

© Copyright 2020

Daniel Osterhage

# **Seattle Vision Zero Street Improvements to Reduce Traffic Related Injuries and Deaths: What is the Economic Impact to Local Businesses?**

Daniel Osterhage

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Public Health

&

Master of Urban Planning

University of Washington

May 2020

Committee:

Andrew Dannenberg

Paul Fishman

Programs Authorized to Offer Degrees:

Public Health and Urban Design & Planning

**University of Washington**

**Abstract**

**Seattle Vision Zero Street Improvements to Reduce Traffic Related Injuries and Deaths:  
What is the Economic Impact to Local Businesses?**

Daniel Osterhage

Chairs of the Supervisory Committee:

Affiliate Professor, Dr. Andrew Dannenberg  
Department of Environmental & Occupational Health Sciences and  
Department of Urban Design and Planning

&

Professor, Dr. Paul Fishman  
Department of Health Services

Vision Zero is a road safety project, originating in Sweden, with the goal of eliminating all road traffic fatalities and injuries through street design changes.(1)(2) While proven to lead to improved safety, city transportation planners often meet opposition from business owners when implementing Vision Zero projects.(3) Many business owners oppose Vision Zero safety projects because of the belief that changes to adjacent roads will negatively impact sales.(3)

The City of Seattle adopted a Vision Zero program in 2015 with the goal of ending all traffic related deaths and injuries by 2030. While Vision Zero brought a new name to and expanded scope for street design safety projects, Seattle implemented Vision Zero type safety projects decades before the uptake of the new program.(1) This research seeks to better define the relationship between Seattle's past Vision Zero road treatments and their impact on the economic vitality of retail, food, and service based businesses in Seattle.

The study selected seven diverse Vision Zero projects throughout Seattle and gathered the taxable sales data for the surrounding retail, food, and service based businesses. For each study location, 2-3 matched locations, that did not have Vision Zero treatments within the study timeframe, were selected to compare taxable sales data trends. The larger geographic area in which study and

control sites are located acted as an additional comparison for study sites. Data analysis consisted of aggregated trend analyses and t-tests.

The results found no negative impact on economic vitality for adjacent retail, food, and service businesses in all seven of the Vision Zero study sites. Three sites showed significant positive impacts. These findings suggest that Vision Zero improvements may have a neutral or positive economic impact on adjacent retail, food, and service businesses.

This research serves to inform transportation practitioners and implementers in Seattle about the economic impacts of Vision Zero projects on businesses. Better information about Vision Zero economic impacts will set expectations, ease tensions, and possibly move the implementation of projects forward to achieve the Vision Zero goal of eliminating traffic related injuries and fatalities

## TABLE OF CONTENTS

Chapter 1. Introduction .....	1
1.1 Crashes Related to Motor Vehicles and a Need for Safety.....	1
1.2 Research Problem .....	1
1.3 Purpose Statement.....	2
Chapter 2. Literature Review .....	3
2.1 Vision Zero Origins .....	3
2.2 Vision Zero Project Goals and Intervention Types.....	3
2.3 Analyzing Vision Zero Projects.....	5
2.4 Potential Benefits of Vision Zero Projects for Businesses .....	6
2.5 Economic Measures of Vision Zero Projects.....	7
2.6 Key Takeaways from the Literature Review .....	12
Chapter 3. Methods.....	13
3.1 Overview.....	13
3.2 A Matched Case Study Design .....	13
3.3 A Retrospective and Longitudinal Design.....	14
3.4 Selection of Study Sites .....	14
3.5 Selection of Control Sites .....	15
3.6 Selection of Larger Geographic Control Areas .....	17
3.7 Data Collection .....	18
3.8 Selection of NAICS Codes .....	19
3.9 Adjusting for Inflation .....	19

3.10	Data Analysis Plan.....	20
Chapter 4. Results and Discussion of Case Studies.....		21
4.1	Results for Study Site 1: 2 <sup>nd</sup> Ave.....	23
4.2	Results for Study Site 2: Rainier Ave S.....	29
4.3	Results for Study Site 3: Broadway.....	35
4.4	Results for Study Site 4: Stone Way N.....	41
4.5	Results for Study Site 5: Aurora Ave N.....	47
4.6	Results for Study Site 6: Greenwood Ave N.....	53
4.7	Results for Study Site 7: Bell St.....	59
Chapter 5. Limitations.....		64
Chapter 6. Conclusions.....		66
Chapter 7. Works Cited.....		68

## LIST OF FIGURES

Figure 3.6 Seattle’s City Council Districts.....	17
Figure 4.0 Vision Zero Case Study Sites.....	21
Figure 4.1 Study Site 1: 2 <sup>nd</sup> Ave.....	22
Figure 4.1.1 2 <sup>nd</sup> Ave Before Project Implementation .....	23
Figure 4.1.2 2 <sup>nd</sup> Ave After Project Implementation .....	23
Figure 4.1.3 Change in Sales Aggregated Trend Analysis: Study Site 1 .....	26
Figure 4.2 Study Site 2: Rainier Ave.....	28
Figure 4.2.1 Rainier Ave South Before and After Project Implementation .....	29
Figure 4.2.2 Change in Sales Aggregated Trend Analysis: Study Site 2 .....	32
Figure 4.3 Study Site 3: Broadway .....	34
Figure 4.3.1 Broadway Before Project Implementation .....	35
Figure 4.3.2 Broadway After Project Implementation .....	35
Figure 4.3.3 Change in Sales Aggregated Trend Analysis: Study Site 3 .....	38
Figure 4.4 Study Site 4: Stone Way N .....	40
Figure 4.4.1 Stone Way N Before Project Implementation .....	41
Figure 4.4.2 Stone Way N After Project Implementation .....	41
Figure 4.4.3 Change in Sales Aggregated Trend Analysis: Study Site 4 .....	44
Figure 4.5 Study Site 5: Aurora Ave N .....	46
Figure 4.5.1 Aurora Ave N Before Project Implementation .....	47
Figure 4.5.2 Aurora Ave N After Project Implementation .....	47
Figure 4.5.3 Change in Sales Aggregated Trend Analysis: Study Site 5 .....	50
Figure 4.6 Study Site 6 .....	52

Figure 4.6.1 Greenwood Ave N Before Project Implementation .....53

Figure 4.6.2 Greenwood Ave N After Project Implementation .....53

Figure 4.6.3 Change in Sales Aggregated Trend Analysis: Study Site 6 .....56

Figure 4.7 Study Site 7: Bell Street .....58

Figure 4.7.1 Bell Street Before Project Implementation .....59

Figure 4.7.2 Bell Street After Project Implementation .....59

Figure 4.7.3 Change in Sales Aggregated Trend Analysis: Study Site 7 .....62

Figure 6.1 Change in Sales Aggregated Trend Analysis: All Study Sites .....66

## LIST OF TABLES

Table 2.3.1 Signs, Markings/Operational Countermeasures Crash Reduction Factors .....	4
Table 2.3.2 Geometric Countermeasure Crash Reduction Factors .....	4-5
Table 2.3.3 Signs, Markings, Operational Countermeasure Crash Reduction Factors .....	5
Table 4.1.1: Study and Control Sites .....	25
Table 4.1.2: Change in Sales from Baseline/Improvement Year .....	25
Table 4.2.1: Study and Control Sites .....	31
Table 4.2.2: Change in Sales from Baseline/Improvement Year .....	31
Table 4.3.1: Study and Control Sites .....	37
Table 4.3.2: Change in Sales from Baseline/Improvement Year .....	37
Table 4.4.1: Study and Control Sites .....	43
Table 4.4.2: Change in Sales from Baseline/Improvement Year .....	43
Table 4.5.1: Study and Control Sites .....	49
Table 4.5.2: Change in Sales from Baseline/Improvement Year .....	49
Table 4.6.1: Study and Control Sites .....	55
Table 4.6.2: Change in Sales from Baseline/Improvement Year .....	55
Table 4.7.1: Study and Control Sites .....	61
Table 4.7.2: Change in Sales from Baseline/Improvement Year .....	61

# ACKNOWLEDGEMENTS

A special thanks to the following people:

Dr. Andrew Dannenberg – Thesis Chair

Dr. Paul Fishman – Thesis Chair

Jonathan Dong – SDOT Supervisor

SDOT Vision Zero Program

Anna Yamada – WA-DOR Research Specialist

Dr. Brandon Born – Research Methods Course Instructor

Peter Dunn – Research Methods Course Instructor

My family

My partner, Erica Orange

# Chapter 1. INTRODUCTION

## 1.1 CRASHES RELATED TO MOTOR VEHICLES AND A NEED FOR SAFETY

In the United States, close to 40,000 people are killed and another 4.4 million people are injured every year in crashes related to motor vehicles.(6)(7) This includes people hit when walking, biking, and rolling. Crashes related to motor vehicles are a leading cause of death for people aged 1-54 and disproportionately impact people of lower socioeconomic status.(7) Although Washington has a lower per capita and per vehicle miles traveled death rate than other states, preventable crashes related to motor vehicles killed between 536 and 566 Washingtonians between 2015 and 2018.(8)(9) An additional 2,000 Washingtonians are seriously injured in crashes every year.(10) These statistics create the impression that traffic fatalities and injuries are an accepted consequence of everyday life. However, injuries and deaths from crashes related to motor vehicles can be prevented through safety programs such as Vision Zero that implement street design changes.(1)(2)

## 1.2 RESEARCH PROBLEM

Vision Zero is a road safety project started in 1997 in Sweden with the goal of eliminating all road traffic fatalities and injuries through street design changes.(1) Safer roads are achieved through street design changes such as implementing speed reductions, building road diets, increasing pedestrian crossings, accounting for driver error in design, and creating roads for all users. (2)(11) In 2005, the estimated economic loss from U.S. road traffic crashes reached \$167 billion.(12) To combat the scourge of crashes related to motor vehicles, countries and cities around the world implemented Vision Zero projects, successfully reducing deaths and injuries.(11)(13)(14) In 2015,

the City of Seattle adopted a Vision Zero program with the goal of ending all traffic related deaths and injuries by 2030. While Vision Zero brought a new name to and expanded scope for street design safety projects, Seattle implemented Vision Zero type safety projects decades before the uptake of the new program.(1)

While proven to lead to improved safety, city transportation planners often meet opposition from business owners when implementing Vision Zero projects.(3) Opposition comes from a belief that changes to adjacent streets will deter customers and negatively impact a business' sales.(3) Opposition from such a significant stakeholder group creates a substantial obstacle to implementing Vision Zero projects. Transportation planners, government officials, and politicians can be influenced to abandon street design projects because of vocal opposition from local businesses. (3)

In addition to making roads safer, Vision Zero changes make places more walkable, accessible, and desirable to frequent.(15) Instead of negatively impacting sales, Vision Zero treatments could promote the economic wellbeing of businesses in the years following project implementation. Street design changes are most likely to impact retail, food, and service businesses.(4)(5) This study seeks to better understand the relationship between Vision Zero projects and the economic vitality of retail, food, and service based businesses in Seattle.

### 1.3 PURPOSE STATEMENT

The goal of this research is to inform transportation practitioners and implementers in Seattle about the economic impacts of Vision Zero projects on businesses. Better information about Vision Zero economic impacts will set expectations, ease tensions, and possibly move the implementation of projects forward to achieve the Vision Zero goal of eliminating traffic related injuries and fatalities.

## Chapter 2. LITERATURE REVIEW

### 2.1 VISION ZERO ORIGINS

The foundational Vision Zero literature explores the history of how personal vehicles took over as the prevailing mode of transportation after World War II.(14,16) After World War II, cars speeds increased and highway systems expanded, leading to a stark rise in serious crashes related to motor vehicle, which continued through the following decades.(16)

This literature questions accepting road traffic crashes as a norm. Ezra says that decisions about street design should be based on facts and research, not on opinions and the status quo.(17) Hakkert and Gitelman speak to the evolution that some Scandinavian governments went through in asking for further research about crashes related to motor vehicles, shaping public opinion about the problem, increasing demand to act, and beginning to implement projects from a systems approach.(16) Vision Zero evolved out of these processes and began in Sweden in 1997.(16)

### 2.2 VISION ZERO PROJECT GOALS AND INTERVENTION TYPES

Vision Zero's goal is clear: "that no-one is killed or seriously injured as a consequence of road accidents within the road transport system".(18) Vision Zero's other objectives are: "Achieve slow speeds for motor vehicles; attract investment, redevelopment, and new businesses; create aesthetically beautiful streets; create safe and attractive streets; enhance the street environment; improve social links; meet the needs of people working, playing, and residing in an area; increase access for all modes of transportation; increase the safety and the perception of safety for non-motorized street users; promote pedestrian, bicycle, and transit use; raise property values; reduce collision frequency and severity; reduce cut-through auto traffic; reduce the need for traffic enforcement."(3)

The Federal Highway Administration (FHA) created a *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes*. Vision Zero projects are typically made up of one or a combination of these components. The toolbox outlines specific street design changes and their expected risk reduction:

Table 2.3.1 Signs, Markings/Operational Countermeasures Crash Reduction Factors (CRF) (19)

Countermeasure(s)	Crash Severity	All Crashes	Pedestrian
Add exclusive pedestrian phasing	All		34%
Improve signal timing [to intervals specified by the ITE Determining Vehicle Change Intervals: A Proposed Recommended Practice (1985)]	Fatal/Injury		37%
Replace existing WALK / DON'T WALK signals with pedestrian countdown signal heads	All		25%
Modify signal phasing (implement a leading pedestrian interval)	All		5%
Remove unwarranted signals (one-way street)	All		17%
Convert permissive or permissive/protected to protected only left-turn phasing	All	99%	
Convert permissive to permissive/protected left-turn phasing	All	16%	

The standard error for all CRFs is 12

Table 2.3.2 Geometric Countermeasure Crash Reduction Factors (19)

Countermeasure(s)	Crash Severity	All Crashes	Pedestrian
Convert unsignalized intersection to roundabout	Fatal/Injury		27%
Install pedestrian overpass/underpass	Fatal/Injury		90%
	All		86%
Install pedestrian overpass/underpass (unsignalized intersection)	All		13%
Install raised median	All		25%
Install raised median (marked crosswalk) at unsignalized intersection	All		46%
Install raised median (unmarked crosswalk) at unsignalized intersection	All		39%
Install raised pedestrian crossing	All	30%	
	Fatal/Injury	36%	
Install refuge islands	All		56%

Install sidewalk (to avoid walking along roadway)	All		88% *
Provide paved shoulder (of at least 4 feet)	All		71% *
Narrow roadway cross section -road diet (e.g. four lanes to three lanes)	All	29%	

\* This only applies to “walking along the roadway” type crashes  
The standard error for all CRFs is 12

Table 2.3.3 Signs, Markings, Operational Countermeasure Crash Reduction Factors (19)

Countermeasure(s)	Crash Severity	All Crashes	Pedestrian
Add intersection lighting	Injury	27% *	
	All	21% *	
Add segment lighting	Injury	23% *	
	All	20% *	
Improve pavement friction (skid treatment with overlay)	Fatal/Injury		3%
Increase enforcement **	All		23%
Prohibit right-turn-on-red	All	3%	
Prohibit left-turns	All		10%
Restrict parking near intersections (to off-street)	All		30%

\* This applies to nighttime crashes only

\*\* This applies to crash reduction on corridors where sustained enforcement is used related to motorist yielding in marked crosswalks combined with a public education campaign

The standard error for all CRFs is 12

## 2.3 ANALYZING VISION ZERO PROJECTS

Methods commonly used to analyze Vision Zero projects include road safety evaluations, safety frameworks, and speed measurements.(20–22) Road safety evaluations and frameworks look at standardized measures to assess streetscapes before and after a Vision Zero project.(20) The measures are typically focused on street use and safety.(20) Speed is typically a successful way of determining the effectiveness of Vision Zero treatments, as it can be measured before and after implementation of a project and it is a good proxy for the danger of a potential crash.(23) Crashes at lower speeds, especially for those involving pedestrians and persons rolling, result in much

greater instances of survival when compared to higher speed crashes.(23) Lower speeds also help to reduce the risk and frequency of crashes.(24)

The literature extensively examines reduced deaths and injuries attributable to Vision Zero projects.(11)(13)(14) Berg and Jamroz, for example, examine the strengths and weaknesses of country specific Vision Zero projects.(2,25) The Institute for Transportation Engineers lay out the most up to date ways to design safe, walkable urban streets.(26) Overall economic crashes related to motor vehicles can be seen in disability adjusted life years, showing massive losses each year in the United States- \$167 billion in 2005.(12)

While Vision Zero projects help to reduce deaths and prevent overall economic loses, the typical Vision Zero measurement does not include some of the externalities that might result from the implementation of a project, such as the economic impact on adjacent businesses.

## 2.4 POTENTIAL BENEFITS OF VISION ZERO PROJECTS FOR BUSINESSES

Drennen succinctly lays out six ways that Vision Zero traffic calming projects could directly and indirectly benefit small businesses in urban areas:

1. “Economic Revitalization and Property Values –Traffic calming can increase residential and commercial property values, which attracts wealthier residents to the area (gentrification) and can increase retail sales and bring economic revitalization to a commercial corridor.”(3)
2. “Attractiveness and Safety – Traffic calming creates more attractive environments, reduces auto speed, and increases safety for pedestrians, bicyclists, drivers, and other users of the street, which is good for business.”(3)

3. “Sales and Attracting Customers – Traffic calming encourages local residents to buy in their own neighborhoods, and also attracts customers from a wider area due to reduced travel time, hassle, and cost. Traffic calming can also help people live less car-dependent lifestyles, which will increase the amount of discretionary income they can spend on things other than transportation.”(3)

4. “Parking – Most businesses are concerned about the quality and quantity of customer parking and access for delivery trucks. However, too large a supply of subsidized, on-street parking can harm businesses.”(3)

5. “Impact on Employees – Poor bicycle, pedestrian, and transit conditions can harm businesses by losing worker productivity and time to gridlock, and by impairing employee recruitment. Conversely, improved transportation facilities can provide more convenience for employees.”(3)

6. “Construction and Costs – Traffic calming projects often require only minimal “down time” for construction, and most do not require any investment from business owners.”(3)

## 2.5 ECONOMIC MEASURES OF VISION ZERO PROJECTS

Less attention has been paid to the economic impact of Vision Zero projects on surrounding businesses. Past studies used on-street intercept surveys of customers and business owners in an attempt to ascertain an association of safety project impacts on businesses.(5,27–30) Drennen’s survey sought to measure the economic impact on adjacent businesses of a bike lane on San Francisco’s Valencia Street; however, the analysis has several limitations. First, researchers administered surveys to business owners several years after the implementation of street design changes. Second, the study did not provide comparative data through either a “pre-post” analysis at the study location or a survey for a matched location that did not receive the treatment. Despite

these concerns, Drennen's analysis provides a roadmap for how local businesses may benefit from Vision Zero projects and highlights the opportunity for more robust study designs to test their hypothesis.

In 2009, Sztabinski used similar methods to analyze the potential impacts of a future bike lane on the Bloor-Danforth corridor in Toronto.(30) The survey found that customers arrived most frequently by foot and bicycle and those same people spent the most money per month.(30) Additionally, the study found that a majority of businesses supported expanding the sidewalks and putting in bike facilities.(30)

While encouraging results, neither Sztabinski or Drennen proved street design changes resulted in improved economic conditions for retail, food, and service businesses. Furthermore, both surveys represent one point in time and are subject to selection bias and recall bias.(31,32) While Drennen's and Sztabinski's work laid a foundation, the sub-field needed more rigorous methodologies. As Drennen states: "Econometric studies (especially based on annual tax receipts, assessed property values, and rents for multiple jurisdictions) could perhaps more definitively determine what benefits traffic calming brings to urban small businesses."(3)

In 2014, the New York City Department of Transportation (NYCDOT) revolutionized how to measure the economic impact of street design changes in *The Economic Benefits of Sustainable Streets*.(29) Addressing the weaknesses of prior studies, the authors say "Most of the existing data on the impacts of changes to street environments on local businesses is weakened by its qualitative nature or lack of comprehensiveness. Another major weakness of many prior studies is that they do not compare conditions both before and after a change is made, so it is impossible to know what, if anything, would have happened in the absence of the improvement being examined."(29)

The New York City study became the first of its kind to use retail sales tax data to measure the impact of street design changes on economic vitality. Retail sales tax data are reliable and can be measured in time, therefore serving as a reliable proxy for the impact of street design change on businesses.(29)

The NYCDOT authors used an aggregated trend analysis which they state, “does not prove causality between the street improvement projects and any resulting economic changes.” However, a majority of the street design projects analyzed showed a non-statistically significant, positive association with improved economic success. The authors determine that, “for those locations that had positive results as compared to their borough and their comparison sites, it is reasonable to conclude that their gain in retail sales can at least in part be attributed to changes stemming from the higher quality street environment.”(33) Being the first of its kind, lacking in statistical validity, and taking place in the biggest city in the United States, additional research was required to validate the study design. Other studies quickly began to emulate and add to the study design. Almost in tandem, Rowe mirrored “The Economic Benefits of Sustainable Streets” in his work *Bikenomics*.(32) Set in Seattle, Rowe attempted to replicate the NYCDOT study with fewer resources. The research looked at two study sites that added bike lanes and compared each to several control sites and a larger business area. Importantly for this study, Rowe showed that taxable sales data are available in Washington and that this type of research can be accomplished in Seattle. However, Rowe ran into similar issues with statistical validity as he continued to use the aggregated trend analysis through sales indexes.

Deviating slightly from Rowe and NYCDOT, Poirier wrote a 2018 study called *Bicycle Lanes and Business Success: A San Francisco Examination*. Using longitudinal data from the National Establishment Time-Series (NETS) dataset, Poirier looked at business sales in three corridors that

implemented bike lanes. One of the biggest additions to the literature is the inclusion of impacted businesses based on specific NAICS (North American Industry Classification System) business codes.(27) Another addition is the analysis of sales data by number of employees in addition to sales per business, establishing a creative way to measure the productivity of a business.(27) Interestingly, Poirier's data are based on block groups and thus encapsulate businesses that are several blocks away from the street improvement. Poirier makes the argument that street design changes might impact businesses not immediately adjacent to a project.(27) The study adjusts for inflation and utilizes a change over time analysis method looking at absolute dollar differences and percentage change differences.(27) Poirier makes the argument that the percentage change figures are more significant as they help to display the variation in sales compared to the beginning of the study.(27) The study found the percentage change figures, while descriptive, were not statistically valid. The study also fails to match study sites to control sites, as done in previous studies.

A year later Poirier wrote another article called *Bikes or Bust? Analyzing the Impact of Bicycle Infrastructure on Business Performance in San Francisco*. The article again used NETS data to determine the economic impact of bicycle infrastructure on surrounding businesses while expanding on the previous study design and data analysis. In the analysis, Poirier adjusted for inflation and utilized an ordinary least squares regression to compare the change in sales from the years before to the years after project installation.(5) Several other improvements strengthened this study. First, study sites are compared to areas that did not receive treatment. Second, to help decrease bias, the study analysis removed outlying businesses. Third, and formative to this study, Poirier used NAICS codes to identify businesses that street design changes are likely to impact: “storefront retail, food service, and other service-providing businesses.”(5) One problematic

component of this study is the removal of businesses that closed before or after the installation of the bicycle facilities. Excluding businesses unlikely to do well because of the street design change might bias the results. The article concluded that bicycle infrastructure generally did not impact businesses, positively or negatively, with a few exceptions.(5)

The most recent study, Liu, Shi, and Green's 2019 *National Street Improvement Study* is the most comprehensive study in this subfield. The study looked at six U.S. cities with several study sites in each city, including Seattle, and used control sites to compare results to study sites. Three datasets and three analysis techniques helped determine the impact of street design changes on business. One of the datasets examined sales tax. The authors acknowledged a weakness of sales tax data is that it might leave out certain food categories or goods that are exempt from tax and that it may be difficult to distinguish between industry sectors without NAICS data.(4) The three analysis techniques included: 1) an aggregated trend analysis 2) a difference-in-difference approach and 3) an interrupted time series analysis.(4) The difference-in-difference approach is a way to determine statistical significance between the trajectories of business in the study and control groups while the aggregated trend analysis allows for excellent data visualization. (4) The interrupted time series analysis shows an estimation of the impact of a street design change on a trend line; however, it requires longer periods of data availability.(4) The authors concluded the street design changes in the Seattle study sites did not have significant impacts on businesses, nor significant positive impacts on businesses. Notably, findings did not include significant negative impacts on businesses.(4)

## 2.6 KEY TAKEAWAYS FROM THE LITERATURE REVIEW

Several takeaways from a review of the literature influence the design of this study. First, traffic related deaths and injuries are unwanted, and everyone desires their reduction. Second, Vision Zero projects reduce driving speeds, ultimately translating into fewer fatalities and injuries for all users of the road. Third, Vision Zero projects increase the walkability, accessibility, and desirability of an area. Fourth, road design plays a large role in crashes related to motor vehicles; poorly designed roads lead to more crashes and better design leads to fewer crashes. Fifth, NAICS codes are acceptable proxies for selecting businesses that focus on retail, food, and service. Lastly, retail sales tax data, or a comparable measure such as taxable sales, are a strong indicator of the economic vitality of retail, food, and service businesses in an area over time. It is important to note that while taxable sales are a robust indicator of economic vitality, they are not necessarily always representative of profits or equity. If an area is going through gentrification, a business' taxable sales could increase while rent and costs simultaneously increase, resulting in reduced profits and the displacement of existing businesses and residents.

## Chapter 3. METHODS

### 3.1 OVERVIEW

We assessed the impact on taxable sales for seven Vision Zero projects within the City of Seattle relative to comparator locations that had no safety projects. The study aimed to measure the impact of Vision Zero street improvements on the economic vitality of a surrounding area through the proxy of taxes on retail sales. Most of this study's methodologies are adapted and modified from past literature.

Data for this study are taxable sales for retail, food, and service focused businesses. The research team obtained all data from the Washington State Department of Revenue (WA-DOR). As part of Washington State law, all businesses are required to report on their taxable sales. This is a ubiquitous reporting method that is compiled on a regular basis for almost all businesses. As such, taxable sales are a good reflection of the true sales for businesses and can be considered a reliable data source.

### 3.2 A MATCHED CASE STUDY DESIGN

Urban streets are part of complex urban system. It is difficult to attribute increased or decreased business vitality solely to a street design change because of all the potential contributing factors influencing an area. Therefore, it is important to control for as many factors as possible in the study design. The research team identified seven study sites that received Vision Zero treatments. The research team matched each study site with 2-3 control sites based on specific criteria. Importantly, control sites did not have Vision Zero street design changes implemented during the study period. In addition to the control sites, the research team obtained data for Seattle City Council Districts,

the larger geographic areas in which the study sites and control sites reside. Control sites and Seattle City Council Districts both act as controls for the study sites.

### 3.3 A RETROSPECTIVE AND LONGITUDINAL DESIGN

The research team obtained taxable sales data for one year leading up to project implementation and up to three years post implementation. A retrospective design was implemented, to reduce the time and resources required to wait two to three years to measure the results of a new Vision Zero projects. WA-DOR has an existing “study file” for City of Seattle annual taxable sales data from 2006-2016. The “study file” allowed for a less labor-intensive data request from the WA-DOR. The 2006-2016 timeframe reduced the possible Vision Zero study sites, as data are needed for a year prior and between two and three years after implementation.

For example, a project implemented in 2006 could not be selected due to a lack of prior data and, likewise, a 2016 project could not be selected due to a lack of post project data. Potential study site projects from 2007-2014 all received consideration as they had data for three years after project completion. Potential study sites implemented in 2015 only had two years of post-implementation data available but received consideration for inclusion.

### 3.4 SELECTION OF STUDY SITES

The term ‘study site’ refers to Vision Zero project areas analyzed in this project. The research team selected study sites based on the following criteria:

1. **Find potential Study Sites:** To locate Vision Zero study sites, the research team found past safety projects through the Seattle Department of Transportation’s (SDOT) records, blog posts such as the Seattle Bike Blog, news articles, and the Street View feature in

Google Maps. Data availability limited the consideration of study sites to those implemented between 2007-2015.

2. **Presence of Businesses:** After locating potential study sites, the research team conducted an analysis to determine sufficient business presence in the surrounding area. A GIS map showing city zoning classifications helped determine adequate presence of businesses. Potential study sites received consideration if most of the area included “commercial development” zoning. This is an important step as the addition of a pedestrian crossing in a residential area is a Vision Zero treatment, but it is not located in an area where businesses would be impacted; therefore, that project would not be desirable for selection in this study.
3. **Confirming Presence of Businesses:** The “Time Portal” feature in Google Street View helped to visually confirm the presence of surrounding businesses at the time of project implementation, acting as a confirmatory analysis method.
4. **Geographic Diversity of Study Sites:** Lastly, the research team selected projects throughout Seattle to gain a breadth of study sites. Of the seven City Council Districts in Seattle, the research team selected a study site from every Council District except District 1 as a Vision Zero safety project did not fit the selection criteria from that district.

### 3.5 SELECTION OF CONTROL SITES

‘Control sites’ allow for comparison to study sites. Ideal control sites match the study site as closely as possible in all characteristics except for having a Vision Zero treatment during the study period. The research team matched every study site to 2-4 control sites based on the following criteria:

1. **“Commercial Development” Zoning Classification:** A control site and study site should be made up of a similar mix of businesses. Zoning classification is one method to help achieve that goal as they can be indicative of the type of buildings and commercial activity allowed and expected in an area. Using a GIS map displaying city zoning classifications, the research team confirmed “commercial development” zoning comprised most of a potential control site.
2. **Confirming Presence of Businesses:** Using the “Time Portal” feature in Google Street View, the research team confirmed the presence of businesses in a potential control site.
3. **Traffic Flow:** Ensuring similarities in street type, width, and usage are all good ways to help match control sites to study sites.(5,27) Traffic flow of an area can be used as a proxy of the type of street, width, and usage. The team created a GIS map with traffic flow rates from the year of Vision Zero project implementation. Potential control sites with traffic flow comparable to that of the study site warranted consideration.
4. **Vision Zero Improvements:** If a potential control site received a Vision Zero treatment during the analysis timeframe it no longer met inclusion criteria. For example, if a study site received a Vision Zero treatment in 2009 and a potential control site received a safety project in 2011, the potential control site would not be selected. In this case, the study methodologies dictate that taxable sales data are looked at from 2008 to 2012 for the study site and control sites. Thus, any potential control site could not receive a Vision Zero treatment during the 2008-2012 timeframe. The research team confirmed the presence or absence of Vision Zero projects for each potential control site using the “Time Portal” feature in Google Street View.

5. **Larger Geographic Area:** To ensure proximity of control and study sites, the research team only considered potential control sites from the same Seattle City Council District as the study site. A GIS map with Seattle’s City Council Districts showed the boundaries.

### 3.6 SELECTION OF LARGER GEOGRAPHIC CONTROL AREAS

A larger geographic area acted as an additional control and comparison for the general economic trend in an area. This allowed for the comparison of study sites to control sites and the larger area in which they reside. The research team decided to utilize the Seattle City Council District boundaries as the larger geographic control area. City Council Districts have concretely defined boundaries with available GIS maps. Another utility of City Council Districts is that they are politically defined areas that give a good representation of different areas of Seattle.

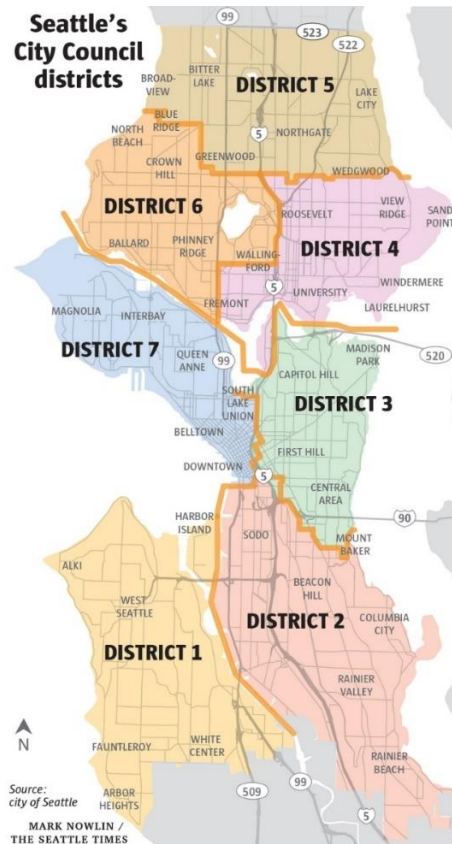


Figure 3.6 Seattle’s City Council Districts (Source: Seattle Times)

### 3.7 DATA COLLECTION

Due to privacy protections, the WA-DOR cannot release taxable sales data for individual businesses. That level of data specification would include sensitive information such as a business owner's name, address, and earnings. However, it is possible to make a "Public Records" request from the WA-DOR if businesses are categorized into some form of aggregation greater than three businesses per category. Examples of possible categorizations are geographic location, number of employees, or North American Industry Classification System (NAICS) industry code. NAICS codes show a business' primary activity and are a common way to categorize business.(34)

The ability to request data by location and NAICS code fit the study model. It enabled the analysis of the impact of street design changes on surrounding business vitality for specific locations. The research team worked with a representative from the WA-DOR to obtain the data. The research team generated GIS maps, drew polygons around the study and control sites, and asked for businesses within those boundaries to be grouped by NAICS code. The research team gave the WA-DOR representative a GIS shapefile of 7 study sites, 18 control sites, and 7 Seattle City Council Districts. The request specified timeframes for each site. The WA-DOR representative created a dataset of total taxable annual sales aggregated by NAICS code.

The research team chose to include all businesses during the analysis timeframe. Therefore, this meant the inclusion of incoming and outgoing businesses in the analysis. Excluding those businesses might favor established businesses or exclude businesses unlikely to perform well after street design changes, biasing the data. It is important to note that the incoming and outgoing businesses might represent gentrification and present an equity issue.

### 3.8 SELECTION OF NAICS CODES

NAICS codes are specific six-digit codes or general two-digit codes. To ensure enough data points, this study uses two-digit NAICS industry codes to select which businesses to include for analysis. Businesses were included if street design changes impact their sales. Examples of potentially impacted businesses are restaurants, gas stations, bakeries, bars, car washes, drycleaners, salons, and grocery stores. In contrast, street design changes are less likely to impact businesses in the manufacturing, public administration, and construction industries. The study deemed the following codes applicable:

1. 44- Retail Trade
2. 45- Retail Trade
3. 72- Accommodation and Food Services
4. 81- Other Services

All study sites and control sites had sufficient presence of these NAICS codes which allowed the study to focus on retail, food, and service based businesses.

### 3.9 ADJUSTING FOR INFLATION

To account for inflation, the research team adjusted the data for each study site to the first year of data for that site. For example, Study Site 1 has taxable sales data from 2013-2016. An Inflation Calculator adjusted the taxable sales data from 2014, 2015, and 2016 by 0.98, 0.98, and 0.97, respectively, to revert to 2013 dollars.(35)

### 3.10 DATA ANALYSIS

After adjusting for inflation, each study went through the following data analysis:

1. A sales index, a method to compare something of interest, a set of businesses, districts, or study sites of different sizes on the same scale, was created by taking the total retail sales for a study site or control site then dividing that by the number of businesses in the site.<sup>(32)</sup> A baseline of 100% was set for the first year of reported retail sales. The average of all following years was compared to the baseline. Then, matched study sites, City Council Districts, and control sites were compared to one another.
2. An aggregated trend analysis was used to compare the trends of the study site to the control sites and the larger geographic area. Study areas that showed greater changes in taxable sales compared to control sites may be representative of a positive economic impact from the Vision Zero street design change. As the *National Street Improvement Study* points out, ‘This method is easy to follow and represents the aggregated trend of business activities. However, it lacks the rigor of econometric estimates and statistical tests that explicitly test whether or not the street improvement caused the changes.’<sup>(4)</sup>
3. Performed paired t-tests to determine if there are statistically significant differences between the year to year percent changes in taxable sales of study sites and control sites. This method adds statistical significance to the aggregated trend analysis. Findings may show that street design changes had a positive, negative, or no statistically significant impact on retail, food, and service based businesses.

## Chapter 4. RESULTS AND DISCUSSION OF CASE STUDIES

### **Vision Zero Case Study Sites**

Study Site 1– 2nd Ave – Two-way bike facility and road diet

Study Site 2 – Rainier Ave S – Road diet and safety project

Study Site 3 – Broadway – Two-way bike facility and road diet

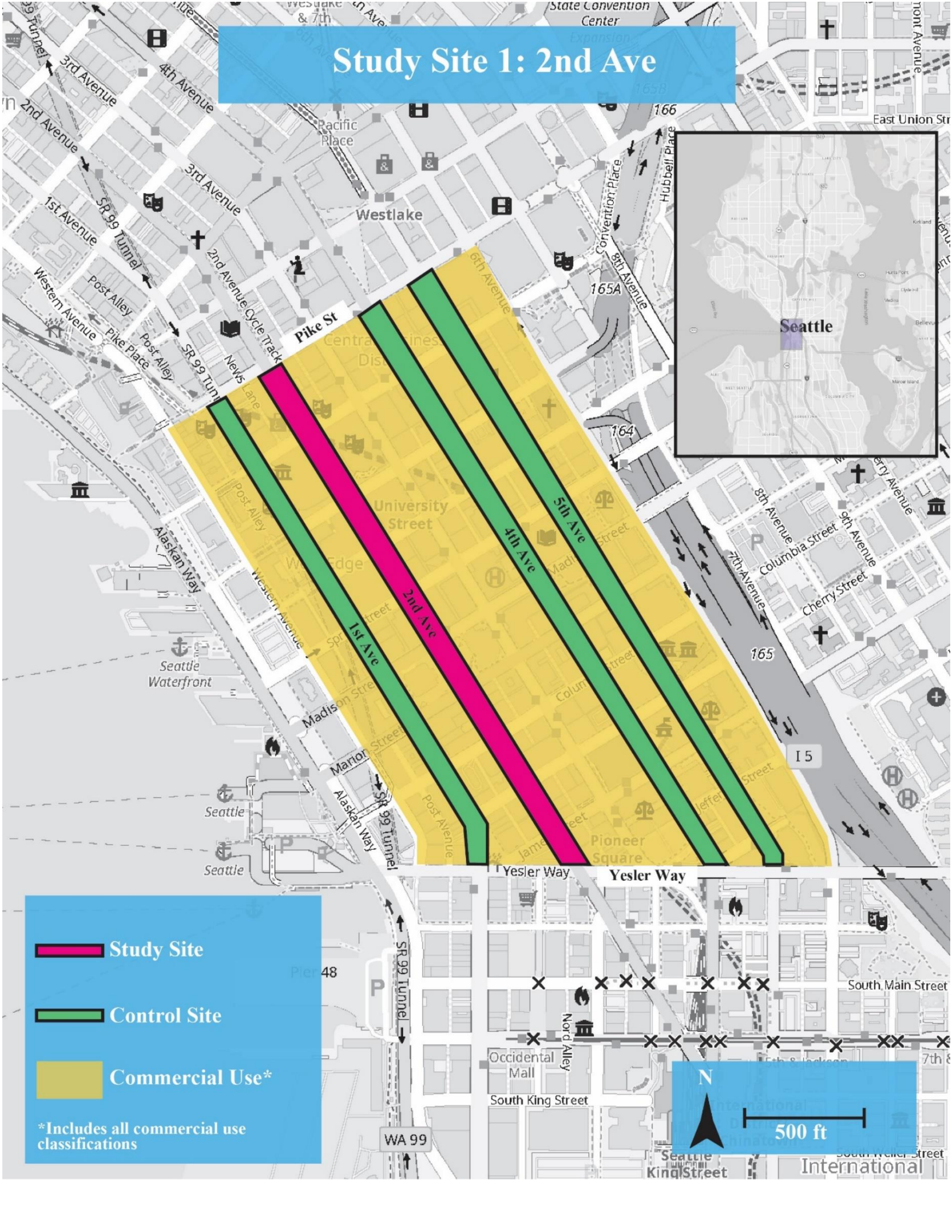
Study Site 4 – Stone Way N – Bike lane and road diet

Study Site 5 – Aurora Ave N – Speed and safety project

Study Site 6 – Greenwood Ave N – Bike lane and road diet

Study Site 7- Bell St – Woonerf style redesign

# Study Site 1: 2nd Ave



 Study Site

 Control Site

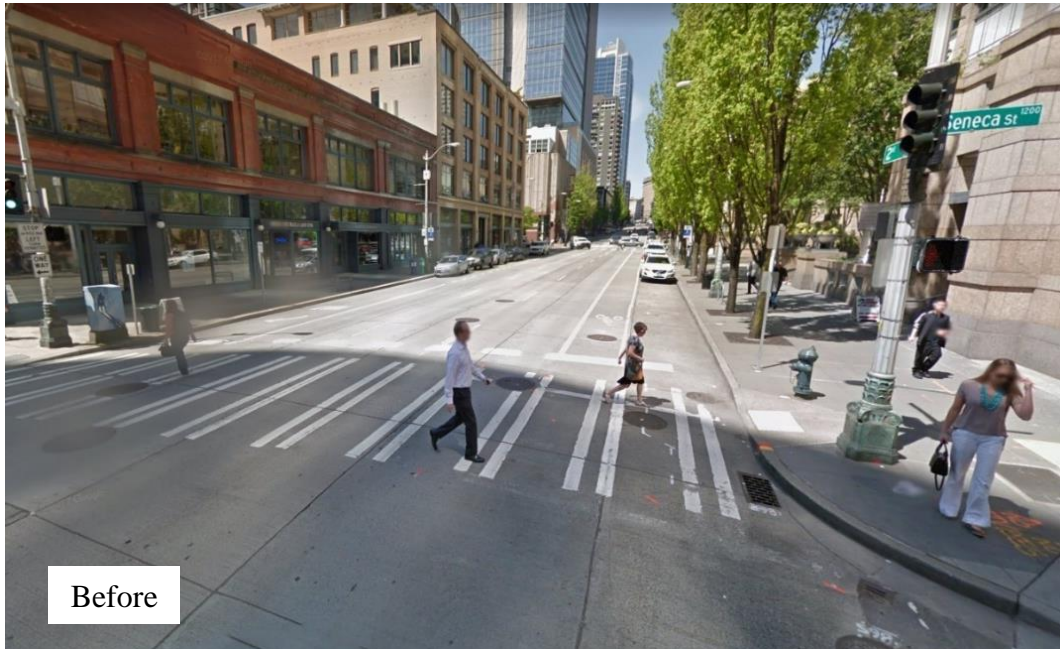
 Commercial Use\*

\*Includes all commercial use classifications



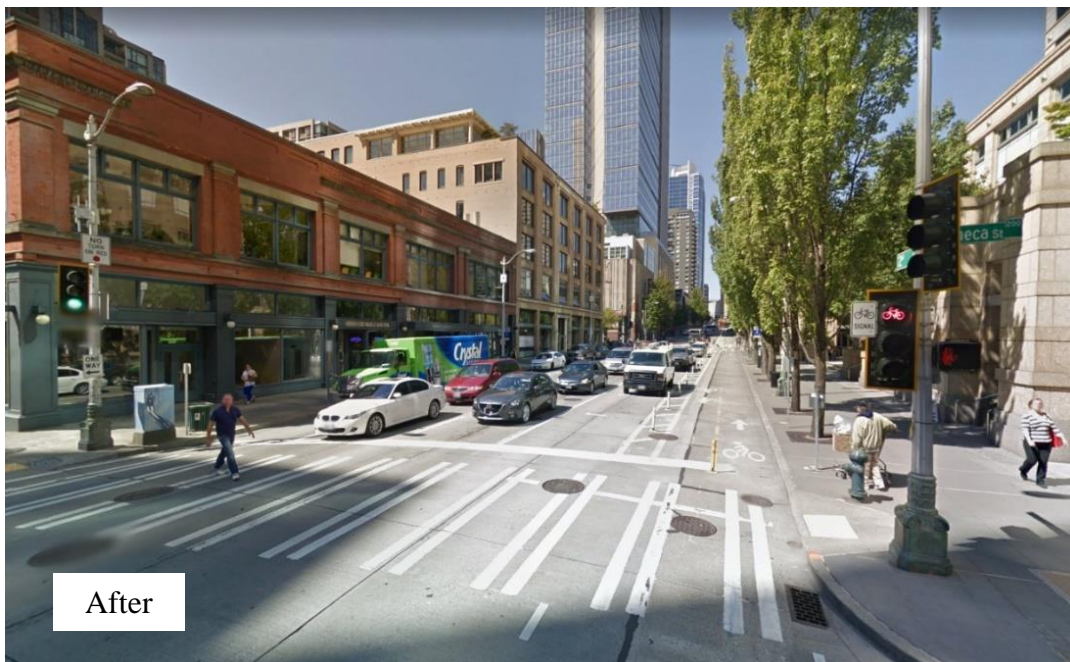
## 4.1 RESULTS FOR STUDY SITE 1: 2<sup>ND</sup> AVE

### Study Site 1- 2<sup>nd</sup> Ave – Two-way Bike Facility and Road Diet



Before

Figure 4.1.1 2<sup>nd</sup> Ave Before Project Implementation (36)



After

Figure 4.1.2 2<sup>nd</sup> Ave After Project Implementation (36)

#### 4.1.1 *Implemented- September 2014*

#### 4.1.2 *Context*

The 2<sup>nd</sup> Ave corridor is a busy street in downtown Seattle. Prior to the implementation of the ten block two-way bike lane and road diet, the corridor had an underutilized southbound bike lane which many in the bike community considered dangerous. Seattle lacked downtown north to south bike connections and for many years the bike community demanded a reliable connection. At the beginning of the study period the study site had 31 retail, 39 food, and 14 service based businesses. At the end of the study period the study site had 25 retail, 29 food, and 13 service based businesses. The total number of businesses decreased from the start of the study period to the end of the study period. While this largely did not impact the total sales of Study Site 1, it may represent a general trend of gentrification.

#### 4.1.3 *Project Goals*

1. To add a reliable north-to-south downtown bike connection
2. Improve bicycle safety
3. To improve safety of all users
4. Reduce speed of vehicles
5. Increase predictable movements of all users

#### 4.1.4 *Approach*

1. Install a two-way bike facility
2. Add bike signals
3. Improve signal timing
4. Convert permissive or permissive/protected to protected only left-turn phasing
5. Narrow roadway cross section through a road diet
6. Prohibit turn-on-red

#### 4.1.5 Safety Benefits Post Project (37)

1. Bike traffic tripled
2. Reduction in vehicles making illegal left turns
3. More reliable facility dedicated to people biking
4. Reduced crossing distance for pedestrians

#### 4.1.6 Study Results

Table 4.1.1: Study and Control Sites

Study Site	Control Sites
<p style="text-align: center;"><b>2<sup>nd</sup> Ave</b> Pike St to Yesler Way - 10 blocks</p>	<p>1. 1<sup>st</sup> Ave Pike St to Yesler Way –10 Blocks</p>
	<p>2. 4<sup>th</sup> Ave Pike St to Yesler Way –10 Blocks</p>
	<p>3. 5<sup>th</sup> Ave Pike St to Yesler Way –10 Blocks</p>

Table 4.1.2: Change in Sales from Baseline/Improvement Year

Area	Baseline Annual Sales -2013	Change in Sales from Baseline/Improvement Year		
		Year 1 – 2014	Year 2 – 2015	Year 3 – 2016
Study Site				
2 <sup>nd</sup> Ave	\$166,695,441	-2%	+12%	+14%
Seattle City Council District				
District 7	3,424,825,799	+6%	+15%	+17%
Control Sites				
1. 1 <sup>st</sup> Ave	\$125,069,155	+1%	-1%	-7%
2. 4 <sup>th</sup> Ave	\$170,172,741	+18%	+38%	+29%
3. 5 <sup>th</sup> Ave	\$105,702,743	+5%	+4%	+7%

**Aggregated Trend Analysis:** Study Site 1, 2<sup>nd</sup> Ave, performed similarly to most of the control sites. After the implementation of the two-way bike facility and road diet, businesses along the study site saw an initial drop of 2% in the first year but rebounded to increase 12% in year two and 14% in year three. 4<sup>th</sup> Ave is the only control site to outperform the study site. Study Site 1 kept pace with Seattle City Council District 7. The sales trends suggest that the street design changes

in Study Site 1 did not negatively impact retail, food, and service businesses and may have had a positive impact.

### Change in Sales Aggregated Trend Analysis: Study Site 1 2nd Ave vs. Control Sites

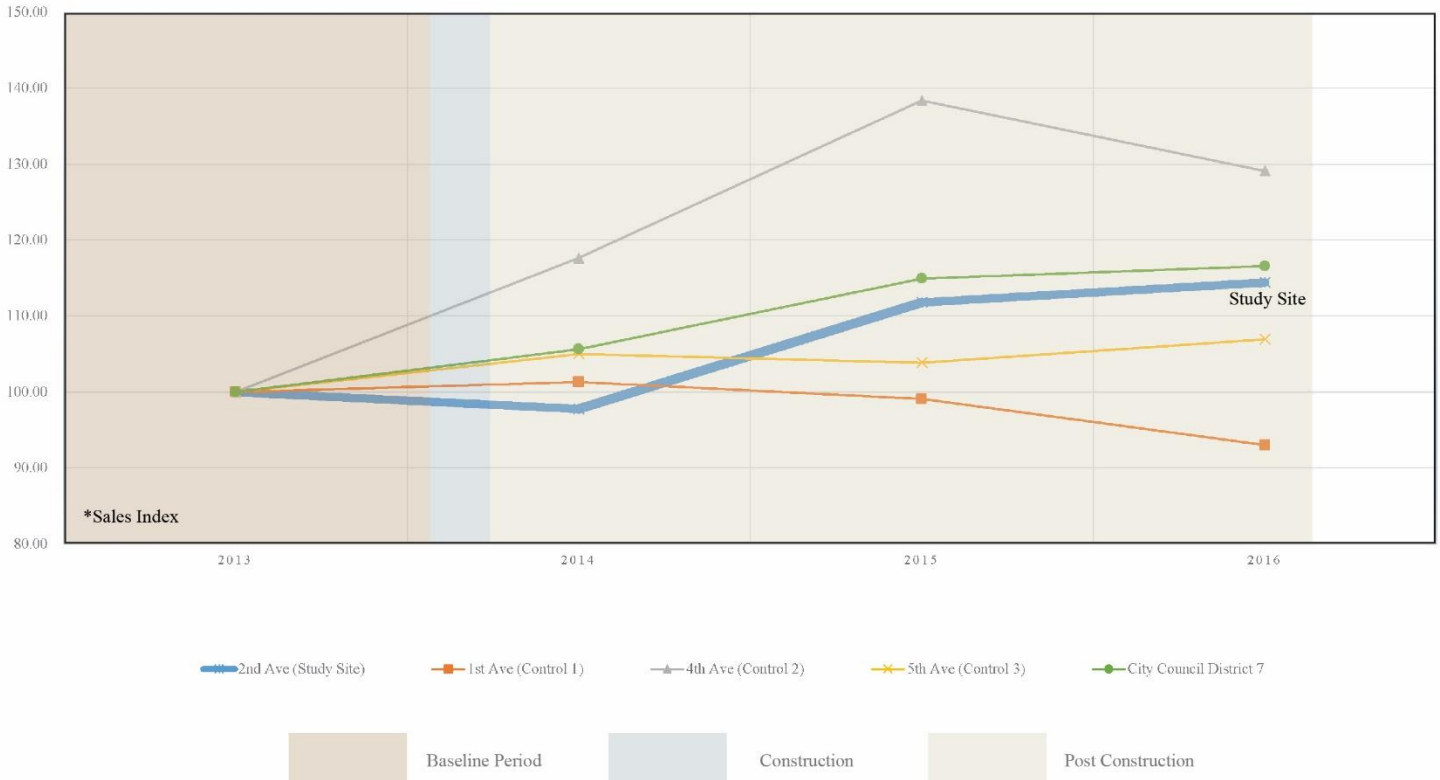


Figure 4.1.3 Change in Sales Aggregated Trend Analysis: Study Site 1

**Paired T-tests:** None of the paired t-tests showed a statistically significant difference between Study Site 1 and the control sites.

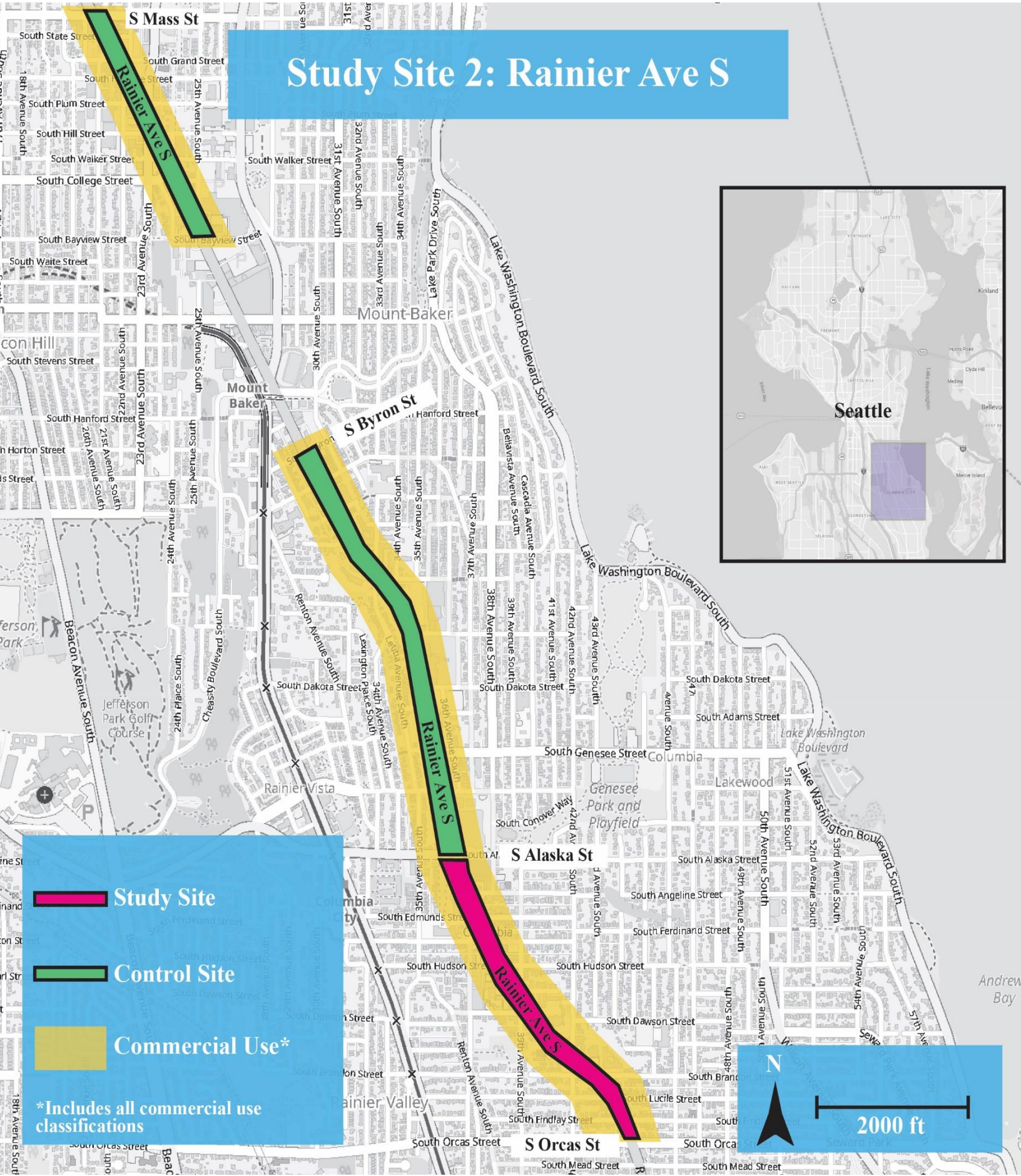
#### 4.1.7 *Discussion*

These analyses suggest that the Vision Zero street design changes on 2<sup>nd</sup> Ave did not have a significant negative or positive impact on adjacent retail, food, and service based businesses.

One might point out that many people using the 2<sup>nd</sup> Ave bike lane are mostly commuting and are unlikely to stop and frequent the surrounding businesses during their ride. A counter argument is that the presence of the bike lane is “free advertising” for the people biking who might work nearby and not take that route with another mode of transit.

Although this study site failed to find a positive or negative impact from the street design changes on 2<sup>nd</sup> Ave businesses, the project succeeded in achieving a better downtown bike connection, increasing bike traffic, and improving safety for all users.

# Study Site 2: Rainier Ave S



## 4.2 RESULTS FOR STUDY SITE 2: RAINIER AVE S

### Study Site 2: Rainier Ave S - Two-way Bike Facility and Road Diet



Figure 4.2.1 Rainier Ave South Before and After Project Implementation (38)

#### 4.2.1 *Implemented* - August 2015

#### 4.2.2 *Context*

The 2015 road diet and safety improvements completed on Rainier Ave S from S Alaska St to S Juneau St are the first step in a long range safety project on Rainier Ave S. The nine block corridor runs through the Rainier Valley through some of the most diverse and historically marginalized populations in Seattle. As a main arterial, Rainier Ave S consisted of two travel lanes in each

direction with a parking lane on one side of the street. The old design resulted in high speeds and dangerous pedestrian environments along the corridor, even in the heart of neighborhood business districts such as Columbia City. From 2011-2014, a four mile stretch of Rainier Ave S saw 1,243 collisions, 630 injuries, and 11 deaths.(38) At the beginning of the study period the study site had 37 retail, 48 food, and 10 service based businesses. At the end of the study period the study site had 23 retail, 40 food, and 11 service based businesses. The total number of businesses decreased from the start of the study period to the end of the study period. While this largely did not impact the total sales of Study Site 2, it may represent a general trend of gentrification.

#### 4.2.3 *Project Goals* (38)

1. Make a safer environment for all users
2. Reduce vehicle speeds
3. Improve conditions for people walking and biking
4. Decrease the number of injuries
5. Make intersections safer
6. Maintain or improve the level of transit service

#### 4.2.4 *Approach*

1. Narrow roadway cross section through a road diet
2. Recanalization that includes a center turn lane
3. Install refuge islands
4. Improve signal timing
5. Install left turn pockets at intersections
6. Convert permissive or permissive/protected to protected only left-turn phasing
7. Reduce speed limit from 30 mph to 25 mph
8. Prohibit turn-on-red
9. Install transit cue jumps
10. Install bus and turn lanes

11. Increase enforcement

4.2.5 *Safety Benefits Post Project (38)*

1. 15% reduction in collisions
2. 30% decrease in collisions resulting in injury
3. 40% decrease in collisions with people walking or biking
4. Reduction of vehicle speeds and number of vehicles speeding

4.2.6 *Study Results*

Table 4.2.1: Study and Control Sites

Study Site	Control Sites
<b>Rainier Ave S</b> S Alaska St to S Juneau St – 9 Blocks	1. Rainier Ave S Massachusetts to Bayview – 9 Blocks
	2. Rainier Ave S Byron to Alaska – 10 Blocks

Table 4.2.2: Change in Sales from Baseline/Improvement Year

Area	Baseline Annual Sales - 2014	Change in Sales from Baseline/Improvement Year	
		Year 1 – 2015	Year 2 – 2016
Study Site			
Rainier Ave S (Alaska to Juneau)	\$14,084,441	+9%	+1%
Seattle City Council District			
District 2	\$1,166,794,193	+13%	+20%
Control Sites			
1. Rainer Ave S (Massachusetts to Bayview)	\$15,082,249	+8%	+4%
2. Rainier Ave S (Byron to Alaska)	\$45,067,147	-20%	-22%

**Aggregated Trend Analysis:** Study Site 2, Rainier Ave S (S Alaska St to S Juneau St) performed similarly to most of the control sites. After the implementation of the safety project on Rainier Ave S, businesses along the corridor saw an initial increase of 9% in the first year but then fell to a 1% increase after the second year. Study Site 2 kept pace with the control site of Rainier Ave S from S Massachusetts St to S Bayview St while outperforming the section of Rainier from S Byron St

to S Alaska St. Seattle City Council District 2 outperformed all the study and control sections on Rainier Ave S.

The sales trends suggest that the street design changes in Study Site 2 did not negatively impact retail, food, and service businesses and may have had a positive impact when compared to Control Site 2.

### Change in Sales Aggregated Trend Analysis: Study Site 2 Rainier Ave S vs. Control Sites

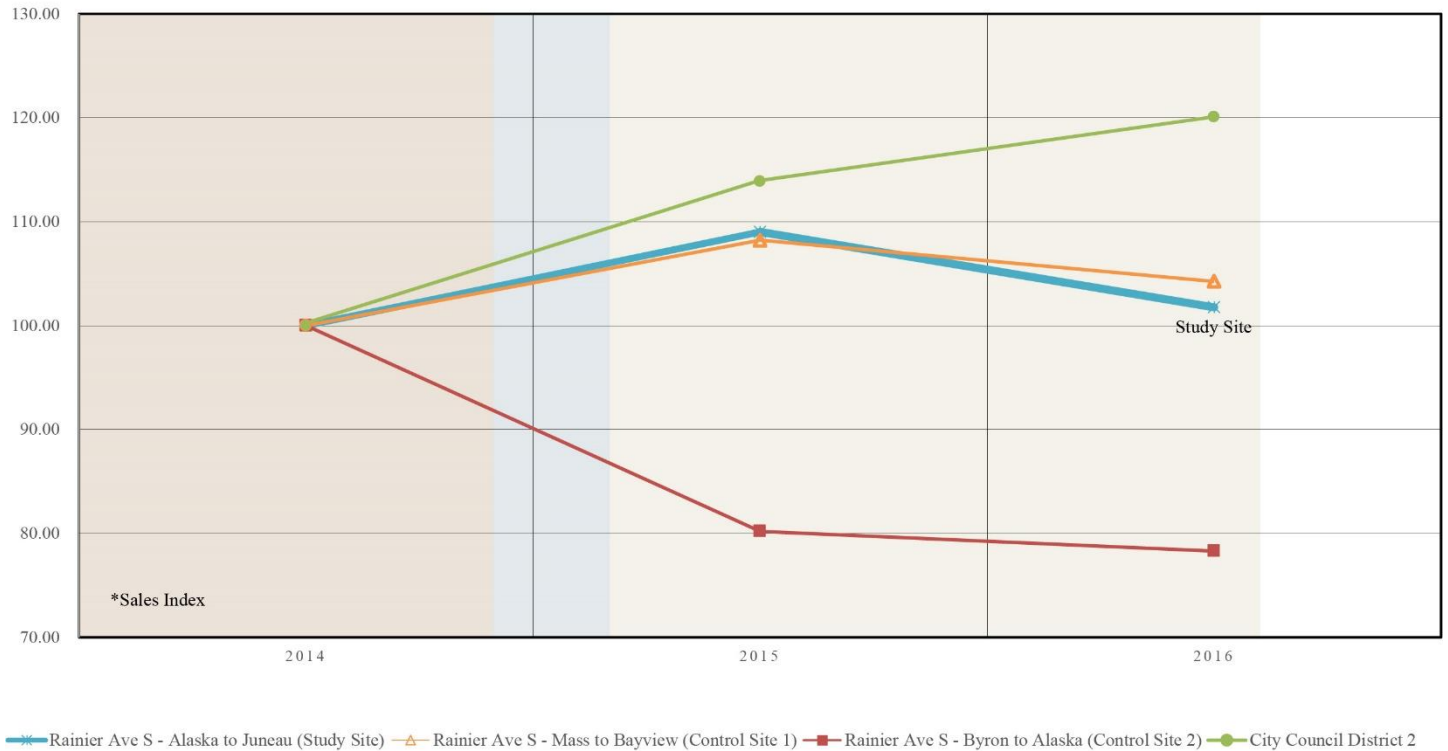


Figure 4.2.2 Change in Sales Aggregated Trend Analysis: Study Site 2

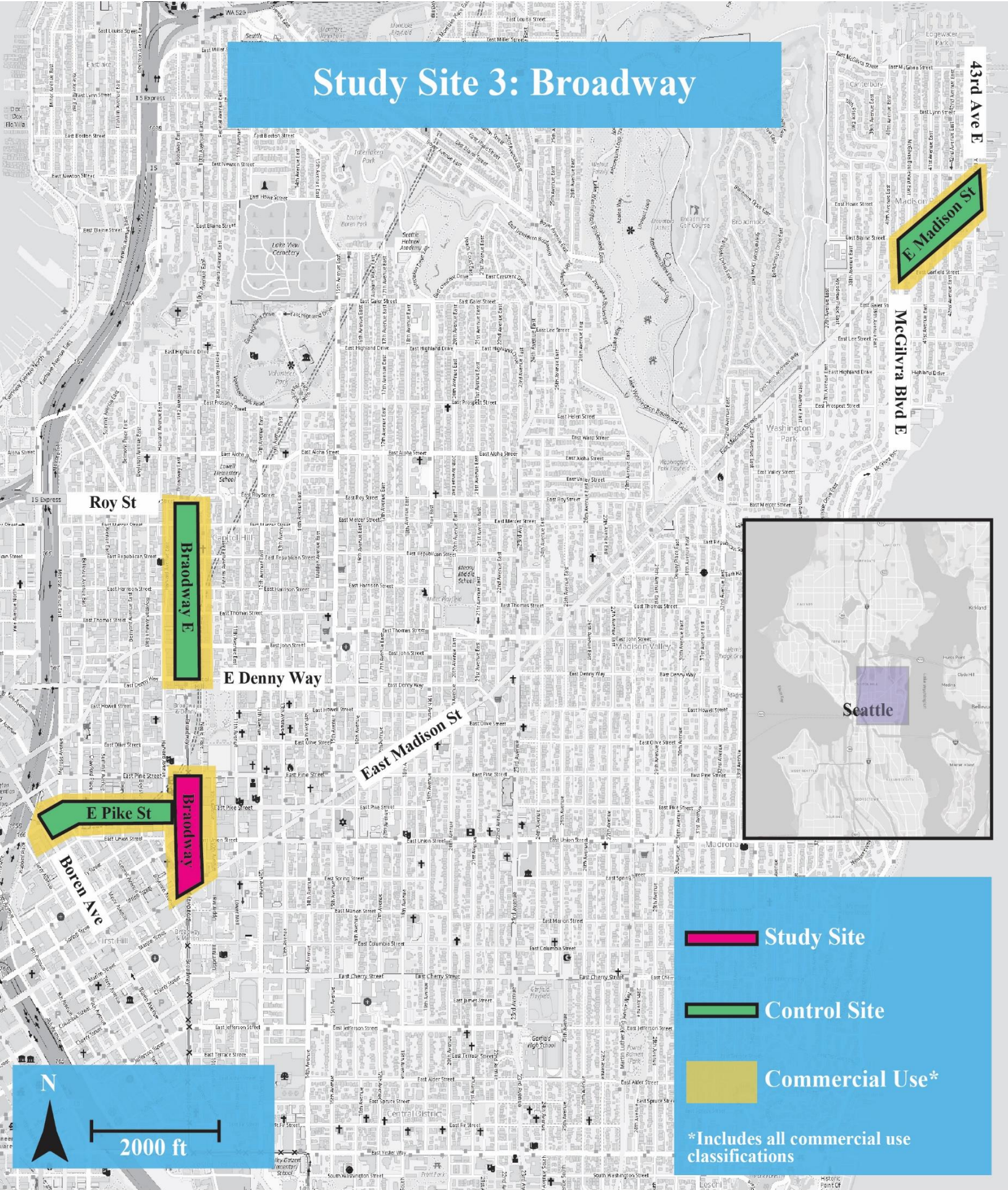
**Paired T-tests:** The paired t-test for Study Site 2 and Control Site 1 showed a significant difference (p-value of 0.02). The rest of the paired t-tests failed to show a statistically significant difference between Study Site 2, Control Site 2, and Seattle City Council District 2.

#### 4.2.7 *Discussion*

The significant t-test indicates that the Vision Zero street design changes on Rainier Ave S may have had a positive impact on the adjacent retail, food, and service businesses when compared to Control Site 1. The failed t-tests indicate that the Vision Zero street design changes on Rainier Ave S did not have significant negative or positive impacts on adjacent retail, food, and service businesses when compared to Control Site 2 or City Council District 2.

In addition to finding that the Vision Zero project on Rainier Ave S may have had a positive impact for businesses, the project succeeded in reducing collisions, decreasing speeds, and making the environment more welcoming to all users.

# Study Site 3: Broadway



- Study Site
  - Control Site
  - Commercial Use\*
- \*Includes all commercial use classifications

### 4.3 RESULTS FOR STUDY SITE 3: BROADWAY

#### Study Site 3- Broadway- Two-way Bike Facility and Road Diet

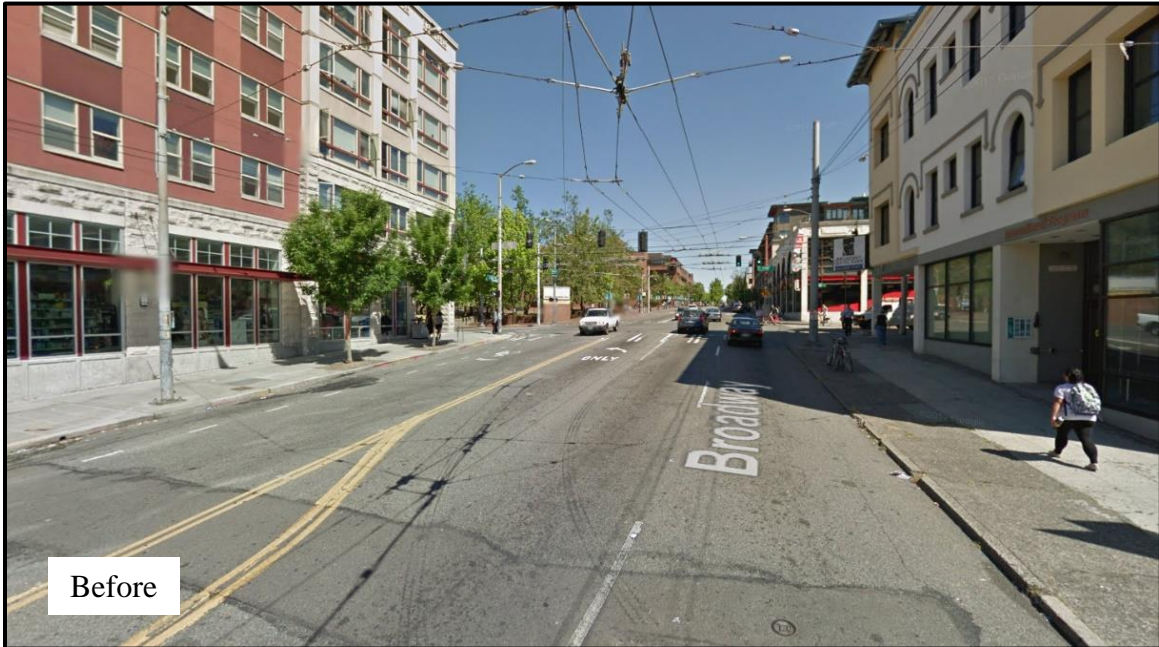


Figure 4.3.1 Broadway Before Project Implementation (36)



Figure 4.3.2 Broadway After Project Implementation (36)

#### 4.3.1 *Implemented* - April 2014

#### 4.3.2 *Context*

Funding for the Broadway two-way bike facility came with the expansion of the First Hill Streetcar.(39) Broadway is historically a main thoroughfare for bicycle riders and a busy neighborhood commercial center. The installation of the streetcar tracks necessitated a bicycle facility to separate people biking from the streetcar tracks as bicycle wheels can get caught in the tacks.(40) With the goal of becoming a “complete street” for all users, Broadway required additional street design changes to ensure safety and usability. At the beginning of the study period the study site had 25 retail, 26 food, and 7 service based businesses. At the end of the study period the study site had 26 retail, 22 food, and 7 service based businesses. The total number of businesses decreased from the start of the study period to the end of the study period. While this largely did not impact the total sales of Study Site 3, it may represent a general trend of gentrification.

#### 4.3.3 *Project Goals*

1. Add a reliable bike connection to the Seattle network
2. Add a separate facility from the road and streetcar to improve bicycle safety
3. Improve safety of all users
4. Reduce speeding vehicles
5. Increase predictable movements of all users
6. Decrease the number of injuries
7. Make intersections safer

#### 4.3.4 *Approach*

1. Add two-way bike facility
2. Add bike signals
3. Improve signal timing

4. Narrow roadway cross section through a road diet
5. Convert permissive or permissive/protected to protected only left-turn phasing
6. Narrow roadway cross section
7. Prohibit turn-on-red

#### 4.3.5 Safety Benefits Post Project

1. Dedicated facility for people biking separate from the streetcar tracks
2. Increased bicycle traffic
3. Improved walking safety (41)
4. Improved safety for all users (31)

#### 4.3.6 Study Results

Table 4.3.1: Study and Control Sites

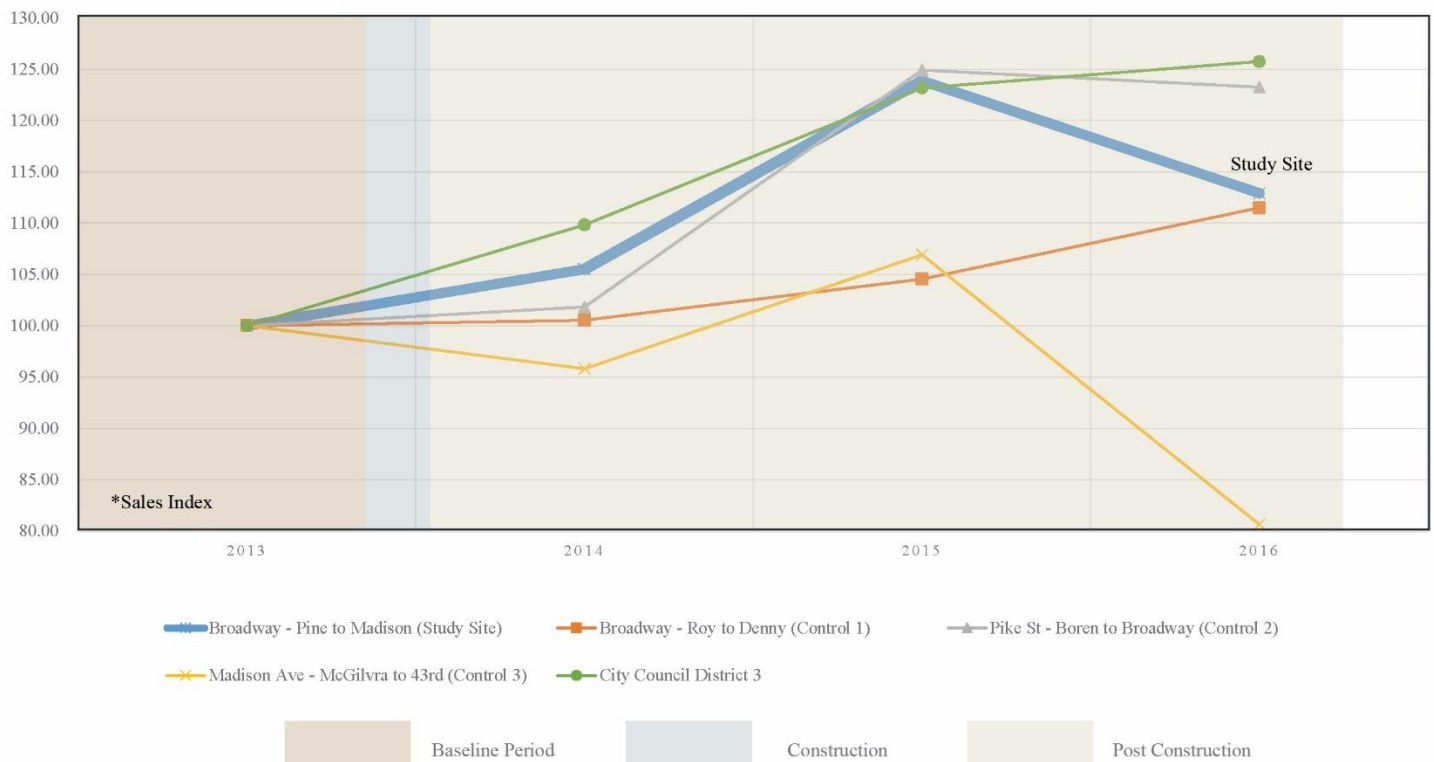
Study Site	Control Sites
<b>Broadway</b> Pine to Madison – 3 Blocks	1. Broadway Roy to Denny – 6 Blocks
	2. Pike St Boren to Broadway -7 Blocks
	3. E Madison St McGilvra to 43 <sup>rd</sup> – 4 Blocks

Table 4.3.2: Change in Sales from Baseline/Improvement Year

Area	Baseline Annual Sales - 2013	Change in Sales from Baseline/Improvement Year		
		Year 1 – 2014	Year 2 – 2015	Year 3 – 2016
Study Site				
Broadway (Pine to Madison)	\$51,327,203	+6%	+24%	+13%
<b>Seattle City Council District</b>				
District 3	\$805,166,553	+10%	+23%	+26%
<b>Control Sites</b>				
1. Broadway (Roy to Denny)	\$56,561,962	+1%	+5%	+12%
2. Pike St (Boren to Broadway)	\$18,931,601	+2%	+25%	+23%
3. E Madison St (McGilvra to 43 <sup>rd</sup> )	\$21,421,272	-4%	+7%	-19%

**Aggregated Trend Analysis:** Study Site 3, Broadway, performed similarly to two of the control sites and Seattle City Council District 3 in that they saw a steady increase in sales. After implementation of the project, businesses on the Broadway corridor saw an initial increase of 6% in the first year, up to 24% from baseline in the second year, and then back to 13% in year three. Study Site 3 kept pace with the control sites of Pike St and Broadway (Roy St to Denny St) while outperforming the control site of E Madison St. The Seattle City Council District 3 saw slightly increased sales to that of Study Site 3 in the third year, but comparable sales in the other years after project implementation. The sales trends suggest the street design changes in Study Site 3 did not negatively impact retail, food, and service businesses sales and may have had a positive impact.

**Change in Sales Aggregated Trend Analysis: Study Site 3  
Broadway vs. Control Sites**



**Figure 4.3.3 Change in Sales Aggregated Trend Analysis: Study Site 3**

**Paired T-tests:** None of the paired t-tests showed a statistically significant difference between Study Site 3 and the control sites.

#### 4.3.7 *Discussion*

These analyses suggest that the Vision Zero street design changes on Broadway Ave did not have a significant negative or positive impact on adjacent retail, food, and service businesses.

Like the 2<sup>nd</sup> Ave bike lanes, one could argue that the Broadway two-way bike facility is used for commuting. Thus, people are unlikely to stop and frequent the surrounding businesses during their commute. Again, the bike lanes can serve as a way of showing people what is in the area, advertising that might not translate in other modes of transit. The bike lane certainly makes Broadway a more desirable place to walk and frequent as it increases the separation between people walking on the sidewalk and traffic in the street.

Although this study site failed to find a positive or negative impact from the street design changes on Broadway businesses, the project succeeded in achieving a better bike connection and improved safety for all users.



#### 4.4 RESULTS FOR STUDY SITE 4: STONE WAY N

##### Study Site 4- Stone Way N- Two-way Bike Lane and Road Diet



Figure 4.4.1 Stone Way N Before Project Implementation (36)



Figure 4.4.2 Stone Way N After Project Implementation (36)

#### 4.4.1 *Implemented - July 2007*

#### 4.4.2 *Context*

Before the implementation of the 12 block safety project, Stone Way N had four general purpose travel lanes, no bike facilities, and uncontrolled marked pedestrian crossings.(42) Uncontrolled marked crosswalks no longer met City guidelines and the newly adopted Bicycle Master Plan had designated Stone Way N as a desired corridor.(42) A 2007 repaving project on Stone Way N triggered several changes to better align with these updated City policies. At the beginning of the study period the study site had 16 retail, 9 food, and 12 service based businesses. At the end of the study period the study site had 27 retail, 10 food, and 14 service based businesses.

#### 4.4.3 *Project Goals*

1. Add a reliable bike connection to the Seattle network
2. Improve bicycle safety
3. Improve pedestrian safety
4. Improve safety of all users
5. Reduce speeding vehicles
6. Increase predictable movements of all users
7. Decrease the number of injuries
8. Make intersections safer

#### 4.4.4 *Approach*

1. Narrow roadway cross section through a road diet
2. Recanalization that includes a center turn lane
3. Install left turn pockets at intersections
4. Add up-hill bike facility
5. Install downhill bike sharrow markings

#### 4.4.5 Safety Benefits Post Project (42)

1. Reduced 85<sup>th</sup> percentile driving speeds
2. Decreased number of vehicles going 10 MPH or more over the speed limit
3. Increase in bicycle traffic of 35%
4. Decreased diversion of traffic to residential streets
5. 14% reduction of all collisions of from 159 to 137
6. 33% fall in injury collisions from 52 to 35
7. 80% decline in pedestrian collisions of from 5 to 1
8. 25% decrease in left turn collision from 12 to 9
9. 56% drop in angled collisions of from 34 to 15

#### 4.4.6 Study Results

Table 4.4.1: Study and Control Sites

Study Site	Control Sites
<b>Stone Way N</b> N 40 <sup>th</sup> St to N 50 <sup>th</sup> St – 12 Blocks	1. Eastlake Ave E Newton to I-5 – 8 Blocks
	2. Roosevelt Way NE 50 <sup>th</sup> to 70 <sup>th</sup> – 16 Blocks
	3. 35 <sup>th</sup> Ave NE 70 <sup>th</sup> to 87 <sup>th</sup> – 10 Blocks

Table 4.4.2: Change in Sales from Baseline/Improvement Year

Area	Baseline Annual Sales - 2006	Change in Sales from Baseline/Improvement Year		
		Year 1 – 2007	Year 2 – 2008	Year 3 – 2009
Study Site				
Stone Way N	\$9,765,218	+10%	+12%	+29%
<b>Seattle City Council District</b>				
District 4	\$890,488,736	+3%	+1%	+7%
<b>Control Sites</b>				
1. Eastlake Ave E	\$14,662,338	+13%	-1%	-5%
2. Roosevelt Way NE	\$31,331,611	-12%	-17%	-19%
3. 35 <sup>th</sup> Ave NE	\$63,244,942	+7%	-5%	-1%

**Aggregated Trend Analysis:** Study Site 4, Stone Way N, performed superior to all the control sites and Seattle City Council District 4. After implementation of the project, businesses on Stone Way N corridor saw an initial sales increase of 10% in the first year, 12% the second year, and 29% in the third year. Study Site 4 appeared to well outperform the control sites, especially in 2008 and 2009. Seattle City Council District 4 saw slightly increased sales during the study period, whereas Study Site 4 saw substantial increases in sales. The sales trends suggest the street design changes in Study Site 4 may have had a positive impact on retail, food, and service businesses.

### Change in Sales Aggregated Trend Analysis: Study Site 4 Stone Way N vs. Control Sites

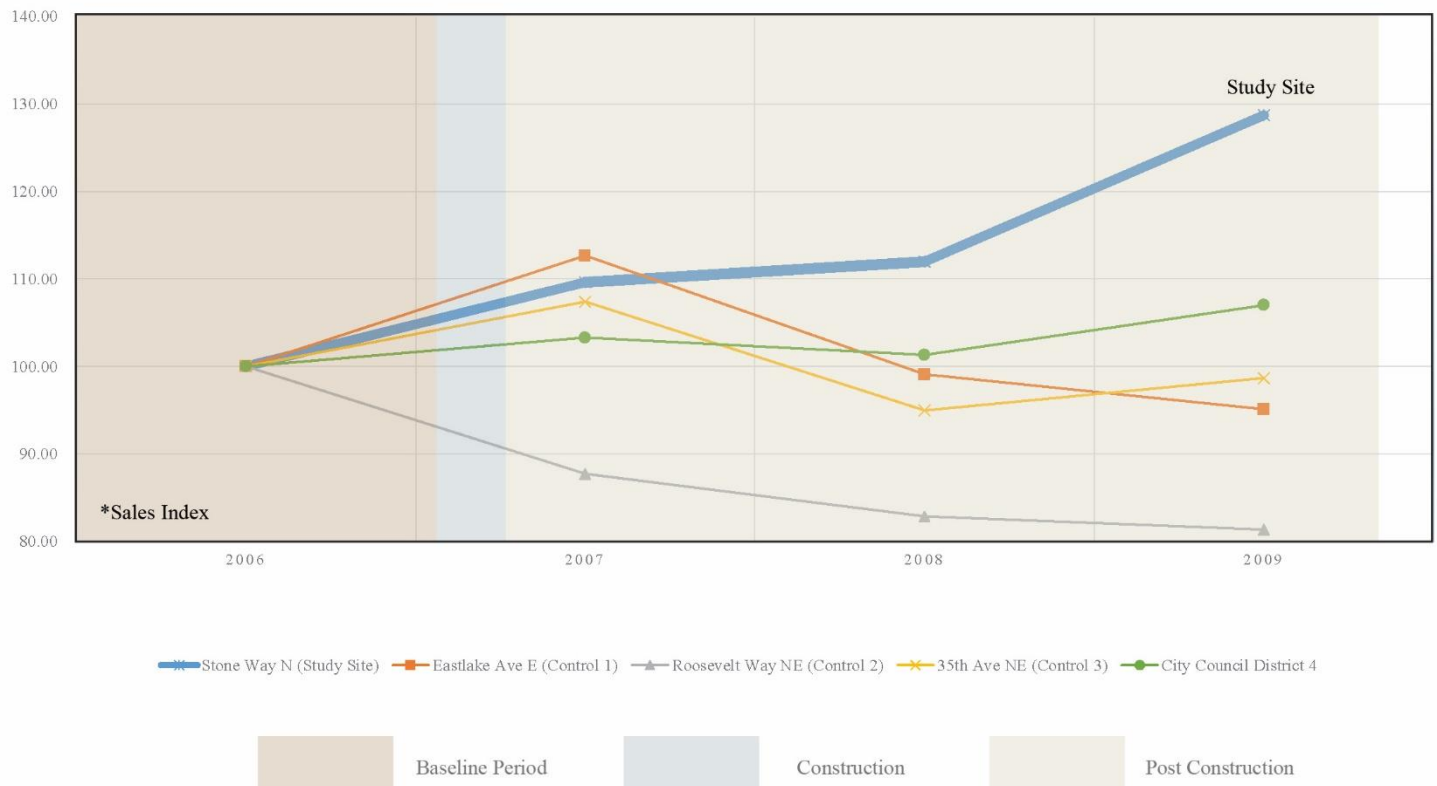


Figure 4.4.3 Change in Sales Aggregated Trend Analysis: Study Site 4

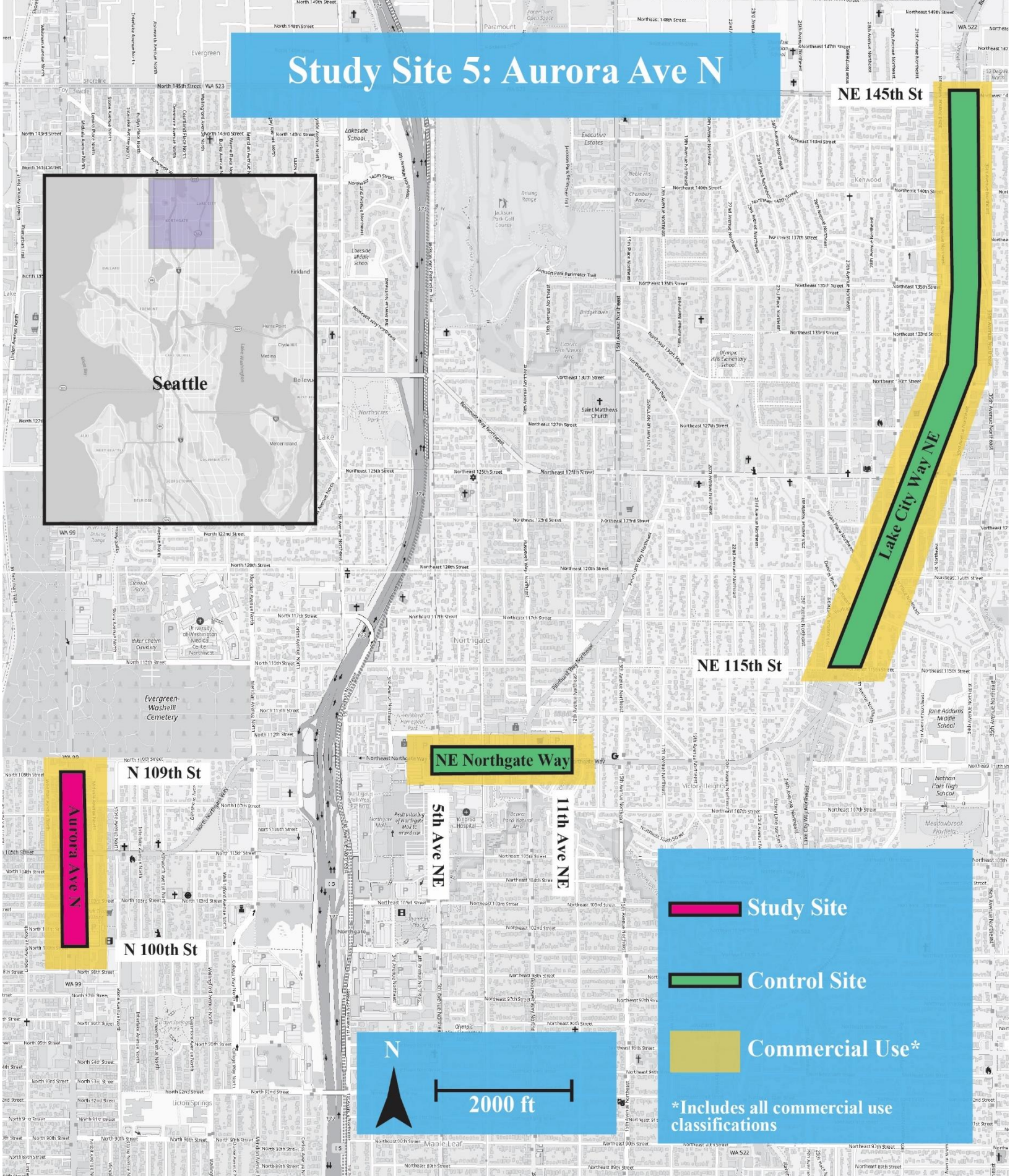
**Paired T-tests:** The paired t-test between Study Site 4, Stone Way N, and Control Site 2, Roosevelt Way NE, showed statistical significance (p-value of 0.007). The rest of the paired t-tests failed to show a statistically significant difference between Study Site 4 and the control sites.


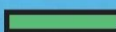

#### 4.4.7 *Discussion*

The significant t-test indicates that the Vision Zero street design changes on Stone Way N may have had a positive impact on adjacent retail, food, and service businesses when compared to Control Site 2. The failed t-tests indicate that the Vision Zero street design changes on Stone Way N did not have a significant negative or positive impact on adjacent retail, food, and service businesses when compared to Control Site 1, Control Site 3, or City Council District 4.

In addition to finding that the Vision Zero project on Stone Way N may have had a positive impact for businesses, the project reduced collisions, decreased vehicle speeds, added a bike connection, make the environment more welcoming to all users, increased bike traffic, reduced fatal crashes, and better protected pedestrians.

# Study Site 5: Aurora Ave N



-  Study Site
  -  Control Site
  -  Commercial Use\*
- \*Includes all commercial use classifications

## 4.5 RESULTS FOR STUDY SITE 5: AURORA AVE N

### Study Site 5- Aurora Ave N – Speed and Safety Project



Figure 4.5.1 Aurora Ave N Before Project Implementation (36)

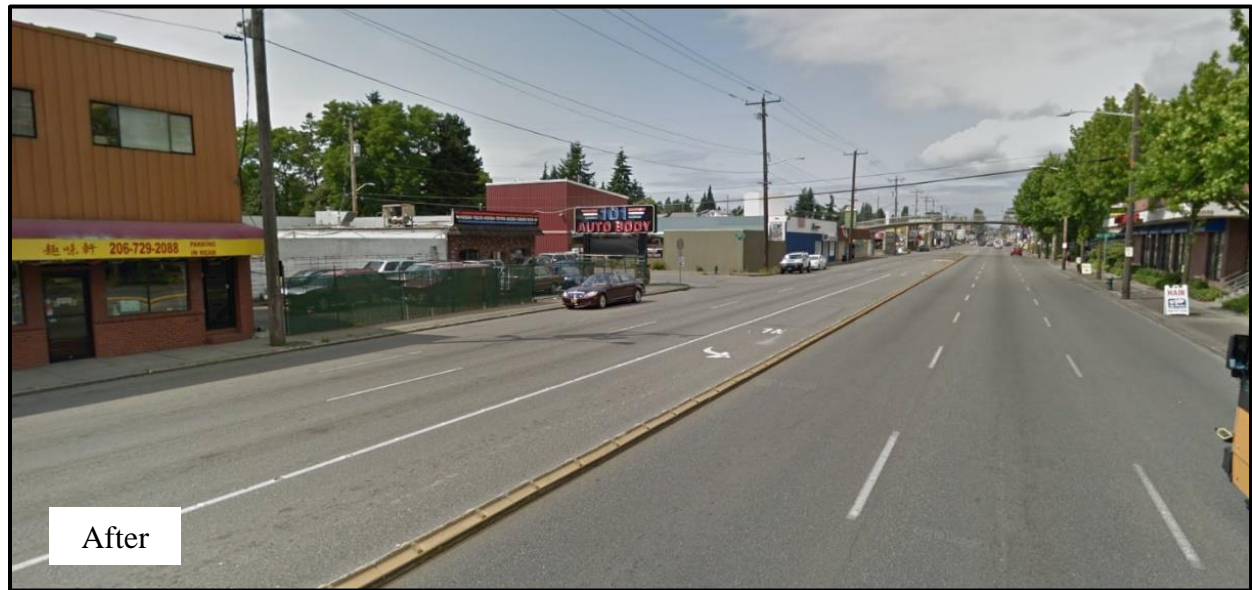


Figure 4.5.2 Aurora Ave N After Project Implementation (36)

#### 4.5.1 *Implemented* - May 2011

#### 4.5.2 *Context*

Between 2005 and 2008 over 1,500 collisions occurred on Aurora Ave N between the Battery St Tunnel to N 145<sup>th</sup> St.(43) The Aurora Traffic Safety Project launched in 2009 at the behest of concerned citizens to improve safety on Aurora Ave N. (43) The project implemented street design changes on the wider corridor to achieve the desired safety outcomes; however, the study site between N 100<sup>th</sup> St to N 109<sup>th</sup> St did not receive physical street design improvements. Increased law enforcement is the main improvement in the study site.(43) At the beginning of the study period the study site had 26 retail, 21 food, and 14 service based businesses. At the end of the study period the study site had 25 retail, 16 food, and 15 service based businesses. The total number of businesses decreased from the start of the study period to the end of the study period. While this largely did not impact the total sales of Study Site 5, it may represent a general trend of gentrification.

#### 4.5.3 *Project Goals*

1. Improve safety of all users
2. Reduce speeding vehicles
3. Increase predictable movements of all users
4. Decrease the number of injuries
5. Make intersections safer

#### 4.5.4 *Approach*

1. Increase enforcement

#### 4.5.5 Safety Benefits Post Project (43)(42)

1. Corridor wide collision reduction of 20%
2. 3 MPH reduction in speed
3. 18% drop in corridor wide fatal or serious injury collisions
4. Fewer collisions from failure to yield – 34%
5. Reduced collisions from distracted driving – 28%
6. Lowered collisions due to speeding – 20%

#### 4.5.6 Study Results

Table 4.5.1: Study and Control Sites

Study Site	Control Sites
<b>Aurora Ave N</b> N 100 <sup>th</sup> St to N 109 <sup>th</sup> St – 7 Blocks	1. NE Northgate Way 5 <sup>th</sup> to 11 <sup>th</sup> Ave NE – 3 Blocks
	2. Lake City Way NE 115 <sup>th</sup> to 145 <sup>th</sup> – 7 Blocks

Table 4.5.2: Change in Sales from Baseline/Improvement Year

Area Study Site	Baseline Annual Sales - 2010	Change in Sales from Baseline/Improvement Year		
		Year 1 – 2011	Year 2 – 2012	Year 3 – 2013
Aurora Ave N	\$14,835,111	+4%	-26%	-28%
<b>Seattle City Council District</b>				
District 5	\$1,116,402,341	-6%	-7%	-4%
<b>Control Sites</b>				
1. NE Northgate Way	\$24,323,835	+29%	+40%	-3%
2. Lake City Way NE	\$83,422,725	+7%	+10%	+18%

**Aggregated Trend Analysis:** Study Site 5, Aurora Ave N, performed inferior to the control sites and Seattle City Council District 5. After implementation of the project, businesses on the Aurora Ave N corridor saw an initial sales increase of 4% in the first year, and then sales fell 26% from baseline in the second year and 28% in the third year. Study Site 5 appeared to underperform

compared to the control sites, especially in 2012 and 2013. Seattle City Council District 5 saw slightly decreased sales during the study period, whereas Study Site 4 saw substantial decreases in sales. The sales trends suggest the safety project in Study Site 5 may have had a negative impact on retail, food, and service businesses.

### Change in Sales Aggregated Trend Analysis: Study Site 5 Aurora Ave N vs. Control Sites

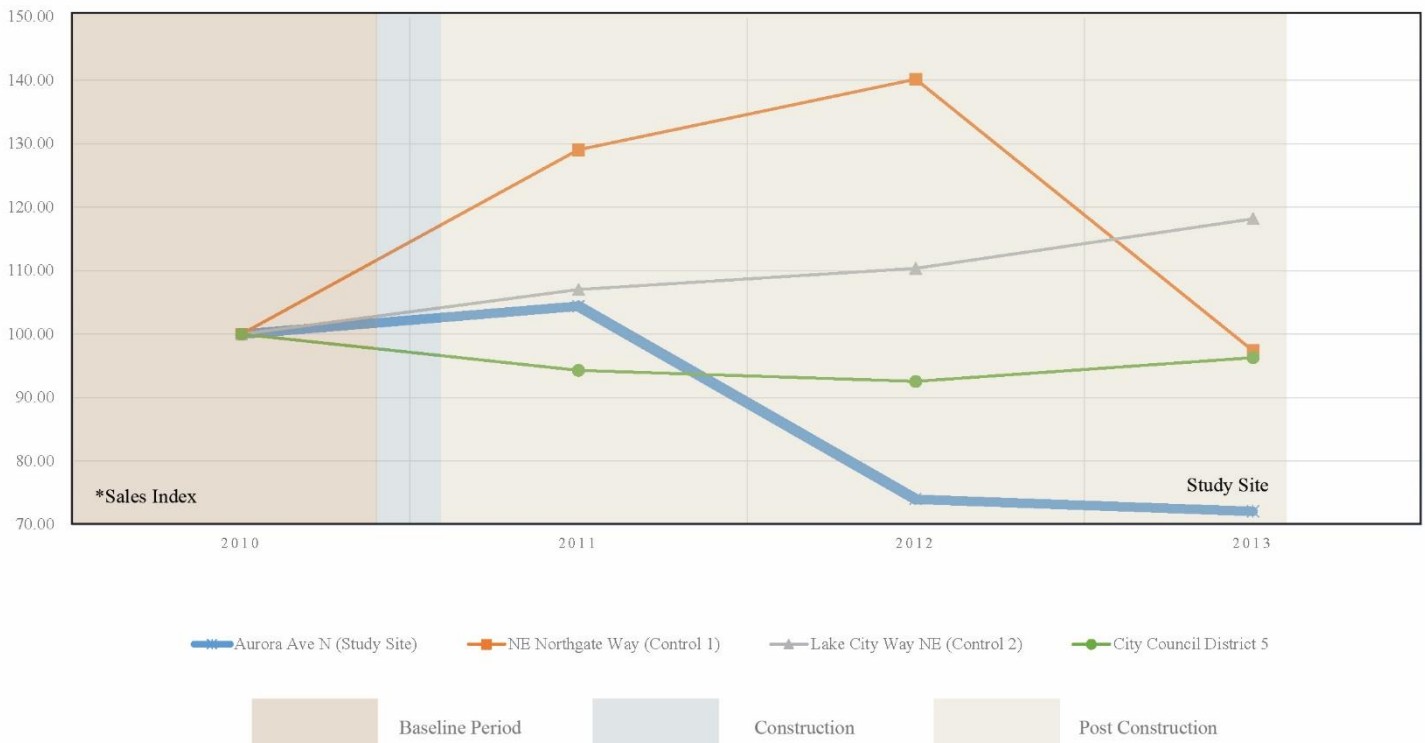


Figure 4.5.3 Change in Sales Aggregated Trend Analysis: Study Site 5

**Paired T-tests:** The paired t-tests failed to show a statistically significant difference between Study Site 5 and the control sites.

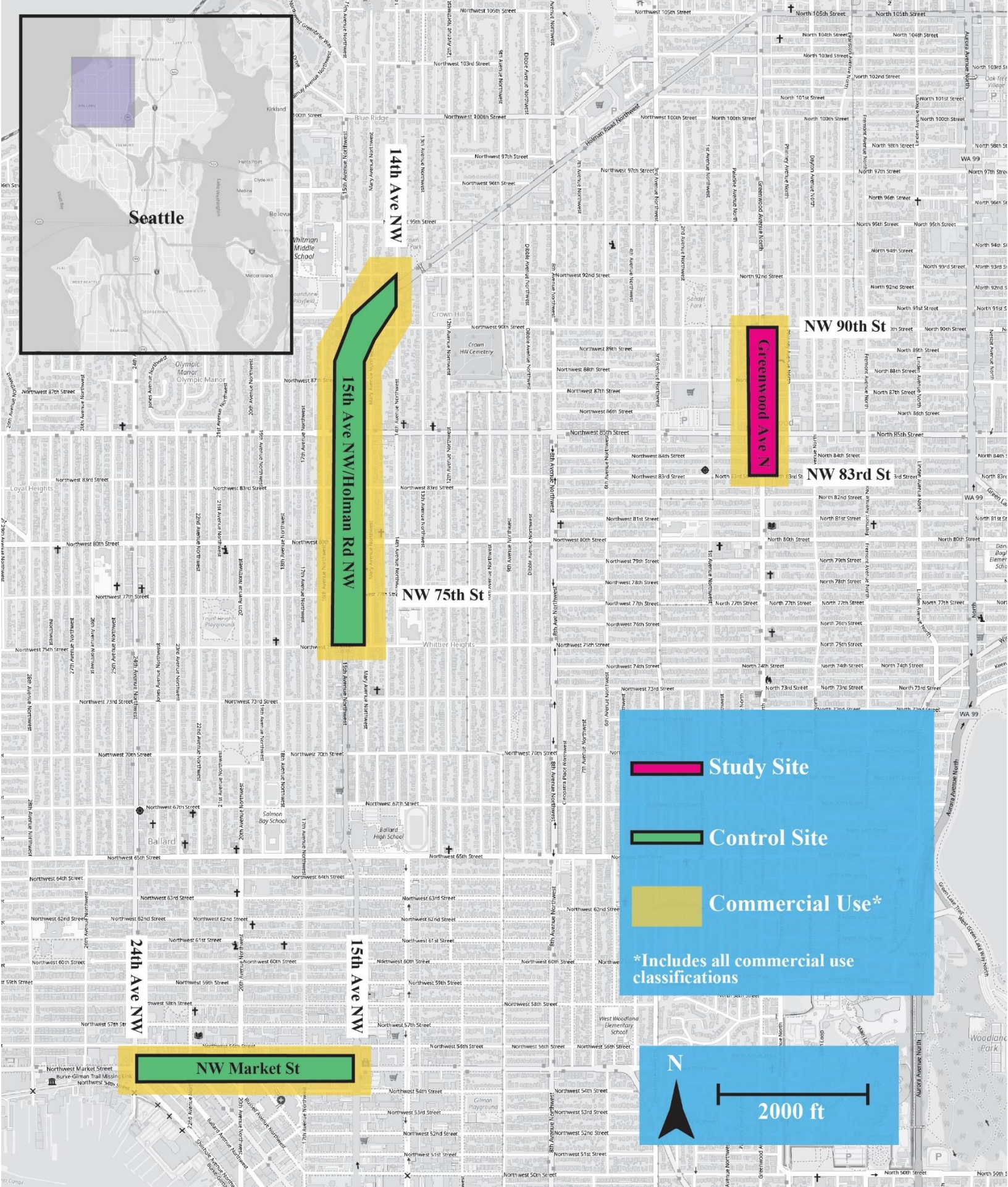
#### 4.5.7 *Discussion*

These analyses suggest that the Vision Zero safety project on Aurora Ave N did not have a significant negative or positive impact on adjacent retail, food, and service businesses when compared to Control Site 1, Control Site 2, or City Council District 5.

Study Site 5 is the only study site that did not have physical street design changes in its corridor. While temporary enforcement tactics can be effective in reducing speeds and preventing crashes, they may not be impactful in enhancing the environment around businesses. Study Site 5 performed the worst of all the study sites in the sales index.

Although this study site failed to find a positive or negative impact from the safety project changes on Aurora Ave N businesses, the project did succeed in reducing collisions and decreasing speeds of vehicles.

# Study Site 6: Greenwood Ave N

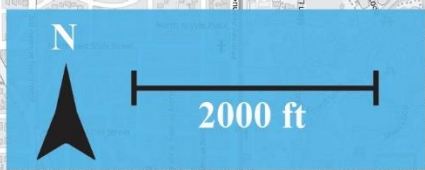


**Study Site**

**Control Site**

**Commercial Use\***

**\*Includes all commercial use classifications**



## 4.6 RESULTS FOR STUDY SITE 6: GREENWOOD AVE N

### Study Site 6- Greenwood Ave N – Bike Lane and Road Diet



Figure 4.6.1 Greenwood Ave N Before Project Implementation (36)



Figure 4.6.2 Greenwood Ave N After Project Implementation (36)

#### 4.6.1 *Implemented* - End of 2010

#### 4.6.2 *Context*

Greenwood Ave N runs through the Seattle neighborhood of Greenwood. To improve conditions for the neighborhood and the broader corridor, the Seattle Department of Transportation implemented a safety project at the end of 2010 which added a bike lane and carried out a road diet.(32) The project ran from N 85<sup>th</sup> St to N 105<sup>th</sup> St. The road had two travel lanes in each direction before the project. After the Vision Zero safety project, Greenwood Ave N had one travel lane in each direction, left turn pockets at the major intersections, bike lanes in both directions, parking on one or both sides of the street, and a center turn lane where space allowed. At the beginning of the study period the study site had 29 retail, 29 food, and 8 service based businesses. At the end of the study period the study site had 27 retail, 26 food, and 8 service based businesses. The total number of businesses decreased from the start of the study period to the end of the study period. While this largely did not impact the total sales of Study Site 6, it may represent a general trend of gentrification.

#### 4.6.3 *Project Goals*

1. Add a reliable bike connection to the Seattle network
2. Improve bicycle safety
3. Improve safety of all users
4. Reduce speeding vehicles
5. Increase predictable movements of all users
6. Decrease the number of injuries
7. Make intersections safer

#### 4.6.4 *Approach*

1. Narrow roadway cross section through a road diet

2. Recanalization that includes a center turn lane
3. Improve signal timing
4. Install left turn pockets at intersections
5. Add a bike facility in both directions

#### 4.6.5 *Safety Benefits Post Project*

1. Dedicated facility for people biking
2. Reduced vehicle speeds
3. Increased bicycle traffic

#### 4.6.6 *Study Results*

Table 4.6.1: Study and Control Sites

Study Site	Control Sites
<b>Greenwood Ave N</b> NW 83 <sup>rd</sup> St to NW 90 <sup>th</sup> St – 4 Blocks	1. 15 <sup>th</sup> Ave NW/Holman Rd NW 75 <sup>th</sup> St to 14 <sup>th</sup> Ave NW – 9 Blocks
	2. NW Market St 15 <sup>th</sup> to 24 <sup>th</sup> Ave NW – 4 Blocks

Table 4.6.2: Change in Sales from Baseline/Improvement Year

Area Study Site	Baseline Annual Sales - 2009	Change in Sales from Baseline/Improvement Year		
		Year 1 – 2010	Year 2 – 2011	Year 3 – 2012
Greenwood Ave N	\$21,644,122	+0%	-23%	-2%
Seattle City Council District				
District 6	\$676,736,444	+6%	+1%	+7%
Control Sites				
1. 15 <sup>th</sup> Ave NW/ Holman Rd NW	\$60,443,994	-7%	-33%	-24%
2. NW Market St	\$42,352,989	-3%	-5%	-12%

**Aggregated Trend Analysis:** Study Site 6, Greenwood Ave N, performed similarly to the control sites and Seattle City Council District 6. After implementation of the project, businesses on the Greenwood Ave N corridor saw sales remain consistent in the first year. Sales fell 22% from baseline in the second year and rebounded to only down 2% from baseline in the third year. The

sales trends suggest the street design changes in Study Site 6 did not negatively impact retail, food, and service businesses sales.

### Change in Sales Aggregated Trend Analysis: Study Site 6 Greenwood Ave N vs. Control Sites

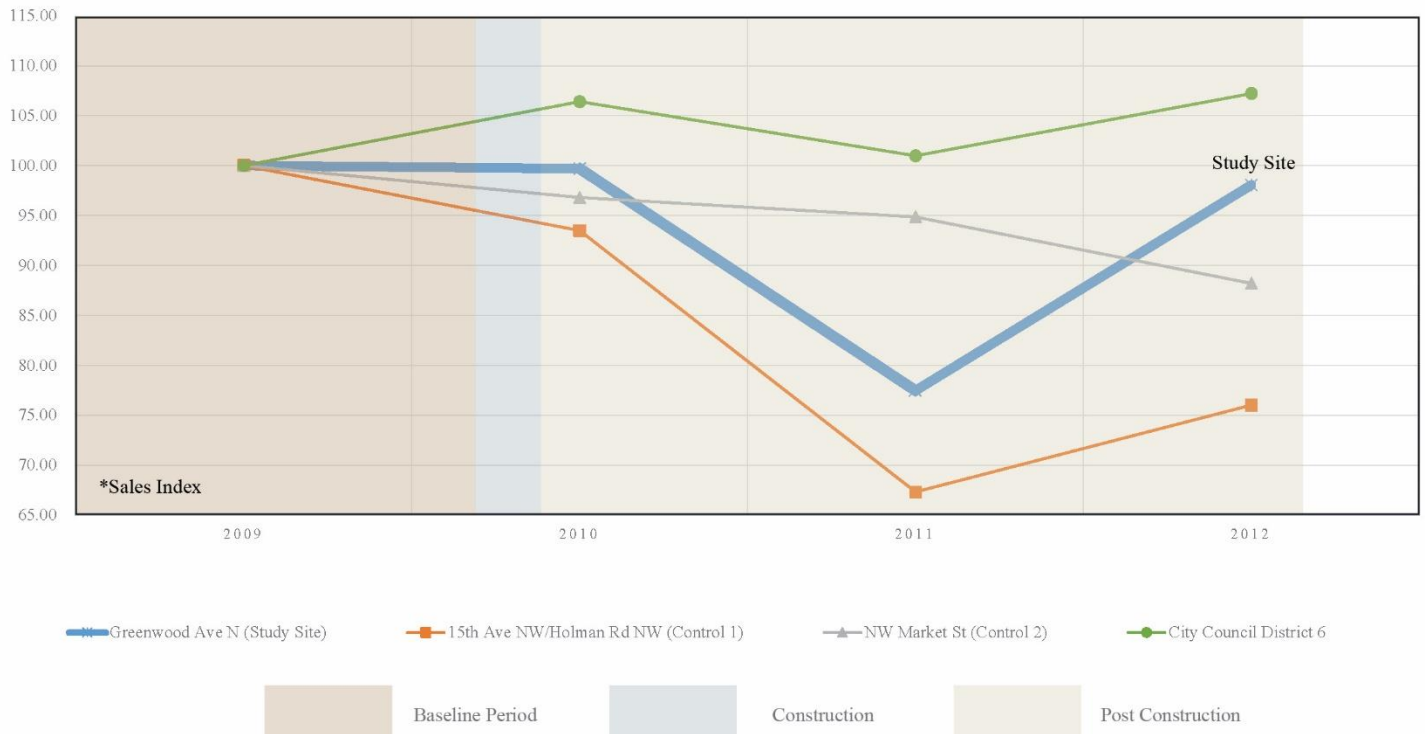


Figure 4.6.3 Change in Sales Aggregated Trend Analysis: Study Site 6

**Paired T-tests:** The paired t-tests failed to show a statistically significant difference between Study Site 6 and the control sites.

#### 4.6.7 *Discussion*

These analyses suggest that the Vision Zero street design changes on Greenwood Ave N did not have significant negative or positive impacts on adjacent retail, food, and service businesses when compared to Control Site 1, Control Site 2, or City Council District 6.

Although this study site failed to find a positive or negative impact from the street design changes on Greenwood Ave N businesses, the project added to the bicycle network and created a safer environment for all users.

# Study Site 7: Bell Street



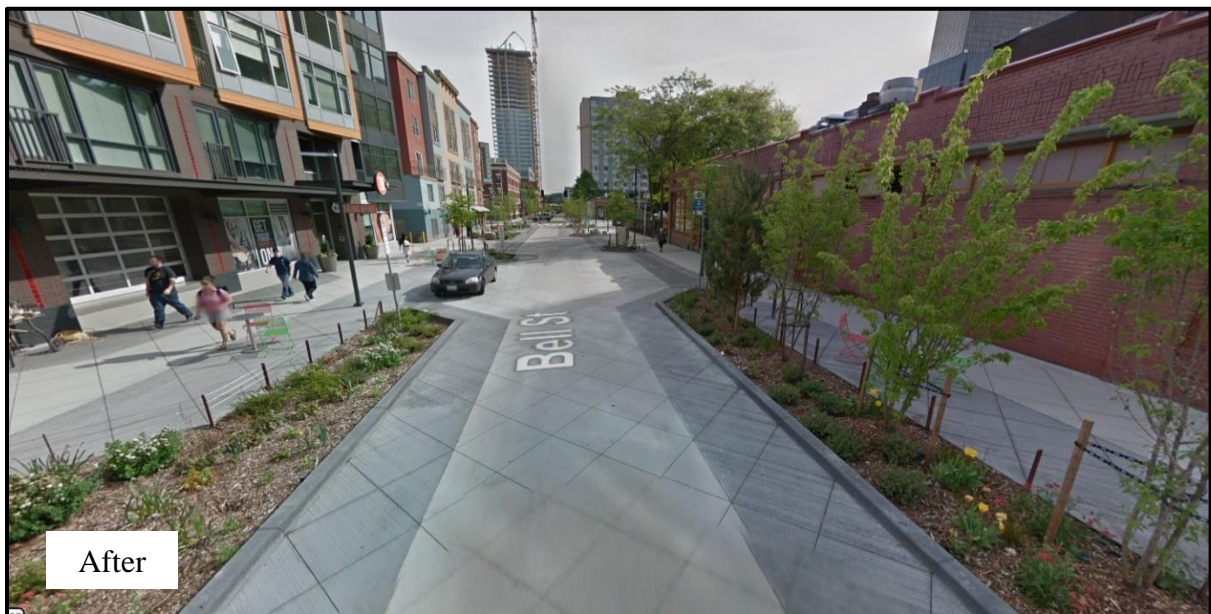
## 4.7 RESULTS FOR STUDY SITE 7: BELL ST

### Study Site 7- Bell Street – Woonerf Style Redesign



Before

Figure 4.7.1 Bell Street Before Project Implementation (36)



After

Figure 4.7.2 Bell Street After Project Implementation (36)

#### 4.7.1 *Implemented* - Completed in early 2014

#### 4.7.2 *Context*

A 2008 City audit found Belltown did not meet its goal for open space.(44) The community approved a ‘Park and Open Space Levy’ to help transfer the Bell St right-of-way (1<sup>st</sup> Ave to 5<sup>th</sup> Ave) from SDOT to Seattle’s Parks and Recreation Department.(44) The project looked to expand shared open space for the community.(44) Before the project, one-way Bell Street consisted of two travel lanes and parking.(44) At the beginning of the study period the study site had 17 retail, 27 food, and 12 service based businesses. At the end of the study period the study site had 15 retail, 22 food, and 4 service based businesses. The total number of businesses decreased from the start of the study period to the end of the study period. While this largely did not impact the total sales of Study Site 7, it may represent a general trend of gentrification.

#### 4.7.3 *Project Goals*

1. Expand shared open space for the community
2. Make the area more desirable to frequent
3. Improve safety of all users
4. Reduce speeding vehicles
5. Increase predictable movements of all users
6. Decrease the number of injuries
7. Make intersections safer

#### 4.7.4 *Approach* (44)

1. Make Bell St into a Woonerf, a “living street” for all users
2. Narrow roadway cross section (road diet)
3. Mandate cars turn off Bell St at the first opportunity to restrict traffic flow
4. Reclaim space previously dedicated to vehicles for all users
5. Elevate the street to make a level surface without curbs

6. Make the grid at a human scale instead of vehicle scale
7. Twist and meander the street to deter speeds and “emphasize store fronts and street amenities over thru-travel”
8. Install bulb outs, curb ramps, and truncated domes at avenue crossings to better show pedestrians and improve sight lines
9. Install tables, chairs, bike parking, public art, and lighting
10. Install driveway curbs to change the elevation and indicate shared space

4.7.5 *Safety Benefits Post Project (44)*

1. Slowed traffic speeds
2. Reduced traffic volumes
3. Slower vehicle speeds
4. Safer walking environment

4.7.6 *Study Results*

Table 4.7.1: Study and Control Sites

Study Site	Control Sites
<b>Bell St</b> Western Ave to 5 <sup>th</sup> Ave – 5 Blocks	1. Blanchard St Western Ave to 5 <sup>th</sup> Ave – 5 Blocks
	2. Lenora St Western Ave to 5 <sup>th</sup> Ave – 5 Blocks
	3. Virginia St Western Ave to 5 <sup>th</sup> Ave – 5 Blocks

Table 4.7.2: Change in Sales from Baseline/Improvement Year

Area Study Site	Baseline Annual Sales - 2013	Change in Sales from Baseline/Improvement Year		
		Year 1 – 2014	Year 2 – 2015	Year 3 – 2016
Bell St	\$21,199,381	+25%	+49%	+47%
<b>Seattle City Council District</b>				
District 7	\$3,424,825,799	+6%	+15%	+17%
<b>Control Sites</b>				
1. Blanchard St	\$12,476,787	+21%	+19%	+11%
2. Lenora St	\$20,393,825	+4%	+51%	+77%
3. Virginia St	\$51,071,952	+1%	+11%	+16%

**Aggregated Trend Analysis:** Study Site 7, Bell St, performed superior to Seattle City Council District 7 and the control sites except for Control Site 2. After implementation of the project, businesses on Bell St saw an initial sales increase of 25% in the first year from baseline, 49% the second year, and 47% in the third year. Study Site 7 appeared to well outperform Control Sites 1 and 3, notable in 2015 and 2016. Seattle City Council District 7 saw steadily increased sales during the study period, whereas Study Site 4 and Control Site 2 saw substantial increases in sales. The sales trends suggest the street design changes in Study Site 4 did not negatively impact retail, food, and service businesses sales and may have had a positive impact.

### Change in Sales Aggregated Trend Analysis: Study Site 7 Bell Street vs. Control Sites

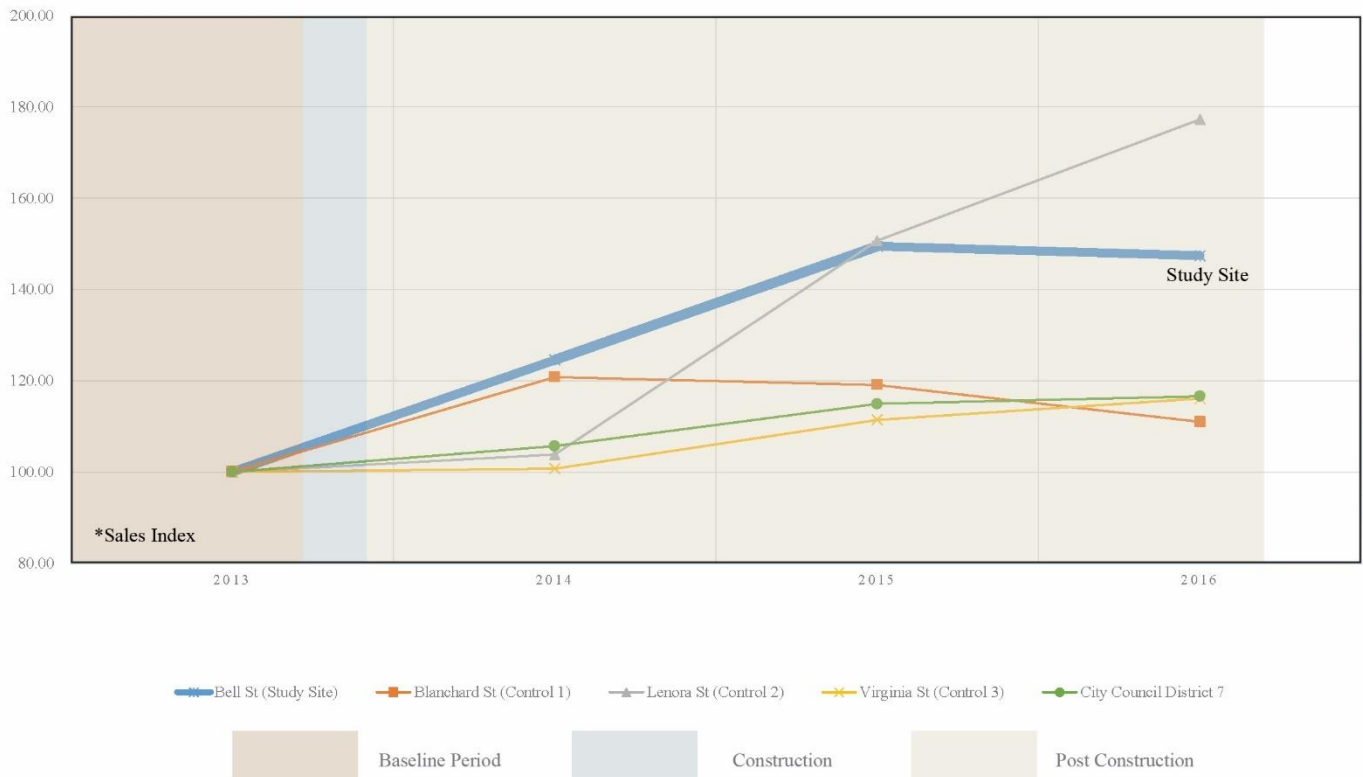


Figure 4.7.3 Change in Sales Aggregated Trend Analysis: Study Site 7

**Paired T-tests:** The paired t-test between Study Site 7, Bell St, and Control Site 1, Blanchard St, showed statistical significance (p-value of 0.05). The paired t-test between Study Site 7 and Control Site 3, Virginia St showed statistical significance (p-value of 0.03). The paired t-test between Study Site 7 and Seattle City Council District 7 showed statistical significance (p-value of 0.03). The paired t-tests between Study Site 7 and Control Site 2 failed to show a statistically significant difference.

#### 4.7.7 *Discussion*

The significant t-tests indicate that the Vision Zero street design changes on Bell St may have had a significant positive impact on adjacent retail, food, and service businesses when compared to Control Site 1, Control Site 3, and Seattle City Council District 7. The failed t-test indicates that the Vision Zero street design changes on Bell St did not have a significant negative or positive impact on adjacent retail, food, and service businesses when compared to Control Site 2.

The establishment of the Woonerf on Bell St represents a study site with the most extreme street design changes. The changes attempted to enhance safety, create community, and improve business vitality. The community loves the project, one article said, “Since project completion, the Bell Street Park has become a favorite in the community, especially among business owners and neighborhood residents.” (40) It is likely this holistic approach is why Bell St performed the best out of all the study sites in the sales index.

In addition to finding that the Vision Zero project on Bell St may have had a positive impact for businesses, the project additionally reduced collisions, decreased vehicle speeds, made the environment more welcoming to all users, provided better protection for pedestrians, and created a place for community gathering.

## Chapter 5. LIMITATIONS

The following are potential limitations of this study:

1. The WA-DOR study data are not broken down by quarter. Annual data are limiting in the number of data points and in the ability to line up analysis with when projects took place. Quarterly data are better for this study design.
2. The methodology includes new and departing businesses. This intentional inclusion aimed to avoid biasing the results in favor of established businesses or business that fare better with Vision Zero street design changes. However, it could be argued that the inclusion of these businesses created inconsistencies in the dataset.
3. It is unknown if total taxable sales are the best measure of business vitality. Past studies used NETS data and retail sales data. The ability to disaggregate businesses by NAICS code is an asset and is an advisable tactic in future work.
4. The utilization of the two digit NAICS code is a macro level of selecting business types. By using the two digit NAICS code, it is not possible to disaggregate impacts on specific business types at a level smaller than “retail”, “food”, or “service”. Although that level of analysis is sufficient for this study, future work may want to utilize four or six digit NAICS codes if enough businesses exist in the study areas.
5. The study did not break down the impact of the street design changes on the four specific NAICS business codes. Instead, the research team used pooled data for analysis. Thus, the study grouped retail, food, and service categories together if the street design changes found a positive, negative, or neutral outcomes for businesses. A further study of this data might show disparate impacts for retail, food, and service based businesses.

6. It is unclear if creating a sales index is the best way to analyze this type of data. In this study a sales index is created by taking the total retail sales for a study site or control site then dividing that by the number of businesses in the site. A baseline of 100% is set for the first year of reported retail sales. The average of all following years is compared to the baseline. Then, matched study sites, City Council Districts, and control sites can be compared to one another.
7. This study only had one year of data before project implementation and two to three years after an implemented project. The one instance of two years post project showed that length of time may not be enough time for analysis. Collecting data for a longer period before a project might help to establish a more reliable baseline. Doing so would give a better indication of trend and would allow for the use of an interrupted time series analysis. Thus, it is advisable to have data for three years before a project and for at least three years after a project.
8. While several instances found statistical significance, generally a small number of inputs went into calculations. Thus, even though p-values show significance, the findings should be taken with reservation. Obtaining data on a quarterly basis and extending the study time frame would help to increase confidence in significance in any future statistical findings.
9. Further research on this topic and using this dataset could be beneficial

## Chapter 6. CONCLUSIONS

There was no negative impact on economic vitality for adjacent retail, food, and service businesses in all seven of the Vision Zero study sites and three sites, Bell St, Rainier Ave S, and Stone Way N, showed significant positive impacts. None of the study sites showed a significant negative impact. The most extreme example of the street design changes, Bell St, showed the best results of all the study sites. Whereas the study site without any street design improvements, Aurora Ave N, fared the worst; while such a safety program based on enforcement may successfully reduce speed and crashes temporarily, it might not be helpful to nearby businesses.

### Change In Sales Aggregated Trend Analysis: All Study Sites

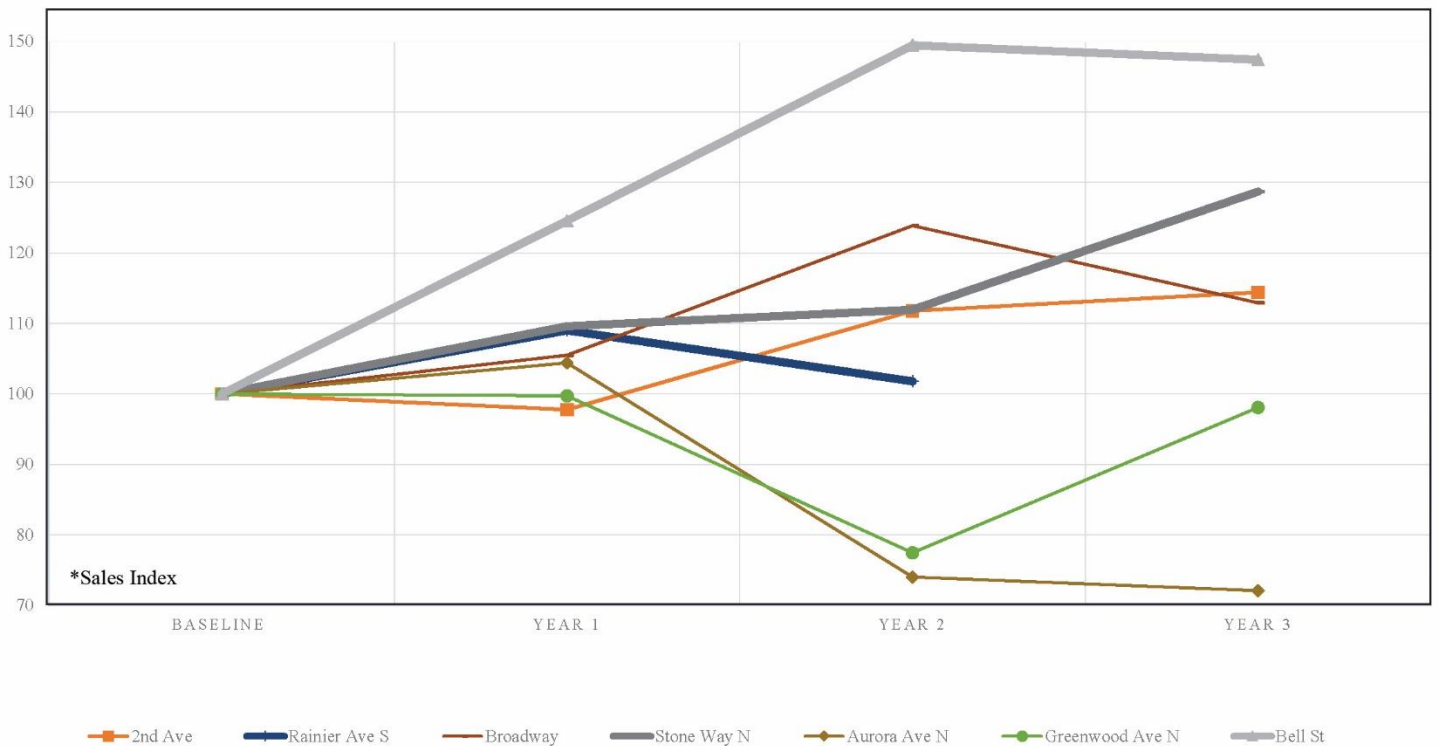


Figure 6.1 Change in Sales Aggregated Trend Analysis: All Study Sites

The total number of businesses decreased in six of the seven study sites from the start of the study period to the end of the study period. While this largely did not impact the total sales of study sites, it may represent a general trend of gentrification.

The study's findings suggest that Vision Zero improvements may have a neutral or positive economic impact on adjacent retail, food, and service businesses. These findings are consistent with Liu, Shi, and Green's 2019 *National Street Improvement Study* on Seattle, which concluded study sites either did not have significant impacts on businesses or had significant positive impacts on businesses. (4)

This research serves to inform transportation practitioners and implementers in Seattle about the potential economic impacts of Vision Zero projects on retail, food, and service focused businesses. Hopefully, such knowledge will help set expectations, ease tensions, and move the implementation of projects forward to achieve the Vision Zero goal of eliminating traffic related injuries and fatalities.

## Chapter 7. WORKS CITED

1. Seattle Department of Transportation. Vision Zero: Seattle's Plan to End Traffic Deaths and Serious Injuries by 2030 [Internet]. 2015. Available from: <https://www.seattle.gov/Documents/Departments/beSuperSafe/VisionZeroPlan.pdf>
2. Bergh T, Carlsson A, Larsson M. Swedish Vision Zero Experience. *Int J Crashworthiness* [Internet]. 2003;8(2):159–67. Available from: <https://link.springer.com/article/10.1533/ijcr.2003.0224>
3. Drennen E. Economic Effects of Traffic Calming on Urban Small Businesses [Internet]. San Francisco State University; 2003. Available from: <https://cedik.ca.uky.edu/files/ecoeffectsofdowntowntrafficalming.pdf>
4. Liu, Shi, Green. National Street Improvements Study: Findings from Seattle [Internet]. 2019. Available from: <https://wsd-pfb-sparkinfluence.s3.amazonaws.com/uploads/2020/03/Seattle-2020-Street-Improvements-Study.pdf>
5. McCoy R, Poirier JA, Chapple K. Bikes or Bust? Analyzing the Impact of Bicycle Infrastructure on Business Performance in San Francisco. *Transp Res Rec* [Internet]. 2019 [cited 2020 Feb 1];2673(12):277–89. Available from: <https://doi.org/10.1177/0361198119850465>
6. Center for Disease Control and Prevention. Road Traffic Injuries and Deaths—A Global Problem [Internet]. Center for Disease Control and Prevention. 2019. Available from: <https://www.cdc.gov/features/globalroadsafety/index.html>
7. Association for Safe International Road Travel. Annual United States Road Crash Statistics [Internet]. Association for Safe International Road Travel. 2020. Available from: <https://www.asirt.org/safe-travel/road-safety-facts/#:~:text=More than 38% 2C000 people die,for people aged 1-54.>
8. Dekker SWA, Long R, Wybo JL. Zero Vision and a Western Salvation Narrative. *Saf Sci* [Internet]. 2016;88:219–23. Available from: <http://sidneydekker.com/wp-content/uploads/2017/09/ZeroVision.pdf>
9. National Highway Traffic Safety Administration. Fatality and Injury Reporting System Tool [Internet]. National Highway Traffic Safety Administration. 2019. Available from: <https://cdan.dot.gov/query>
10. Washington Traffic Safety Commission. Washington State 2018 Traffic Safety Annual Report [Internet]. 2018. Available from: [https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/wa\\_fy2018\\_ar.pdf](https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/wa_fy2018_ar.pdf)
11. Kristianssen AC, Andersson R, Belin MÅ, Nilsen P. Swedish Vision Zero Policies for Safety – A comparative Policy Content Analysis. *Saf Sci* [Internet]. 2018;103:260–9. Available from: <https://www.sciencedirect.com/science/article/pii/S0925753517309013>
12. Dalal K, Lin Z, Gifford M, Svanström L. Economics of Global Burden of Road Traffic Injuries and Their Relationship with Health System Variables. *Int J Prev Med* [Internet]. 2013;4(12):1442–50. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3898451/>
13. Seattle Department of Transportation. City of Seattle Bicycle and Pedestrian Safety Analysis [Internet]. 2016. Available from: <https://www.seattle.gov/Documents/Departments/SeattleBicycleAdvisoryBoard/presentati>

- ons/BPSA\_Draft\_Public\_093016.pdf
14. Elvebakk B. Vision zero: Remaking Road Safety. *Mobilities* [Internet]. 2007 Nov;2(3):425–41. Available from: <https://doi.org/10.1080/17450100701597426>
  15. Cervero, R., Guerra, Erick, & Al S. *Beyond mobility : Planning Cities for People and Places*. Washington, DC: Island Press.; 2017.
  16. Shalom Hakkert A, Gitelman V. Thinking About the History of Road Safety Research: Past Achievements and Future Challenges. *Transp Res Part F Traffic Psychol Behav* [Internet]. 2014;25(Part B):137–49. Available from: <https://doi.org/10.1016/j.trf.2014.02.005>
  17. Ezra H. On the Relationship Between Road Safety Research and the Practice of Road Design and Operation. *Accid Anal Prev* [Internet]. 2019;128:114–31. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0001457518311710>
  18. Belin MÅ, Tillgren P, Vedung E. Vision Zero - A Road Safety Policy Innovation. *Int J Inj Contr Saf Promot* [Internet]. 2012 Jun;19(2):171–9. Available from: <https://www.tandfonline.com/doi/full/10.1080/17457300.2011.635213>
  19. U.S Department of Transportation Federal Highway Administration. *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes* [Internet]. 2008. Available from: [https://safety.fhwa.dot.gov/ped\\_bike/tools\\_solve/ped\\_tctpepc/](https://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_tctpepc/)
  20. Strandroth J. Validation of a Method to Evaluate Future Impact of Road Safety Interventions, a Comparison Between Fatal Passenger Car Crashes in Sweden 2000 and 2010. *Accid Anal Prev* [Internet]. 2015;76:133–40. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0001457515000020?via%3Dihub>
  21. Johansson R. Vision Zero - Implementing a Policy for Traffic Safety. *Saf Sci* [Internet]. 2009;47(6):826–31. Available from: <https://www.sciencedirect.com/science/article/pii/S0925753508001859>
  22. World Health Organization. *Road Traffic Injuries* [Internet]. WHO. World Health Organization; 2019 [cited 2019 Oct 6]. Available from: <https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries>
  23. Grundy C, Steinbach R, Edwards P, Green J, Armstrong B, Wilkinson P. Effect of 20 Mph Traffic Speed Zones on Road Injuries in London, 1986-2006: Controlled Interrupted Time Series Analysis. *BMJ* [Internet]. 2009 Dec 3;339(7736):31. Available from: <https://www.bmj.com/content/339/bmj.b4469>
  24. Richards DC. *Relationship between Speed and Risk of Fatal Injury : Pedestrians and Car Occupants* [Internet]. 2010. Available from: [https://nacto.org/docs/usdg/relationship\\_between\\_speed\\_risk\\_fatal\\_injury\\_pedestrians\\_and\\_car\\_occupants\\_richards.pdf](https://nacto.org/docs/usdg/relationship_between_speed_risk_fatal_injury_pedestrians_and_car_occupants_richards.pdf)
  25. Jamroz K, Kustra W, Budzynski M, Zukowska J. Pedestrian Protection, Speed Enforcement and Road Network Structure the Key Action for Implementing Poland's Vision Zero. *Transp Res Procedia* [Internet]. 2016;14:3905–14. Available from: <https://www.sciencedirect.com/science/article/pii/S2352146516304860>
  26. Institute of Transportation Engineers. *Designing Walkable Urban Thoroughfares : A Context Sensitive Approach*. [Internet]. Institute of Transportation Engineers; 2010. 1–215 p. Available from: <https://www.ite.org/pub/?id=e1cff43c-2354-d714-51d9-d82b39d4dbad>
  27. Poirier JA. Bicycle Lanes and Business Success: A San Francisco Examination. *Artic Transp Res Rec* [Internet]. 2018 [cited 2020 Feb 1];2672(7):47–57. Available from: <https://doi.org/10.1177/0361198118792321>

28. David Hurwitz S, Ghodrat Abadi M, McCormack E, Goodchild A, Sheth M. An Examination of The Impact of Commercial Parking Utilization on Cyclist Behavior in Urban Environments [Internet]. 2017. Available from: <https://digital.lib.washington.edu/researchworks/handle/1773/43520>
29. New York City Department of Transportation. The Economic Benefits of Sustainable Streets [Internet]. 2014. Available from: <http://www.nyc.gov/html/dot/downloads/pdf/dot-economic-benefits-of-sustainable-streets.pdf>
30. Sztabinski F (Clearn AP. Bike Lanes, On-Street Parking and Business A Study of Bloor Street in Toronto's Annex Neighbourhood [Internet]. 2009. Available from: <https://grist.files.wordpress.com/2011/04/bike-lanes-parking.pdf>
31. New York City Department of Transportation. Measuring the Street: New Metrics for 21st Century Streets [Internet]. 2012. Available from: <http://www.nyc.gov/html/dot/downloads/pdf/2012-10-measuring-the-street.pdf>
32. Rowe K. Bikenomics - Measuring the Economic Impact of Bicycle Facilities on Neighborhood Business Districts [Internet]. University of Washington; 2013. Available from: [http://bikewalkkc.org/wp-content/uploads/2016/03/Bikenomics\\_v4.pdf](http://bikewalkkc.org/wp-content/uploads/2016/03/Bikenomics_v4.pdf)
33. Sahuguet A. Vizion Zero NYC: Toward Ending Fatalities on the Road [Internet]. Vol. 4. Columbia University Press; 2018. 277–303 p. Available from: <https://www.jstor.org/stable/10.7312/dalm18374.17>
34. Washington Department of Revenue. WA-DOR NAICS Info [Internet]. Washington State Department of Revenue. 2020. Available from: <https://dor.wa.gov/open-business/apply-business-license/naics-info>
35. Liu, Shi, Green. National Street Improvements Study: Findings from Seattle [Internet]. 2019. Available from: <https://wsd-pfb-sparkinfluence.s3.amazonaws.com/uploads/2020/03/Seattle-2020-Street-Improvements-Study.pdf>
36. Google Street View [Internet]. Available from: <https://www.google.com/maps/>
37. Fucoloro T. Bike traffic on 2nd Ave triples after city builds protected bike lane [Internet]. Seattle Bike Blog. 2014. Available from: <https://www.seattlebikeblog.com/2014/09/16/bike-traffic-on-2nd-ave-increases-300-after-city-builds-protected-bike-lane/>
38. Seattle Department of Transportation. Rainier Avenue South Safety Corridor [Internet]. 2016. Available from: [https://www.seattle.gov/Documents/Departments/SDOT/MaintenanceProgram/RainierAveS\\_BeforeAfter.pdf%0D](https://www.seattle.gov/Documents/Departments/SDOT/MaintenanceProgram/RainierAveS_BeforeAfter.pdf%0D)
39. Transportation SD of. Broadway Protected Bike Lane Expected to Open Next Week [Internet]. SDOT Blog. 2014. Available from: <https://sdotblog.seattle.gov/2014/05/01/broadway-protected-bike-lane-expected-to-open-next-week/%0D>
40. Alta Planning + Design. Bicycle Interactions and Streetcars: Lessons Learned and Recommendations [Internet]. 2008. Available from: [https://altaplanning.com/wp-content/uploads/Bicycle\\_Streetcar\\_Memo\\_ALTA.pdf](https://altaplanning.com/wp-content/uploads/Bicycle_Streetcar_Memo_ALTA.pdf)
41. Fucoloro T. A tour of Seattle's new Broadway Bikeway + How it makes life better for people walking [Internet]. Seattle Bike Blog. 2014. Available from: <https://www.seattlebikeblog.com/2014/05/09/a-tour-of-seattles-new-broadway-bikeway-how-it-makes-life-better-for-people-walking/>

42. Seattle Department of Transportation. Stone Way N Rechannelization: Before and After Study, N 34th Street to N 50th Street [Internet]. 2010. Available from: <https://www.seattle.gov/Documents/Departments/SDOT/About/DocumentLibrary/Reports/StoneWaybeforeafterFINAL.pdf>
43. Seattle Department of Transportation. Aurora Traffic Safety Project Update [Internet]. SDOT Blog. 2011. Available from: <https://sdotblog.seattle.gov/2011/12/09/aurora-traffic-safety-project-update/>
44. NACTO. Bell Street Park Shared Street, Seattle [Internet]. Transit Street Design Guide. 2014. Available from: <https://nacto.org/case-study/bell-street-park-seattle/>