaken by the City of Portland. The bicycle system in Portland has successfully provided its residents with a method of transportation that gives health benefits while it reduces dependence on the automobile, which San Jose is attempting to emulate.

Route Infrastructure and the Risk of Injuries to Bicyclists: A Case-Crossover Study (Teschke et. al 2012) establishes a relationship between infrastructure and bicyclist safety. This is important because it justifies the allocation of tax dollars by showing these improvements work. The methodology used in this study is rather unique because it directly involved accident victims and examined what improvements were in place at accidents locations across Toronto and Vancouver, Canada. *Dedicated Bike Lanes Can Cut Cycling Injuries in Half* (Badger, 2012) examined the findings of Teschke et al. from an outside perspective, and provides a pragmatic understanding of the findings.

The research in *Bike Share's Impact on Car Use: Evidence from the United States, Great Britain, and Australia* (Fishman, Washington & Haworth 2014) highlights the need for a sophisticated bicycle network. While bike sharing is not a focus of this paper, it is important to acknowledge its existence because bike lanes are just one piece of a larger picture. Explaining how different infrastructure improvements compliment each other helps tie the San Fernando Street Improvement project to San Jose's Bike Plan 2020.

Low-Stress Bicycling and Network (Furth, Mekuria & Nixon, 2012) published by the Mineta Transportation Institute determined that "Bicycling in America suffers from a lack of connected, low-stress routes that appeal to the mainstream, traffic-intolerant population" (Furth, Mekuria & Nixon, 2012). This research shows that most cyclists do not possess the skills or have the desire to ride bicycles in environments they perceive as dangerous. *Do All Roadway Users Want the Same Things?* (Sanders and Cooper, 2013) was a study funded by the California Department of Transportation. It found that cyclists, pedestrians, and motorists all perceived bicycle lanes to be the safest way to harmonize the roads. However, this research was gathered from surveys and the reporting can be classified as ordinal (Sanders and Cooper, 2013).

Although *Biking to Work in American Cities: The Effect of Federal Infrastructure Funding* (Newhall and Ay, 2013) analyzed the correlation between federal infrastructure funding and bicycle use, it provides data about other contributing factors relating to ridership in urban environments. Some examples provided are economic conditions and America's fascination with the automobile (Newhall and Ay, 2013).

The 2014 and 2016 Bicycling and Walking in the United States Benchmarking Report provides a compilation of data, which benchmarks bicycle data between most major cities across the United States. Some of the more important benchmarks are as follows: population density, infrastructure spending per capita, percent of commuters bicycling to work as counted by the city, intersection counts, and fatalities per 10,000 commuters. Each report also provides the name(s) of the city representative(s) who provided the data to the Alliance for Biking and Walking, which may be important for further independent research (Milne, and Melin, 2014; Milne, and Melin, 2016). It should be noted, however, that crime rates were not considered, and this may be a limiting factor in commute mode choice that is unaccounted for. In addition to these reports there are various publications from the United States Census Bureau that discuss the nationwide average for methods of commuting. When looking at the bicycle commuting data, San Jose is above average (McKenzie, 2015).

Fatalities of Pedestrians, Bicycle Riders, and Motorists Due to Distracted Driving Motor Vehicle Crashes in the U.S. (Stimpson, Wilson and Muelleman 2013) provided information on when bicyclists are likely to be struck and killed by distracted drivers. The research also provides data on those who are likely to be the victim and driver involved in a fatal bicycle accident. This research could help formulate ideas on outside factors that may influence accidents that take place in areas where cyclists are using an enhanced bikeway. These outside factors can be the targets of education campaigns designed to increase the safety of all road users in areas with enhanced bikeways (Stimpson, Wilson, and Mulleman, 2013).

*Bicycle Use and Cyclist Safety Following Boston's Bicycle Infrastructure Expansion, 2009–2012 (*Pedroso, Angriman, Bellows, and Taylor, 2013) studied the expansion of Boston's cycling network, and its relation to usage and the number of injuries sustained by riders. Their research found a positive relationship between bicycle networks and ridership. The article also outlines methods to standardize injury rates in relation to miles of bike lanes and overall ridership, which can be applied to an analysis of San Jose's enhanced bicycle lanes. The article relied on limited publically available data from the City of Boston itself, which the authors admit only provided a limited picture because they were not able to examine as far back in time as they would have liked (Pedroso, Angriman, Bellows, and Taylor, 2013).

Walking and Cycling to Health: A Comparative Analysis of City, State, and International Data (Pucher, Buehler, Bassett, and Dannenberg, 2010) found statistically significant inverse relationships between bicycle riding and obesity. Simply put, those who ride their bicycles more frequently are less likely to be overweight because by default; those who exercise are not sedentary. (Pucher, Buehler, Bassett, and Dannenberg, 2010). *Moving urban trips from cars to bicycles: impact on health and emissions* (Lindsay, Macmillin, and Woodward, 2010) found that a 5% urban increase in bicycle travel versus cars can reduce emissions, save fuel, and also confirms the health benefits listed above.

The *2015 Urban Mobility Score Card* (Schrank, Eisele, Lomax, & Bak, 2015) discusses the various implications of congestion across the country. The implications include microeconomic impacts to how congestion correlates with the greater picture. The report found that the cost of congestion to the average auto commuter was $960 in 2014 compared to an inflation-adjusted $400 in 1982; and that in urban areas like San Jose with over 1,000,000 residents, the average annual delays were 63 hours per resident (Schrank, Eisele, Lomax, & Bak, 2015). These numbers are part of the reason that many city leaders across the country are pushing for increased bicycle use.

Estimating Annual Average Daily Bicyclists (Nordback, 2013) examines how cities can measure bicycle ridership. It discuses the advantages and disadvantages of various methods used, such as Inductive Loops, Microloops, Passive Infrared, Active Infrared, and Microwave Radar and the differences between short and long term counting. Nordback (2013) also discusses manual methods of traffic measurements and concludes that is it is infeasible to have someone physically counting bicyclists or reviewing video in an attempt to analyze commuter data.

Public Documents

There are many public documents that were referenced for the background of this study. The first document that will be discussed in this section is the official brochure of San Jose's Bike Plan 2020. This is important because it outlines what the city is attempting to achieve with its bicycle improvement projects that have been occurring over the last eight years. This document also contains information about previous projects and efforts relating to bicycle use that San Jose has implemented since the 1970's (City of San Jose, 2009). The City of San Jose also released a series of flyers discussing the Enhanced Bikeways (Class II) on San Fernando Street. This flyer discusses the plan, how much it costs, and the changes to existing infrastructure needed to complete this project. The San Fernando Street flyer also discloses that the city collects bicycle traffic data, which indicates that this data may be available for public consumption (City of San Jose, 2014). The city has also provided additional fliers that discuss different types of bikeways and paths to help those wishing to know more understand the terminology used in its various documents (City of San Jose, n.d.). In the Bike Plan 2020 Annual Report for 2016 and 2017, San Jose stated its current enhanced bikeway inventories and projections for the future. It is helpful to look at multiple years to ensure that the city is meeting its San Jose Bike Plan 2020 goals. In the later, San Jose published the annual expenses for 2016-2017 and provides projections on its bikeway expenditures through 2020-2021 (Ortbal, 2016; Ortbal, 2017). The 2016 General Plan Performance Review states that the rate of bicycle use is higher in downtown compared to other parts of the city (Brilliot, Hart, and Vacca, 2016). The last document to be used from the City of San Jose is the *Better Bikeways Flier* (City of San Jose, n.d.(c)). The flier outlines future projects San Jose plans on undertaking, which encompasses the area in the San Fernando Street Improvement Project.

FINDINGS

The Data

The findings of this study are based on data obtained from San Jose's Department of Transportation (City of San Jose, 2018). The data is a compilation of all roadway incidents by intersection on San Fernando Street between Diridon Station and 11th Street that occurred between January of 2010 and August of 2017. Due to the method of collection, it also includes incidents that took place within a one block radius (~500 feet) of San Fernando Street on its North and Southbound cross streets. The incidents that took place on cross streets were considered relevant because they are in direct proximity to the San Fernando Street Improvement Project.

The data set includes the intersection of the incident, date, time, distance from the intersection, direction of travel, proximity to intersection, weather, light, road surface, the method of transportation for the accident victim(s), type of collision (how they were struck), the severity of the injury (fatal, major, moderate, and minor), primary collision factor, sex, age, method of transportation and direction of the culpable party, the culpable party's action when the accident occurred (such as turning, proceeding straight), and whether a violation was issued.

The San Fernando Street Improvement Project was officially completed in the fall of 2013 (City of San Jose, n.d.(b)). In order to avoid statistical "noise", data from October through December of 2013 were not included in the findings. The findings of this study were also trimmed to 3.5 years before and after the project's implementation (April 2010 – September 2013 and January 2014 – June 2017) to create uniform time periods. While the data collected is very thorough, many of the factors were incomplete, such as participant sex, age, and whether a violation was issued. While creating profiles of the parties involved could have added to the analysis, it was not feasible to include in the findings of this study.

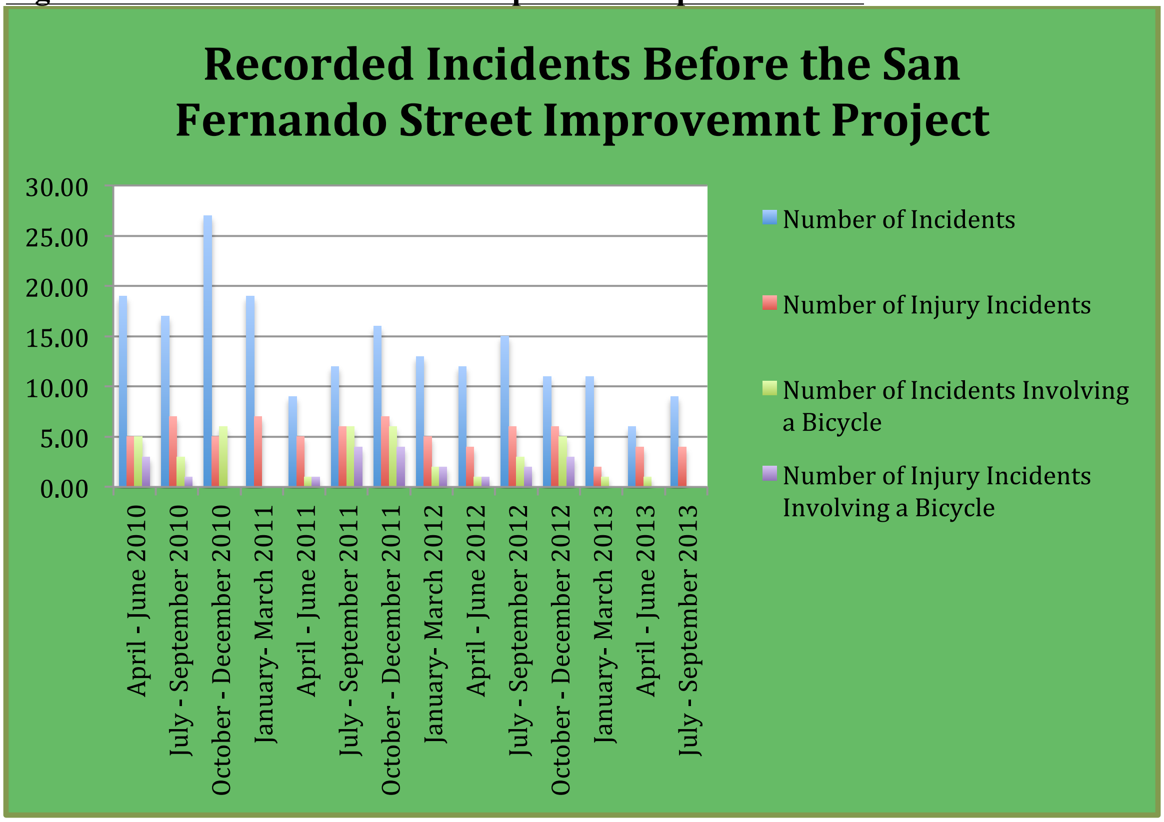
Other factors such as distance, proximity to the intersection, direction of travel, and collision type were also not included in the findings. Time was not included because it was better represented by the “light” measure.

In total, there were 344 incidents that took place during the two time periods studied. While 139 of the reported incidents included some kind of injury, there were only two in which a fatality occurred. In a few of the incidents a bicycle was categorized as “at fault”, but was not listed as a party in the accident. This study will categorize these incidents as involving a bicycle. The findings will be based on two statistical models, and the interpretations of these findings will be further discussed in the analysis section of this study.

Outcome Evaluation

The first model used to determine the study’s findings was a descriptive analysis of the raw numbers. The descriptive model was used to conduct the outcome evaluation based Sylvia and Sylvia’s (2012) ideas for conducting an outcome analysis, and looked at total incidents, number of incidents in which at least one person was injured, number of incidents that involved a bicycle, and number of incidents involving a bicycle in which one person was injured, all on a quarterly basis. These numbers were then used to create an average, standard deviation, margin of error, upper and lower bounds of the 95% confidence interval, maximum, and minimum.

Figure 5: Recorded Incidents from April 2010-September 2013



Source: City of San Jose, 2018.

Figure 6: Statistical Data of Incidents from April 2010-September 2013.

Recorded Incidents Before San Fernando Street Improvement Project				
	Number of Incidents	Number of Injury Incidents	Number of Incidents Involving a Bicycle	Number of Injury Incidents Involving a Bicycle
Total	196.00	73.00	40.00	21.00
Average	14.00	5.21	2.86	1.50
Standard Deviation	5.36	1.42	2.32	1.51
Margin of Error	2.81	0.75	1.21	0.79
Upper Bound	16.81	5.96	4.07	2.29
Lower Bound	11.19	4.47	1.64	0.71
Maximum	27.00	7.00	6.00	4.00
Minimum	6.00	2.00	0.00	0.00
% With Injury (Overall)	37.24%			
% With Bicycle Involved	20.41%			
% Of Bicycle with Injury	52.50%			

Source: City of San Jose, 2018.

Figures 5 and 6 include accident data from April 2010 through September 2013. There were 196 incidents in the period, with an average of 14 per quarter. The standard deviation of this average was 5.36 with a margin of error of 2.81. The upper and lower bounds for the 95% confidence interval were 16.81 and 11.19, respectively. The maximum number in incidents in a quarter was 27, with a minimum 6.

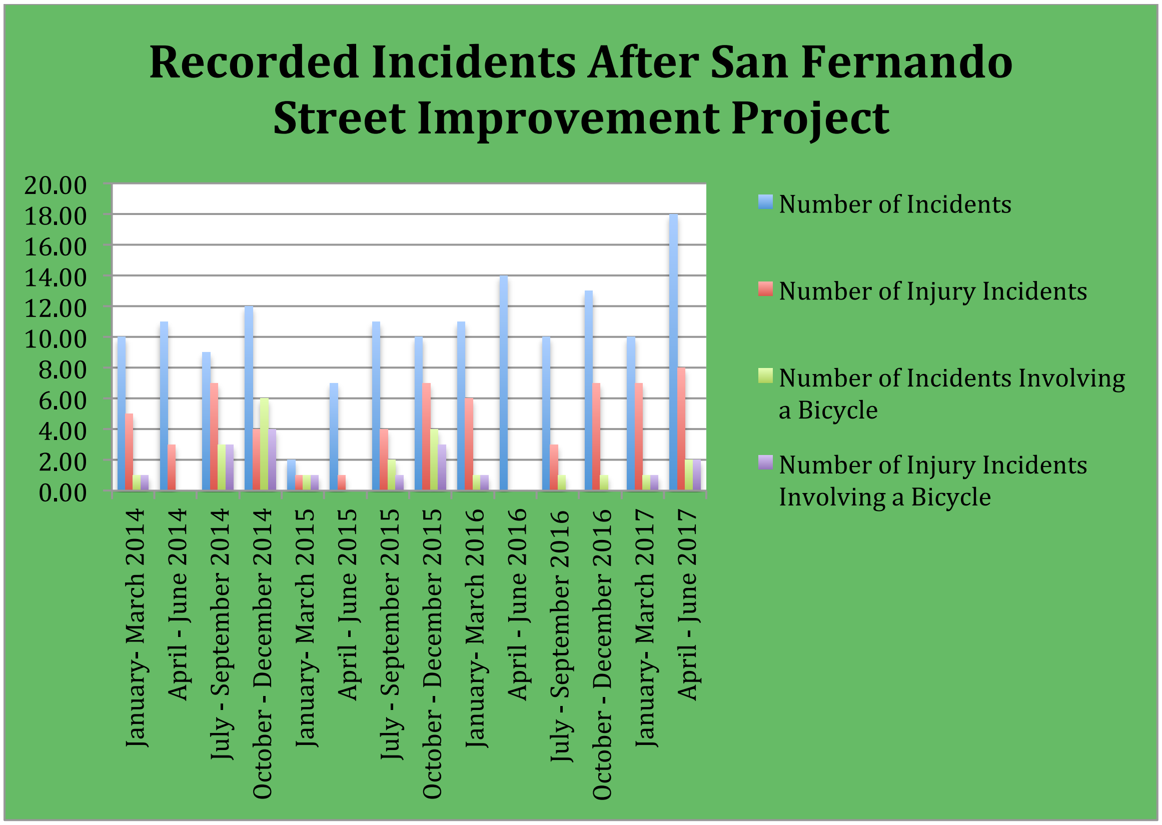
Of the 196 incidents studied before the project's completion, 73 resulted in at least one injury. On average, 5.21 injury accidents occurred in each quarter, with a standard deviation of 1.42. The margin of error was 0.75, which means the upper and lower bounds for a 95% confidence interval were 5.96 and 0.54, respectively. The maximum number of injuries per quarter was 7, with a minimum of 2. An injury was caused in 37.24% of incidents.

Before the San Fernando Street Improvement Project, 40 of the 196 total incidents involved a bicycle, averaging 2.86 per quarter. The standard deviation of this average was

2.32, with a margin of error of 1.21. The upper bound of the 95% confidence interval was 4.09 and lower bound was 1.43. The maximum number of accidents that involved a bicycle in a quarter was 6 and the minimum was 0. Overall, bicycles were involved in 20.41% of all incidents.

Of the 40 incidents involving a bicycle, 21 resulted in at least one injury. On average, there were 1.5 accidents that involved a bicycle and resulted in an injury per quarter, with a standard deviation of 1.51. The margin of error was 0.79, which means the upper bound of the 95% confidence interval was 2.29, and the lower bound was 0.71. The maximum number of accidents per quarter that involved a bicycle and resulted in an injury was 4 and the minimum was 0. Overall, 52.5% of accidents involving a bicycle resulted in an injury.

Figure 7: Recorded Incidents from January 2014-June 2017.



Source: City of San Jose, 2018.

Figure 8: Statistical Data of Incidents from January 2014-June 2017.

Recorded Incidents After San Fernando Street Improvement Project				
	Number of Incidents	Number of Injury Incidents	Number of Incidents Involving a Bicycle	Number of Injury Incidents Involving a Bicycle
Total	148.00	63.00	23.00	17.00
Average	10.57	4.50	1.64	1.21
Standard Deviation	3.57	2.62	1.69	1.31
Margin of Error	1.87	1.37	0.89	0.69
Upper Bound	12.44	5.87	2.53	1.90
Lower Bound	8.70	3.13	0.76	0.53
Maximum	18.00	8.00	6.00	4.00
Minimum	2.00	0.00	0.00	0.00
% With Injury (Overall)	42.57%			
% With Bicycle Involved	15.54%			
% Of Bicycle with Injury	73.91%			

Source: City of San Jose, 2018.

Figures 7 and 8 include accident data from January 2014 through June 2017. There were 148 incidents in the period, with an average of 10.57 per quarter. The standard deviation of total incidents was 3.57, with a margin of error of 1.87. The upper and lower bounds for the 95% confidence interval were 12.44 and 8.70, respectively. The maximum number of incidents in a quarter was 18 and the minimum was 2.

Of the 148 total accidents, there were 63 accidents that resulted in at least one injury during the second date range. The average per quarter was 4.5 with a standard deviation of 2.62. The margin of error was 1.37 with the upper and lower bounds of the 95% confidence interval at 5.87 and 1.84, respectively. The maximum number of injury accidents in a quarter was 8 and the minimum was zero. An injury was caused in 42.57% of all accidents.

After the project's completion, 23 of the 148 total incidents involved a bicycle. The average number of bicycle incidents per quarter was 1.64, with a standard deviation of 1.69. The margin of error was 1.89, with the upper and lower bounds of the 95% confidence interval at 2.53 and 1.77, respectively. The maximum number of bicycle incidents in a quarter was 6 and the minimum was zero. A bicycle was involved in 15.54% of all incidents after the project's completion.

Of the 23 incidents involving a bicycle, 17 resulted in an injury. On average, there were 1.21 accidents that involved a bicycle and resulted in an injury per quarter, with a standard deviation of 1.31. The margin of error was 0.69, with the upper and lower bounds of the 95% confidence interval at 1.9 and 0.53, respectively. The maximum number of accidents that involved a bicycle and resulted in an injury was 4 and the minimum was 0. Overall, 73.91% of incidents that involved a bicycle resulted in an injury.

Linear Regression

The second statistical model used in this study was a linear regression run on IBM's SPSS software. The purpose of a linear regression is to determine the relationship and significance between bicycle accidents and their causes. In order to convert the data into a format that SPSS could process, the desired inputs were converted into binary numbers (1 and 0). In essence, these binary numbers tell SPSS which incidents are connected to which variable.

Figure 9: Outputs of Linear Regression

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.211	.086		2.456	.015
	Before/After	-.064	.042	-.082	-1.523	.129
	Injury / Fatality	.146	.042	.185	3.468	.001
	Clear	.707	.390	.457	1.814	.071
	Day	.029	.045	.037	.648	.517
	Dusk / Dawn	.076	.102	.041	.737	.462
	Dry	-.792	.383	-.522	-2.069	.039
	Alcohol Involved	-.087	.114	-.041	-.760	.448

a. Dependent Variable: Bicycle Involved

Source: San Jose, 2018

Figure 9 constitutes the core of the linear regression. It provides the constant for the independent variable, as well as the beta, T-scores, and significance for each dependent variable. The constant is the likelihood of an incident occurring with all of the other factors removed. The constant is not very meaningful on its own, but can be combined with the betas of the dependent variables to independently determine their relationship. When the beta is positive, there is a likelihood that the dependent variable is correlated with independent variable. However, in order for the beta to be considered significant, the T-score needs to be greater than 1.96. A T-score that is greater than 1.96 indicates that there are at least two standard deviations (95% confidence interval) between the two averages. The significance is another method to determine the confidence interval. The significance needs to be less than or equal to 0.05 for a 95% confidence interval.

The linear regression in this study used bicycle involvement as the independent variable. Like the descriptive model previously described, if a bicycle was listed as the "at fault" party, it was considered to be involved in the incident. If a bicycle was involved, it was listed as (1). If a bicycle was not involved it was listed as (0). This provided a constant of 0.211, T-score of 2.456 and significance of 0.015.

The first dependent variable used in the linear regression was the San Fernando Street Improvement Project. Incidents that occurred from January 2014 though June of 2017 were listed as (1). Incidents that occurred from April of 2010 to October of 2013 were listed as (0). The beta for his variable was -0.64 with a T-score of -1.523 and significance of 0.129.

The next dependent variable was whether an injury or fatality occurred. If at least one person was injured, or killed, the incident was given a (1). If there were no injuries reported, it was listed as a (0). The beta for injuries and fatalities was 1.46. The T-score was 3.468 with a significance of 0.001.

The data set used three different descriptions of weather: clear, cloudy, and raining. Clear or cloudy conditions were considered to be similar and combined. Incidents that occurred with clear or cloudy conditions were given a binary description of (1). Incidents that occurred in rainy conditions were given a (0). The beta for weather conditions was 0.707 with a T-score of 1.814 and significance of 0.071.

The data also had three descriptions for light conditions: day, dusk/dawn, and dark with light. This was further broken down into two separate dependent variables to analyze whether day and dusk/dawn affected the likelihood of an incident. For the first variable, if the accident occurred in the day it was given a (1). If it occurred during dusk/dawn or night, it was given a (0). The beta for this was 0.29 with a T-score of 0.648 and significance of 0.517. For the second light variable, if the accident occurred during the twilight hours, the binary description was (1). Accidents during the day or night were given a (0). The beta for dusk/dawn was 0.076 with a T-score of 0.737 and significance of 0.462.

The regression analysis then looked at roadway conditions. If the accident occurred when the roadway was dry, the incident was given a (1). If the roadway was wet, the incident was given a (0). The beta for roadway conditions was -0.792 ,with a T-score of -2.069 and significance of 0.039.

The last dependent variable used was alcohol impairment. Although this study did not set out to determine whether alcohol increased the likelihood of an accident, it was available and included in the study to reduce statistical noise. Impairment was determined by the violations issued to parties involved. During the time periods studied there were only 12 instances where a party involved was under the influence of alcohol. If the driver was arrested for driving under the influence, the binary variable was (1). If alcohol was not involved, the incident was given a (0). The beta for impairment was -0.087, with a T-score of -0.760, and significance of 0.448.

Figure 10: Model Summary of Linear Regression

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.246[a]	.060	.041	.380

a. Predictors: (Constant), Alcohol Involved, Dry, Injury / Fatality, Dusk / Dawn, Before/After, Day, Clear

Source: City of San Jose, 2018.

The most important output from Figure 10 is R-squared. Read as a percentage, R-squared is used to determine how often the dependent variables affect the independent variable. A larger value for R-squared indicates a greater relationship between the independent and dependent variables. The regression determined that the r-squared value is 0.06. This indicates that the project's completion, injuries, weather, light, road conditions and alcohol influenced the likelihood of a bicycle's involvement 6% of the time.

ANALYSIS

Outcome Evaluation

When comparing the findings in Figures 5 through 8 (City of San Jose, 2018), the descriptive model showed a reduction in total incidents, incidents with injuries, bicycle involved incidents, and bicycle involved incidents that resulted in an injury. While the numbers and averages of incidents, injury incidents, bicycle incidents, and bicycle incidents with an injury are important in determining the effects of the San Fernando Street Improvement Project, they do not tell the full story. The standard deviation, margin of error, and 95% confidence intervals show whether there is a meaningful variation between the two periods. The standard deviation is used as a "measure of the dispersion of a set of data from its mean. It is calculated as the square root of variance by determining the variation between each data point relative to the mean. If the data points are further from the mean, there is higher deviation within the data set" (Standard Deviation, n.d.). The margin of error is "the range of values below and above the sample statistic in a confidence interval" (Margin of Error, n.d). The standard deviation and margin of error are used to calculate the 95% confidence interval. The range of the 95% confidence interval "means that should you repeat an experiment or survey over and over again, 95 percent of the time your results will match the results you get from a population" (How to Find a Confidence Interval, n.d). In this study, if the pre-completion lower bound and post-completion upper bound did not overlap, it would be said that 95% of the time, the averages were at least two standard deviations away from each other and therefore significant.

Total incidents dropped from 196 to 148 (24.48%) after the project was completed. Before the project's completion, there were up to 27 incidents per quarter, compared to 18 after the completion. The quarter with the lowest number of incidents dropped from 6 to 2. The average number of incidents per quarter dropped by 3.43 from 14 to 10.57, with the standard deviation dropping from 5.46 to 3.75. The upper bounds of the 95% dropped from 16.81 to 11.19, and lower bounds dropped from 12.44 to 8.70. The overlap of the pre-completion lower bound and post-completion upper bound led to the conclusion that any given period after the San Fernando Street Improvement Project's completion is not guaranteed to be safer.

As a total figure, injuries dropped from 73 to 63. However, the percentage of accidents in which at least one injury occurred rose from 37.34 to 43.57%. It is important to remember that these percentages include all accidents that occurred in the vicinity of the San Fernando Street Improvement Project. The maximum number of injury incidents within a quarter also rose from 7 to 8 after the completion of the project, while the minimum remained at zero. The average number of injury accidents per quarter dropped from 5.21 to 4.5, but the standard deviation rose from 1.42 to 2.62. This indicates that the number of injuries per period had a higher variance after the project's completion. The upper bound of the 95% confidence interval slightly dropped from 5.96 before to 5.87 after the project was completed. The lower bound of the 95% confidence interval rose from 0.54 to 1.84 after the project. This indicates that while accidents are less likely to occur, those involved in accidents are more likely to sustain injuries.

The number of incidents involving a bicycle dropped from 40 to 23 (42%) after the project's completion. As a percentage, incidents that involved a bicycle dropped from

20.41 to 15.54%. In both periods, the maximum and minimum number of incidents was 6 and 0, respectively. The average number of bicycle incidents per quarter also dropped from 2.86 to 1.64, and the standard deviation dropped from 2.32 to 1.69. The upper bound of 95% confidence interval dropped from 4.07 to 2.53. The lower bound of 95% confidence interval also dropped from 2.53 to 0.77. Once again this means that while the total number, and average number of bicycle incidents dropped, it cannot be said for certain that there were less bicycle accidents in any given quarter after the project's completion.

The number of bicycle-involved incidents in which an injury occurred dropped from 21 to 17 (14%). However, the percentage of injuries in bicycle-involved accidents rose from 52.5% to 73.91%. In both periods, there was a maximum of 4 bicycle-involved incidents in which an injury occurred and minimum of 0. The average number of these incidents per quarter dropped from 1.5 to 1.21, and the standard deviation dropped from 1.51 to 1.31. The upper bound of the 95% confidence interval dropped from 2.29 to 1.9. The lower bound of the 95% confidence interval also dropped from 0.71 to 0.53. The lower bound of the pre-completion and upper bound of the post completion overlapped, meaning that any given quarter after the project's completion was not guaranteed to experience fewer injuries in bicycle-involved accidents.

Linear Regression

The descriptive model shows a less than significant decline in incidents, but knowing which factors contributed to bicycle accidents may help planners further understand why accidents are happening to improve design elements of future projects. It will also examine correlation vs. causation between variables in the linear regression.

The regression shown in Figure 9 (City of San Jose, 2018) first analyzed whether the project affected bicycle-involved incidents. The beta of -0.64 actually shows that the project contributed to greater likelihood of incidents. However, the T-score was -1.523 and significance was 0.129. This means that the beta showing a negative correlation is not significant enough to confidently say that there was an adverse effect. A significant positive correlation would mean that the project was an effective or beneficial use of tax dollars. A negative correlation would make it difficult for the city to justify the project from a return in investment perspective.

Next, the regression looked into the relationship between injuries and bicycle accidents. The beta of 0.164 showed that when a bicycle is involved in an incident, it is more likely than not that there will be an injury. The T-score of 3.468 and significance of 0.001 shows that this is an extremely strong correlation. However, this correlation does not come as a surprise, as it confirms that because of their smaller mass and lack of mandated safety requirements, bicycles are not as safe as motor vehicles in accidents.

The beta for clear and cloudy weather conditions was 0.707. The T-score was 1.814 with a significance of 0.071. The T-score and significance show tat weather was correlated with accidents at an almost significant level, but it cannot be said for certain that conditions affect the likelihood of a bicycle accident.

Light conditions also did not have a significant impact on the likelihood of bicycle incidents. For daylight, the beta was 0.29, with a T-score of 0.648 and significance of 0.517. For dusk and dawn, the beta was 0.076, with a T-score of 0.737 and significance of 0.462. Although it may be expected that lighting conditions would impact the likelihood of an accident, part of the project entailed installing LED lighting along San Fernando Street, and the improved lighting may have prevented accidents.

Although weather did not affect the likelihood of an incident, roadway conditions did. The beta for dry road condition was -0.792, with a T-score of -2.069 and significance of 0.039. This means that wet roadways were more dangerous than their dry counterparts. The regression cannot show why this is the case, but nonetheless shows that wet roads are a major factor in bicycle accidents.

The last variable in the regression was driver impairment. The beta was -0.087, with a T-score 0.760 and significance of 0.448. While driving under the influence has been proven to be very dangerous and reckless (CDC, 2017), it did not influence the likelihood of a bicycle accident on San Fernando Street during the periods analyzed in this study.

When interpreting the results of the regression, the last important to item to discuss is the R-squared shown in Figure 10 (City of San Jose, 2018). As stated in the findings, the value of the R-squared is 0.06. This means that the variables in the data set only account for 6% of all incidents, and that there are other factors at play. The answer to what impacts the likelihood of a bicycle accident may be behavior that was not included in the data set, or behavior that is not measurable.

Limitations

The data and methods used in this study have a few inherent limitations that need to be discussed. The first limitation of this study is that the data being reported by San Jose's Department of Transportation only contained incidents that were reported. Minor incidents without injuries or severe damage to a vehicle may have consisted of parties exchanging insurance information without creating an incident report. There is no way to determine how many of these minor incidents took place, and there is a possibility that the variables of the linear regression may have contributed to them.

The next limitation of this study is not having a method of recording incidents that nearly happened. If the improvements worked as intended, many incidents that nearly happened were avoided. Without having a way to determine, measure, or analyze these incidents, it is difficult to make a definitive affirmation of the extent that the San Fernando Street Improvement Project reduced accidents and injuries for motorists and cyclists.

One factor affecting the thoroughness of the study is that the City of San Jose does not have automobile and bicycle counts along San Fernando Street. The insignificant decline may have simply been the result of less usage. Contrarily, usage may have drastically increased during the periods studied. If usage did increase during this period, the accident rates could be significantly lower. Periodically installing automated counting systems following recommendations of *Estimating Annual Average Daily Bicyclists* (Nordback, 2013) under varying conditions would provide a more complete answer to this study's question.

The last limitation is the small geographic area used in the study. The small area was used in order to reduce potential statistical noise by controlling for surroundings. The results of a citywide analysis would be beneficial to planners across the world, but would have required significantly more resources.

CONCLUSION

While the San Fernando Street Improvement Project failed to significantly contribute to San Jose's goal of reducing bicycle accidents by 50%, it is important to reiterate that this project is part of a bigger network. The entirety of the project's benefits may not be fully recognized, as this project is just one element of San Jose's Bike Plan 2020, which has not been fully implemented. Roadways across the downtown may become significantly safer in years to come.

Ideas for Further Research

Although the linear regression showed an insignificant relationship between wet and dry years, it would be beneficial to further understand the relationship between weather and bicycle incidents. Using a descriptive model and regression to interpret how wet and dry years affect accident and injury rates may influence elements of future projects, as the level of precipitation during California's winters has been unpredictable in recent years. Since road conditions were considered significant, more research into how the dangers of wet roads can be combated could help increase bicycle safety.

A similar study should be conducted a few years after the completion of San Jose's "Better Bikeways" project along the same stretch of road. If protected bikeways prove to significantly increase rider safety over enhanced bikeways, San Jose will likely want to install them throughout the city. If a similar study were to be conducted in the future, it would be beneficial to begin measuring usage in order to gather a more complete understanding of the demand for bikeways, and the ratios of accidents per use.

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