A Policy and Spatial Analysis of Vision Zero: Process and Equity in Three U.S. Cities

by

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ABSTRACT

Although cycling and walking for transportation carry a host of benefits, bicycle culture and infrastructure are associated with privilege and gentrification. Simultaneously, low-income and communities of colour are overrepresented in severe injury and fatality rates among cyclists and pedestrians (Flanagan, Lachapelle, & El-Geneidy, 2016; Smarth Growth America, 2017). Vision Zero is a policy, increasingly common in North American cities, which considers death and serious injury from traffic to be preventable and morally unacceptable. Implementation of this policy encompasses infrastructural, policy, and other changes. This research examines policy documents and the spatial distribution of bike infrastructure and safety improvements in Boston, New York, and San Francisco, among the earliest major U.S. cities to adopt the policy. Findings suggest some consensus regarding physical interventions, but approaches vary in efficacy, comprehensiveness, and methods for integrating equity. Spatial and statistical analysis reveal complex patterns of access to safety interventions across cities, requiring further research.

CHAPTER 1: INTRODUCTION

Although walking and cycling for transportation are associated with a variety of health, social, economic, and environmental benefits, for many they remain dangerous activities due to the risk of crash with motor vehicles (Dill, 2009; Reynolds, Winters, Ries, & Gouge, 2010; Sallis et al., 2015, p. 9). In 2015 alone, there were over 35,000 traffic fatalities in the United States, with over 6,500 of those fatalities representing pedestrians and cyclists. This is an increase in the total fatality rate seen over the last five years, including a marked increase in cyclist/pedestrian fatalities (National Highway Traffic Safety Administration, 2017). While the high baseline fatality rate suggests a certain cultural tolerance for traffic violence, this perspective is being increasingly challenged in U.S. cities.

The Vision Zero movement began in 1997, when the Swedish Parliament passed a Traffic Safety bill stating that "Vision Zero means that eventually no one will be killed or seriously injured within the road transport system" (Johansson, 2009, p. 827). Since then, cities within the United States and throughout the world have adopted the policy, which seeks to eliminate fatalities and serious injuries from traffic crashes by redesigning and implementing new forms of road policy and infrastructure, often targeted at protecting the most vulnerable road users. This includes traffic calming measures[1], shared streets[2], separated bike lanes[3], and speed limit reduction (Cushing, Hooshmand, Pomares, & Hotz, 2016). Simultaneously, however, it has become increasingly clear that many US cities are plagued by issues of unequal access to bicycling infrastructure, with research revealing a relationship between bicycle infrastructure and gentrification in multiple cities (Flanagan et al., 2016; Hoffmann, 2013; Lubitow & Miller, 2013; Sheller, 2015). Meanwhile, low-income and communities of colour are overrepresented in pedestrian and cyclist fatalities (Smarth Growth America, 2017).

[1] Traffic calming measures are implemented to intentionally slow traffic flow.
[2] Shared streets lack formal distinctions between space for various road users, relying instead upon the awareness of each road user. Pedestrians are given right-of-way while vehicles are considered guests (Global Designing Cities Initiative, 2016).
[3] Separated or protected bicycle lanes, or cycle tracks, are facilities for exclusive bicycle use that are physically separated from sidewalks, parking lanes, and sidewalks. They can be distinguished from conventional, or unprotected bicycle lanes, which are designated with pavement markings and signage but do not include a physical barrier (Global Designing Cities Initiative, 2016).

While Vision Zero is gaining increasing prominence in American planning, little research has sought to understand best practices for its application in the distinct North American context. This includes the most appropriate methods for reducing death and serious injury, site and project prioritization, and methods for ensuring the planning process reflects equity. This research considers Boston, New York, and San Francisco, among the first U.S. cities to commit to Vision Zero. Through document, spatial, and statistical analysis, my research aims to understand the decision-making process and role of equity in these cities' implementation of Vision Zero.

This chapter will introduce the theoretical basis for Vision Zero, including its history of implementation, as well as provide the research aims and structure of this thesis.

1.1 Vision Zero

The concept of Vision Zero (*Nollvisionen*) was first highlighted in a policy memorandum composed by the former Swedish Road Administration as part of a vision for a transportation system without health losses (Belin, Tillgren, & Vedung, 2012; McAndrews, 2013). The authors sought to follow standards set by the nuclear, rail, and aviation industries, which consider all deaths to be preventable, and apply the same approach to the road system, where they felt death and serious injury had become socially acceptable and even expected (Kim, Muennig, & Rosen, 2017). The Swedish Parliament codified Vision Zero in a bill passed in 1997, which was considered by many to represent a new traffic safety paradigm (Belin et al., 2012; Johansson, 2009).

The heart of Vision Zero, as articulated by its originators in Sweden, is an ethical commitment to traffic safety: that ‘‘It can never be ethically acceptable that people are killed or seriously injured when moving within the road transport system" (Johansson, 2009, p. 827). Many consider the policy's key innovation, however, to be its reenvisioning of responsibility for road safety (Belin et al., 2012). Rather than the burden of safety resting solely upon the actions of individual road users, road system designers are considered to have a moral responsibility to ensure safety. While road users hold a responsibility to observe the rules set by designers, when injuries occur or users do not observe these rules, the responsibility, the causal responsibility in fact, lays with the designer to take action to counteract this behaviour and ensure safety (Johansson, 2009; McAndrews, 2013). In this sense, responsibility is shared, but starts and ends with system designers.

Vision Zero is also considered innovative in its departure from the approach of adapting the human to the road system. Instead, the focus is adapting the road system to the human and its capabilities, as well as physiological ability, to withstand violent force (Belin et al., 2012). Rather than focus on preventing humans from causing "accidents," Vision Zero takes a public health perspective and proposes that roads must be designed with both human error and capacity to withstand external violence in mind, wherein the design itself ensures that mistakes do not result in death or serious injury (Belin et al., 2012). In this way, Vision Zero is grounded in scientific realities of kinetic energy and human tolerance to force, understanding kinetic energy (speed) as the cause of death and serious injury (Belin et al., 2012). From this perspective, then, a roundabout, while potentially causing more collisions, is a superior safety intervention compared to traffic lights. While installing traffic lights can effectively reduce the number of collisions, crashes will occur at higher speeds and thus be more serious compared to those that happen at low speeds in the roundabout (Belin et al., 2012, p. 177).

The ultimate implication of this policy, as argued by McAndrews (2013), is that safety should not be traded for mobility, and that while crashes are expected, public health must be prioritized so that these collisions do not result in serious injury and death. As such, kinetic energy is managed with speed limits and an approach of "integrating compatible traffic elements" and "separating incompatible ones" (Johansson, 2009, p. 829). This boils down to protecting vulnerable road users from motorized vehicles travelling above 30 km/h (18.6 mph) through physical separation or 30 km/h speed limits, and limiting the exposure of car occupants to motor vehicles travelling above 70 km/h (43.5 mph) or 50 km/h (31.07), dependent on road factors (Johansson, 2009). In this case, however, it is worth noting that separation refers to physical, not temporal barriers (meaning traffic lights are not sufficient), and that the space of a few meters is not considered a sufficient separation (Johansson, 2009). Similarly, pedestrian crossings ("the white lines") cannot of themselves be considered a safety intervention, and should instead be considered a means of regulating priority, with safety dependent upon the speed of cars (p. 831).

The authors of the memo and policy document have emphasized that the philosophy of Vision Zero must permeate throughout the multiple public and private bodies participating in transportation and road design, framing coordination and cooperation between bodies as a necessary factor in determining efficacy (Belin et al., 2012; McAndrews, 2013). This includes

the traditional road designers as well as vehicle designers and industry groups, meaning that vehicle manufacturers can theoretically be held responsible for failing to integrate safety measures into vehicles. This is part of the systems perspective underlying Vision Zero, that understands that "upstream" factors like design and vehicle standards and public participation affect safety (McAndrews, 2013). Indeed, citizen participation is a key part of Vision Zero--not only must it be solicited, but it is actually citizens' responsibility to provide feedback and demand changes (Belin et al., 2012). In this way, road users are reconceptualized from being the cause of accidents, whose behaviour must be controlled and subdued through training and monitoring, into agents whose demands for safety and road improvements play a key role in road design (Belin et al., 2012).

The policy is not without its sceptics, especially when vision must meet reality during the implementation process. Broadly, it has been suggested that Vision Zero's impact is limited by the lack of institutional structure underlying its messages. Critics say that without formal measures to ensure accountability on the one hand, and community input on the other, the efficacy of the movement is left up to self-regulation, which may or may not be effective (McAndrews, 2013). Others have noted that the Sweden's adoption of the policy has represented as assumption of state power, in the way it redefines roles and responsibilities and shifts control and influence to experts, while retaining the ultimate power within the National Road Administration (Andersson & Pettersson, 2008; Elvebakk, 2007; McAndrews, 2013). This ties into larger criticisms of Vision Zero's understanding of how to approach the prevention of traffic deaths. Specifically, that its prioritization of infrastructure changes comes at the expense of other approaches and disciplines (McAndrews, 2013). In this sense, they argue, the policy is not so radical in its redefinition of responsibility after all, and that collaboration has been limited in practice as responsibility largely remains with government traffic engineers. Others suggest that coming close to achieving 'zero' would require significant infringements upon road users' choices and freedoms, be it by mandating certain behaviours, like seat-belt wearing, or introducing technology, like alcohol interlock systems, that restricts autonomy (Elvebakk, 2007). Proponents of Vision Zero, however, point to traffic collisions' costs to society, including loss of life and ability, and the fact that such loss is preventable and thus need not be socially accepted (Elvebakk, 2007).

Of course, as the movement has mobilized beyond its original context, challenges and methods of implementation have differed. Scholars have noted the challenge that North American car culture and car dependency poses to implementation, particularly in the United States (Ahangari, Atkinson-Palombo, & Garrick, 2017). Others have noted that a lack of cycling infrastructure and relatively low rates of bicycle and pedestrian commuting present a significant opportunity for improvement, but a challenge as well due to both attitudes of road users as well as the significant degree of infrastructure investment required to get to 'zero' (Cushing et al., 2016).

In the original, European context, Vision Zero as much applies to the safety of motorists as to cyclists and pedestrians. This thesis, however, will be focused exclusively on bicycle and pedestrian safety. There are several reasons for this. A large reason for this is that cyclists and pedestrians remain overrepresented in traffic fatalities (Alliance for Biking & Walking, 2016, p. XV). In fact, while driving has become increasingly safe, in recent years bicycle and walking commuters have come to represent a larger share of traffic fatalities (Smarth Growth America, 2017, p. 2). Following this, as Vision Zero has been implemented in North America, it has largely been concerned with increasing the safety of these most vulnerable road users. As such, this will be the focus of my thesis.

1.2 Research aims and questions

This thesis seeks to understand Boston, New York, and San Francisco's approaches to Vision Zero implementation, including their commitment to inclusivity and equity, through quantitative and qualitative methods. My research will consider the various ways that these cities have framed this commitment in official planning documents with an eye to proposed actions, to be compared with the actions actually undertaken with regard to infrastructure and policy. This study will also take a spatial and health equity perspective to consider to what extent the cities' planning processes facilitate inclusion and equitable access to safety and transportation investment. A spatial analysis of interventions undertaken will provide some insight into how this has translated to real change. Finally, I will consider which methods have been most successful in making the planning process equitable as well as in achieving improvements in policy and the built environment.

As more cities take on initiatives such as Vision Zero and invest in improving active transit and particularly bike infrastructure, it is important to consider proposed methods for

improving equity in conjunction with actions actually undertaken. Many cities have, over the years, affirmed commitments to equity and accessibility in planning documents; however, such commitments can lack follow-through or consist of insufficient goalsetting in the first place, precluding progress towards greater equity. Considering these together will allow for a holistic understanding of the way Vision Zero is being translated to the North American context. This study will additionally provide analysis of shortcomings and successes in the implementation approaches of three major cities, making it a relevant work as more cities commit to similar goals.

1.3 Thesis structure

Chapter One provides context on the specificities of the initiative, while Chapter Two will provide a context of the transportation landscape and the cities to be studied. Chapter Three includes a review and the definition of key concepts related to equity in transportation planning, followed by an overview of existing scholarship. I will consider the effect of the built environment on mode share[4] and road safety, which will contextualize cities' present realities and potential forms in the future. I will also review the topic of justice in transportation planning, in both theoretical and practical terms. Following this will be a review of the relationship between inequality and bicycle infrastructure, and the role of privilege in "bike culture". Finally, I will explore the various ways GIS can be used in analysis of spatial equity. Chapter Four will explain the methodology employed in this analysis, including content analysis and spatial and statistical analysis. Findings will be described in Chapter Five. I will conclude by discussing and contrasting practices within and between cities and noting implications and best practices, as well as directions for future research, in Chapter Six.

[4] Transit mode share, or mode share, is the "share" of travelers using a specific transportation method. "Active transport" refers to mode choices of walking, cycling, or public transit.

CHAPTER 2: CONTEXT

Here, I discuss the physical and political context underlying this study. In order to situate this research, I first review some of the basics of transportation planning, including transportation plans, an overview of how such plans are enacted, and the actors and jurisdictions governing the process. Following this is a consideration of the larger trends in transportation and urban planning, including where within these trends Vision Zero fits. Finally, I provide an overview of each city's history and socioeconomic context, road and infrastructure network and transportation mode share and safety.

2.1 Process, politics, and trends in transportation planning

Urban planning in general, and transportation planning specifically, involves a variety of actors working in an assortment of jurisdictions. This includes several actors at the federal and regional levels. In the context of the United States, this includes the U.S. Department of Transportation, which grants and oversees funding and development of transportation infrastructure and services; the state departments of transportation (DOTs), which oversee funding and maintenance of state highways, lead state plans, and provide data and technical support to a variety of plans; and metropolitan planning organizations (MPOs), which draw up long-range plans, disburse funds, maintain regional forecasting models, and support other planning efforts (American Planning Association, Steiner, & Butler, 2012, p. 18). Local governments at the city or county level maintain surface transportation, create local plans, and often provide local expertise in regional planning efforts; regional transportation providers have a similar role.

This complicated reality is reflected in the plans themselves. The main types of transportation plans include local transportation plans, corridor plans, metropolitan area long-range transportation plans, and statewide transportation (American Planning Association et al., 2012, p. 18). Local plans are most often prepared by local governments or transit providers, but coordinated closely with state DOTs and MPOs. They address the range from short- to mid- to (some) long-term action items, including small changes and some projects requiring a high degree of capital investment. Corridor plans are most often produced by state DOTs and transit providers for areas that are particularly congested, are predicted to have high future transit use, or have transportation provisions of significance. Metropolitan area long-range transportation plans are prepared by MPOs with a 20-year timeframe, assessing multiple jurisdictions to

consider major improvements and assess use patterns and problems. Statewide plans are prepared by DOTs, cover intermodal travel, and plan for a minimum of 20 years, coordinating data and analysis to support various planning efforts (American Planning Association et al., 2012, p. 19)

Policies and planning to encourage walking and cycling, and improve pedestrian and cyclist safety, appear throughout various types of planning documents. At the federal level, bicycle and pedestrian transport initiatives receive support through federal policy and USDOT recommendations and funding; numerous strategic plans and design guidance documents have been released by USDOT and its internal administrations in the past 20 years (Federal Highway Administration, 2013; U.S. Department of Transportation, 2014). Many states, MPOs, and corridors release design guides or strategic transportation plans, specific to pedestrian and bicycle travel or active transportation more broadly. Specific design interventions primarily appear in local or municipal plans, including city-wide mid-range transportation plans and short-range bicycle or pedestrian plans. This research will focus on the latter two.

Planning's values and methods have shifted over the years, and it is in this context that we can situate Vision Zero. In contrast to the discipline's past of top-down planning, recent decades have emphasized participation of citizens in the process. This includes a more general shift to people-centric planning, in which residents are a key part of determining problems and solutions for improved quality of life and wellbeing (Forsyth, 2005). There has also been an increased focus on sustainability, including planning for active transportation as a way of reducing emissions and providing health benefits. Recent years are notable for integrating a more holistic understanding of sustainability, expanding it beyond environmental sustainability to include concerns about 'social sustainability', which places an emphasis on equity and representation among other things. These focuses on sustainability and participation can be traced, in part, to the environmental movement and subsequent legislation affecting required planning outcomes and the funding process. Notable examples include the 1969 National Environmental Policy Act (NEPA), the 1970 Clean Air Act (CAA) and 1990 Clean Air Act Amendments (CAAA), the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA), and President Bill Clinton's 1994 executive order requiring that environmental justice be included in the mission of all federal agencies in order to ensure "full and fair participation by all potentially affected communities in the transportation decision-making process" (Handy & Sciara, 2017).

2.2 Boston

2.2.1 History and social context

Boston was incorporated as a town in 1630 and as a city in 1822. As one of the oldest cities in the United States, its development ensured it could be traversed by foot and carriage before the automobile gained prominence. Its resulting compactness makes it the U.S.'s densest city after New York and San Francisco, respectively (Alliance for Biking & Walking, 2016). Boston has claimed to be "America's walking city" (Boston Transportation Department, 2017c).

A study on 2014 Census data conducted by the Brookings Institution found the city of Boston to have the highest rate of income inequality among the 100 largest cities in the United States (Brookings Institution, 2016). Following decades of discriminatory land use and transportation planning practices, the city remains highly segregated along racial and income lines (Kahn & Martin, 2011; Logan & Stults, 2011).

2.2.2 Transportation planning context

In 2007, the Boston Transportation Department (BTD) created a Boston Bikes division, aiming to make Boston a "world-class cycling city" and focusing on infrastructure as well as outreach, through programs that provide bikes to low-income residents and training to a variety of age, gender, and ethnic groups ("Boston Bikes," n.d.). In 2009, then-Mayor Thomas Menino inaugurated a complete streets policy, with the goal of making city streets "multimodal, green, and smart" (Boston Transportation Department, 2013). Mayor Martin Walsh announced Vision Zero in 2015, creating a Vision Zero Boston Task Force led by the Boston Transportation Department. The city officially committed to eliminating fatal and serious traffic crashes with GoBoston 2030, a mid-range, "visionary" transportation plan (Boston Transportation Department, 2017c).

Transportation planning in Boston includes a variety of actors and agencies, such as the Boston Transportation Department (BTD), Boston Public Works (BPW), MassDOT, Boston Department of Conservation and Recreation (DCR), and MassPort. BTD, specifically BTD's Boston Bikes division, plays the largest role in bicycle infrastructure design and implementation.

2.2.3 Transportation mode share and safety

Of large U.S. cities, Boston has the highest rate of pedestrian commuters, with 15% of all commuters going by foot, as can be seen in *Table 2.2* (Alliance for Biking & Walking, 2016). Boston does not rank quite so highly with regard to bicycle commuting, however. While its

bicycle commuter share is higher than the national average of large cities, it does not make the top 10 of large U.S. cities (Alliance for Biking & Walking, 2016). However, Boston is tied with Washington, D.C. in having the country's largest combined mode share of walking and bicycling, with 16.7% of commuters walking or cycling.

Boston's fatality rate, or bicycle and pedestrian deaths per 10,000 commuters, was the second-lowest in the United States, and nearly tied with Washington, D.C. for the lowest (see *Table 2.2*). However, bicyclists, only 2% of commuters, are overrepresented in all fatalities, accounting for 7% of all traffic fatalities between 2005 and 2013. This is nearly twice the U.S. average (Alliance for Biking & Walking, 2016). Pedestrian fatalities, in turn, represented 34% of all traffic fatalities 2005-2013. Although this is higher than the national average of 28%, this is the lowest of the three cities being studied.

Table 2.1: Selected city information

	Boston	New York (Manhattan)	San Francisco	Large U.S. cities average[2]
Population[1]	673,184	8,537,673 (1,643,734)	870,887	1,023,729
Land area (mi^2)	49.2	302.643 (22.83)	46.89	282.23
Population density (population/mi^2)	13,903	28,210 (71,999)	18,573	5530.46
Percentage people of colour[3]	46.6	56.3 (52.4)	50.5	44.1
Percentage people living in poverty[1]	21.1	20.3 (17.2[4])	12.5	21.5

[1] U.S. Census Bureau (2016a, 2016b, 2016c)
[2] Alliance for Biking & Walking (2016)
[3] including Hispanic or Latino
[4] U.S. Census Bureau (2017)

2.3 New York City

2.3.1 History and social context

The city of New Amsterdam was founded in 1625 and was incorporated as New York City in 1898. The five boroughs of Brooklyn, Manhattan, The Bronx, Queens, and Staten Island, together represent a land area of 784 km². New York is the United States' largest and densest city (Alliance for Biking & Walking, 2016).

Numerous studies have shown New York to be plagued by persistent inequality and racial disparities (Brookings Institution, 2016; City of New York, 2016; Institute for State and

Local Governance, 2016). Reports have found clustering along lines of race/ethnicity and income, which have in turn been found to correspond to disparities in the accessibility of services, educational attainment, housing quality, and more (City of New York, 2016).

Because the area, population size, and governance system, the entire city of New York is not comparable to the other two cities of study. In analysis I will focus specifically on the borough of Manhattan. Although considering the pattern of action across boroughs would certainly be the best indicator of the values and practices within New York's transportation planning system, looking only at Manhattan will manage the research's scope and allow for comparison with the other study areas, while the relative homogeneity of the borough's road network and city form will allow for more thorough, if limited, understanding and appropriately-focused criticism.

2.3.2 Transportation planning context

NYC DOT launched its first Street Design Manual in 2009, explicitly including measures to improve safety, multimodality, and accessibility (New York City Department of Transportation, 2009). New York first stand-alone bicycle master plan arrived in 2014. The city was one of the earliest major U.S. cities to commit to Vision Zero, launching the initiative with a city-wide action plan in January 2014 and borough-specific plans following in 2015 (City of New York, 2015).

Transportation actors include the New York City Department of Transportation (NYCDOT), the New York Metropolitan Transportation Council (NYMTC), New York State Department of Transportation (NYSDOT), Port Authority of New York and New Jersey (PANYNJ), and Metropolitan Transportation Authority (MTA). NYC DOT is responsible for the large majority of design and decision-making.

2.3.3 Transportation mode share and safety

As of 2015, New York's combined mode share of walking and biking represented about 11% of commutes made. While much higher than the US average, this left New York at #6 among large U.S. cities (Alliance for Biking & Walking, 2016). This is likely due to the large portion of the population that relies on public transit, as well as the effects of Staten Island and Queens, which both have much higher rates of car use (75 and 49%, respectively) (New York City Department of Planning Transportation Division, 2010).

New York's rate of pedestrian and cyclist fatalities was the 8th-lowest of large U.S. cities, but more than twice that of Boston, and higher than San Francisco's as well. As in Boston, cyclists are overrepresented in traffic fatalities, with bicycle fatalities representing 6% of all traffic fatalities 2005-2013 while the average is about 3% (Alliance for Biking & Walking, 2016). New York's pedestrian fatality rate, however, represents the highest value for large US cities during this time, with pedestrian fatalities representing 52% of all traffic fatalities 2005-2013. The average is about 28% (Alliance for Biking & Walking, 2016).

Table 2.2: Active transport context

	Boston	New York (Manhattan)	San Francisco	Large U.S. cities average
Miles of protected lanes per square mile[1,2]	0.05	0.169	0.53	0.045
Miles of unprotected lanes per square mile[1,2]	3.26	0.169	2.56	0.639
Miles of paved paths per square mile[1,2]	1.09	1.02	*No data*	0.274
Total bike infrastructure miles per square mile[1]	4.4	2.4	3.1	0.957
% of commuters who walk to work[1]	14.8 (#1)	10.2 (#4)	10.2 (#3)	5
% of commuters who bike to work[1]	1.9 (#11)	1.0 (#17)	3.7 (#4)	1.2
% of commuters who bike or walk to work[1]	16.7 (#1)	11.2 (#6)	13.9 (#3)	6.2
Fatalities per 10,000 biking commuters[1]	3	7	1	6
Bicycle fatalities as percentage of all fatalities (%)[1]	7	6	5	3
Fatalities per 10,000 pedestrian commuters[1]	2	4	4	9
Pedestrian fatalities as percentage of all fatalities (%)[1]	34	52	49	28
Bicycle and pedestrian fatalities per 10,000 commuters[1]	1.6 (2nd lowest)	3.9 (8th lowest)	2.8 (5th lowest)	

[1] Alliance for Biking & Walking (2016)
[2] U.S. Census Bureau (2016a, 2016b, 2016c)

2.4 San Francisco

2.4.1 History and social context

San Francisco urbanized during the Gold Rush of 1849, as large inflows of both people and resources brought wealth, activity, and social diversity, leaving it the largest city on the Pacific Coast (Godfrey, 1997). Today, San Francisco's population (*Table 2.1*) makes it the 13th-largest U.S. city. Due to the physical constraints to development, namely being on a peninsula, San Francisco developed quite densely as its population rose, making it the second densest U.S. city after New York (Alliance for Biking & Walking, 2016).

Multiple studies have revealed inequality in San Francisco and its surrounding metropolitan region. Inequality in San Francisco has increased much more rapidly than in the United States as a whole, resulting in economic and racial segregation (Brookings Institution, 2016; Race Counts, 2017; Reidenbach, Price, Sommeiller, & Wazeter, 2016; Silicon Valley Institute for Regional Studies, 2015).

2.4.2 Transportation planning context

As of 2014, San Francisco had both standalone bicycle and pedestrian plans; by this time, San Francisco had a significant amount of bicycle infrastructure, mainly in the form of unprotected lanes (Alliance for Biking & Walking, 2016).

In San Francisco, transportation planning involves the San Francisco Municipal Transportation Agency (SFMTA), San Francisco County Transportation Authority (SFCTA), Metropolitan Transportation Commission (MTC) of the San Francisco Bay Area, San Francisco Public Works, and San Francisco Planning. The agency most highly involved in the planning and design of interventions for pedestrian and cyclist safety is the SFMTA.

2.4.3 Transportation mode share and safety

A significant proportion of San Francisco's residents (nearly 14%) walk and bike; this puts San Francisco at #3 among large U.S. cities for combined mode share of biking and walking, behind Boston and Washington, D.C. respectively (Alliance for Biking & Walking, 2016). However, as with Boston and New York, cyclists and pedestrians were highly represented in traffic fatalities. Between 2005 and 2013, cyclists represented 5% of all traffic fatalities, higher than the average among large U.S. cities of about 3%, while pedestrians represented 49% of all traffic fatalities, nearly double the average of large U.S. cities of about 28% (Alliance for Biking & Walking,

2016). Both cyclists and pedestrians are highly overrepresented among fatalities compared to their share of commuters.

CHAPTER 3: LITERATURE REVIEW

This section draws from a number of fields. I largely consider transportation and urban planning literature, describing phenomena and findings relating to traffic safety, road design, and conceptions of access and justice within transportation. The literature of critical geography and communication studies articulate patterns within bicycle culture, while that of Geographic Information Science provides methods for spatial analysis of access and equity. I also draw from professional, governmental, and third sector reports, which provide analysis of active transportation trends and patterns across the United States, as well as an overview of best practices for traffic safety.

3.1 Impact of the built environment on mode share and safety, best practices

Scholarship has found that the form of the built environment has a significant impact on mode share, suggesting that certain urban and infrastructural forms can encourage or discourage active transportation. Connected to this are the safety implications that the built environment has for vulnerable road users such as bicyclists and pedestrians.

McNeil (2011), looking at home-based, utilitarian bicycle and pedestrian trips in the city of Portland, Oregon, suggested that land use, that is, or presence of destinations that were accessible by bike, was an important factor, but that so were the presence of bike lanes and low-traffic through streets. Winters, Brauer, Setton, and Teschke (2010) surveyed trips made by bicycle in Vancouver, and found that increased odds of bicycling were associated with a variety of factors, including infrastructural factors, like bike-oriented interventions including signage, cyclist-activated traffic lights, and safety improvement measures, fewer highways and arterials, and higher intersection density.

Research has underlined the effect of the built environment on mode share. Various studies have posited that one of the most important factors in this interaction is the perceived and real degree of safety associated with various infrastructural designs. One key finding across studies is that vehicle speed has a significant, if not the most significant, impact on the severity of crash for non-motorist road users (Lee & Abdel-Aty, 2005; Räsänen & Summala, 1998; Zahabi, Strauss, Manaugh, & Miranda-Moreno, 2011). Zahabi et al. (2011) surveyed crash data in Montreal to understand the effect of a variety of factors, including that of the built environment, on likelihood of serious injury or fatality for pedestrians and bicyclists. While

many findings regarding the built environment were not statistically significant, one important result found increased risk for cyclists at intersections and decreased risk for pedestrians, meaning careful design and management of intersections is necessary.

Following these studies on dangerous road design, studies and reports have sought to make recommendations and understand 'best practices' for encouraging road safety. Many design practices seek to minimize risks to vulnerable road users by reducing motor vehicle speeds. Several interventions are often recommended throughout academic and professional literature. For non-neighborhood roads, the most significant suggestion is the creation of dedicated bike lanes that separate cyclists from motorists and feature minimal road crossings. For the separation of bike lanes, one survey found that while cyclists were most comfortable with planters or raised concrete curbs separating them from motorists, in general, anything beyond a painted striped lane increased comfort levels dramatically, including flexposts and bollards (NITC, 2014). The use of signal phrasing at traffic lights can also separate conflicting movements of vulnerable road users and motorists and increase safety. At the neighborhood level, a key approach is the use of traffic calming measures such as speed humps, raised intersections, chicanes (curves added intentionally to slow traffic), and road narrowing, which work with posted speed limits to keep average rate of motor vehicle travel low, at roughly 30 km/hr (20 mi/hr) (Elvik, 2001). In general, it is found that discouraging through motor traffic in neighborhoods, while encouraging convenient and direct routes for cyclists, decreases motor speeds while increasing cycling rates and safety for vulnerable road users (NITC, 2014; Pucher & Buehler, 2016).

3.2 Justice in transportation planning

A variety of scholarship has sought to conceptualize and define equity specifically in the context of transportation planning and infrastructure.

The literature provides a strong theoretical background through which we can consider equity in transportation access and planning. Martens (2012) application of Walzer's spheres of justice is an influential approach in how to guide distribution of transport. Martens argues that just transit is equitably accessible, and explores various theories of distribution to make a case for how the "transport good" might be best distributed. Ultimately, Martens suggests that the 'maximax' criterion of distribution, which limits the "maximal gap allowed between the worst-off and the best-off in terms of accessibility levels" (p. 14). Golub and Martens (2014) use the

lens of social justice in order to analyze the distribution of benefits following transportation investment plans and propose the concept of 'access poverty'. In this framework, equity is represented by roughly equal access to opportunities, regardless of mode. In defining it along lines of access, this approach provides a useful conception of transit equity.

In considering an approach to equity, however, it is vital to acknowledge the lingering effects of past realities and inequities. Golub, Marcantonio, and Sanchez (2013), surveying the history and geographies of planning and transportation in Oakland and the East Bay, California through an environmental racism framework, suggest that the legacy of past, racially-motivated planning decisions lives on through an inherited racist geography. Because of this, the authors suggest, race-neutral approaches will yield discriminatory outcomes when overlaid on the racist landscape, meaning that the legacy of the past must be actively and purposefully redressed through planning decisions.

Literature also makes recommendations in how to practically integrate equity into the planning process. In a report for the Prevention Institute, Aboelata, Yanez, and Kharrazi (2017) take a health equity approach and make three key recommendations for implementing transportation planning changes, largely echoing Golub et al. (2013). First, that strategies must be grounded in response to the conditions that create road-safety inequities in the first place, such as disinvestment. Second, that the process of defining solutions must start with community members and ultimately engage a large and diverse set of actors from both within and outside of the government. The third recommendation regards the collection and use of data, and advises, among other things, integrating measures of equity into data collection, engaging community-based organizations in data collection and analysis, and conducting community needs assessments.

Manaugh, Badami, and El-Geneidy (2015) critically analyze the degree to which social equity plays a role in transportation planning, focusing on plans and other documents put forward by 18 North American metropolitan areas. The authors find a lack of consensus on the question of how best to define, integrate, and measure social equity objectives within the transportation planning discipline, but in making recommendations, largely support the approach suggested by Aboelata et al. (2017). They suggest a multi-criteria decision-making approach, involving precise specification of measures that can be easily employed on the ground. Manaugh et al. suggest it is vital that these measures, and indicators selected to evaluate them, must

inherently communicate desired outcomes to both decision-makers as well as the public. The researchers also note that objectives and indicators must reflect the various facets of social equity, and represent outcomes of changes themselves, as a means through which to avoid double-counting. They suggest that disaggregating data collection along various lines of social and logistical factors will allow for more nuanced analysis where the approach is possible.

3.3 Infrastructure, road safety, and privilege

Scholarship has found significant links between bicycle infrastructure and culture, and privilege. Hoffmann (2013), for example, considered conceptions of "bike culture" as well as who is included in the "bike community" through a variety of case studies, suggesting that white cyclists are by far the most visible representation of cyclists. Through her case studies, she suggests that for many years, the interests of bike advocates have been largely white and middle-class. Flanagan et al. (2016) considered the provision of bike infrastructure in Portland, Oregon, and Chicago, Illinois, finding that though the two cities differ in their demographics, patterns of gentrification, and built environments, in both cases infrastructure investment was tied to privilege or gentrification, largely following and mirroring existing socioeconomic privilege. Stehlin (2015) provides an overview of the history of planning and bike advocacy in San Francisco, tracing the start of bike advocacy to claims of 'livability' that ultimately co-opted a gentrification agenda for the sake of encouraging "ecologically responsible and culturally cosmopolitan space" (p. 123). Stehlin suggests a link between the goals of many bike advocates and an idea of 'social transformation' that is inseparable from gentrification.

Just as there is a connection between bike infrastructure and socio-economic privilege, there is also a connection between lower-income and communities of colour, and disadvantage in road safety. Many studies have found that communities of colour are disproportionately represented among vulnerable road users in injuries and fatalities (Alliance for Biking & Walking, 2016; Anderson, Vaca, & Chakravarthy, 2011; Smarth Growth America, 2017; Zimmerman & Kramer, 2013). Between 2005 and 2014, non-white (including Hispanic) people accounted for over 46% of pedestrian deaths while only accounting for 34% of the population. Particularly, Native Americans, African Americans, and adults over 65 are all over-represented among pedestrian deaths (Smarth Growth America, 2017). There is also a clear relationship between income and pedestrian death, with areas with lower median incomes hosting a higher share of pedestrian deaths (Alliance for Biking & Walking, 2016; Anderson et al., 2011; Smarth

Growth America, 2017). A 2014 study found a racial bias in driver yielding-behavior at crosswalks (Goddard, Kahn, & Adkins), while a survey of bike citations and arrests in Minneapolis between 2009 and 2015 found discrimination in enforcement as well as racial profiling (Hoffmann & Kmiecik, 2016). Black bicyclists received nearly half of all bike citations, despite only representing 18% of the population, and were also more likely to be perceived by police as confrontational. The report also found a disproportionate presence of youth, and particularly African American youth, represented in citations.

Though results from the 2008-2012 American Community Survey show that the low-income Americans commuted by bike more than any other census bracket (McKenzie, 2014), and the fact that people of colour represented the largest source of growth in bike commuting population between 2000 and 2009, the distribution of bike infrastructure remains unequal (League of American Bicyclists, 2013). For example, a 2015 analysis found that the majority of Chicago's bike infrastructure was located in areas with the lowest African American and Hispanic populations (Prelog, 2015). This lack of infrastructure access, intertwined with already-existing disadvantage, represents a significant safety issue, as well as a barrier to cycling.

3.4 Spatial analysis of equity

There has been a significant amount written regarding the use of Geographic Information Systems (GIS) to analyze equity in the distribution of various resources.

This literature has presented a variety of approaches, which often fall into one of several categories. The 'container' approach is the simplest, considering the prevalence of the resource in question within a unit of measurement, such as the census block (Nicholls, 2001; Talen & Anselin, 1998). Today, one of the most common approaches is network analysis, which analyses the path distance from an origin (representing home) to the nearest site of the resource in question (Comber, Brunsdon, & Green, 2008; Talen & Anselin, 1998; Tucker & Manaugh, 2017). Residential locations are usually defined at the level of a census unit, such as the census block group, with the unit being assigned a centroid to represent the origin. Access is defined as a maximum distance between the origin and the resource, and varies according to the context of the study. The shortest-distance value from network analysis defines if a spatial unit has "access". Another common approach places a buffer around the resource in question to much the same effect, where access is defined by falling within the buffer (Bertrand, Thérien, & Cloutier, 2008; Prelog, 2015; Wolch, Wilson, & Fehrenbach, 2013).

After GIS is used to define the distribution of access across spatial units, a form of statistical analysis follows. In many cases, this is simple regression analysis with variables such as ethnicity/race, or income level (Comber et al., 2008; Wolch, 2005; Maroko et al., 2009). In other cases, an index is first created, integrating variables deemed significant to the analysis, such as car-dependency or demographic factors. This index is then regressed with the accessibility findings (Bertrand et al., 2008; Prelog, 2015; Tsou, Hung, & Chang, 2005).

While a review of literature on this topic reveals relatively standard approaches, each study takes care to define for its own purposes the what constitutes "access" and "equity," and justify these definitions and interpretations. For this reason, a well-founded conceptual framework and review of literature is vital in ensuring a useful and successful analysis.

CHAPTER 4: METHODOLOGY

4.1 Content Analysis

The first part of this analysis consists of qualitative document analysis, itself a form of content analysis. Qualitative document analysis has been described as an "emergent methodology, rather than a rigid set of procedures with tight parameters" (Altheide, Coyle, DeVriese, & Schneider, 2014, p. 127), but also as a "systematic procedure for reviewing or evaluating documents," and consists of an iterative process including scanning, reading, and interpretation (Bowen, 2009, p. 27). Content analysis can be quantitative or qualitative, inductive or deductive; its approaches can include grounded theory or a quantified analysis of key words or terms. Several studies have used it in conjunction with other methods to triangulate data, while others have used this method exclusively. A variety of studies have specifically considered policy documents or plans, performing qualitative content or document analysis to gather data about the way government and other entities frame issues and their plans and proposed actions (Daugbjerg et al., 2009; Fauré, Arushanyan, Ekener, Miliutenko, & Finnveden, 2017; Lemiengre, Dierckx de Casterle, Denier, Schotsmans, & Gastmans, 2008; Stjernborg & Mattisson, 2016).

The documents to be analyzed consist of official plans released by each city government, including Vision Zero Action Plans, specifically outlining the cities' approach to the initiative, as well as city-wide planning and 'visioning' documents released concurrent to or following the adoption of Vision Zero. The documents available for analysis of San Francisco were limited by the fact that the city's major plans, including the San Francisco Transportation Plan, Transportation 2030, and 2013-2018 Bicycle Strategy, were released just prior to Vision Zero, excluding them from possible analysis. For this reason, the number of pages analyzed for San Francisco is lower than that for the other cities.

The documents were identified and collected via city government websites. Overall, I read eight plans for a total of 572 pages. The documents used in this analysis are organized in *Table 4.1*.

Table 4.1: Planning documents used in content analysis

City	Planning Documents Analyzed
Boston *302 pages*	1. Vision Zero Boston Action Plan (Boston Transportation Department, 2016) *(28 pages)* 2. Neighborhood Slow Streets (Boston Transportation Department, 2017a) *(50 pages)* 3. Go Boston 2030 (Boston Transportation Department, 2017c) *(224 pages)*
New York *230 pages*	1. Vision Zero Action Plan (City of New York, 2014) *(42 pages)* 2. Pedestrian Safety Action Plan - Vision Zero - Manhattan (Viola, Hostetter, Riscica, Kay, & Peck, 2015) *(66 pages)* 3. Strategic Plan 2016 (New York City Department of Transportation, 2016) *(122 pages)*
San Francisco *40 pages*	1. Vision Zero San Francisco: Two Year Action Strategy (Vision Zero SF, 2015) *(24 pages)* 2. Vision Zero San Francisco: Two Year Action Strategy 2017-2018 (Vision Zero SF, 2017) *(16 pages)*

I first scanned the documents and assembled a set of questions based on the texts, the literature, and my research interests. Once I had developed a set of questions, I systematically parsed each document for answers, reading each document several times and adjusting my questions iteratively. *Table 4.2* shows the set of questions ultimately utilized in my content analysis; this consists of seven questions relating to the cities' conceptualization of both Vision Zero and transportation equity, and their plans for implementation.

Table 4.2: Content analysis questions

	Vision Zero	Transportation equity
Theoretical framing	• *How does the city frame its commitment to Vision Zero? Is it a side initiative of the Transport Department, or new framework to be enacted throughout departments? (E.g., is it a buzzword or the framework for decision-making?*	• *How does this document define equity?* • *To what extent is equity a part of this plan? Is it referenced a few times with regard to other things, or is it part of the foundational goals?*
Proposed application	• *What strategies does the document suggest for reaching zero?* o *How specific are they?* o *To what extent does cooperation and shared responsibility between multiple agencies and departments feature?* • *How does the document suggest that success be measured?* o *Are there specific indicators?* o *Are there plans to regularly monitor these indicators?* • *How will decisions be made?* o *E.g. what are the priorities?* o *Does doc offer outline of process for implementing changes? Where does citizen participation feature?*	• *What methods does the document propose for reaching equity?* o *Are they specific and concrete, or vague and aspirational?* o *Are there indicators and will they be measured?*

4.2 Quantitative and spatial analysis

The qualitative analysis is followed by a quantitative spatial analysis, which adds an alternate dimension for understanding equity by considering the spatial distribution of interventions, and by extension, which populations have benefitted most.

The geospatial data is categorized into that representing protected bicycle lanes (line data), and safety improvement measures (generally point data, with some line and polygon feature classes). As can be seen in *Table 4.3*, safety improvements comprise a variety of interventions including traffic calming measures and other physical improvements, as well as speed radar; this varies between cities based on data availability. Socioeconomic data came from the U.S. census; this data is summarized in *Table 4.4*.

Table 4.3: Geospatial datasets and associated transformations

City	Category	Dataset	Data transformations	Source
Boston	Protected bike lanes	*Existing Bike Network (Mar 2017) (line)*	*Create new feature set representing just protected lanes from attribute data: Buffered lanes (BFBL); lanes buffered by parking (PBFBL); cycle tracks (CT); shared use paths (SUP); minor shared use paths (SUC); shared use bridges (SUB); cycletracks on one side, bike lanes on other (CTBL)*	*Analyze Boston (Boston Transportation Department, 2017b)*
	Safety improve-ment	*Vision Zero Safety Projects (2017) (point)* *Neighborhood slow streets proposed zones (2017) (KML polygon)*	*Created polygon feature set representing Slow neighborhoods. Intersect this with census tract data so that presence of Slow Streets within census tract boundary counts as one safety improvement measure.*	*Boston Transpor-tation Department (Boston Transportation Department, 2017d, 2017e)*
New York City	Protected bike lanes	*NYC bike routes (Jul 2017) (line)*	*Create new layer that is solely facility type Class I, completely separated and protected. This includes: protected path, greenway, boardwalk, pedestrian plaza, dirt trail.*	*Vision Zero Data Feed (New York City Department of Transportation, 2017a, 2017b, 2017c, 2017d, 2017e)*
	Safety improve-ment	*-Speed Humps (2017) (line)* *-Neighborhood Slow Zones (2017) (polygon)* *-Street Improvement Projects (Intersections) -(includes pedestrian safety, traffic calming, senior safety) (2017) (point)* *-Enhanced crossings (2017) (point)*	*Merge point layers; intersect line and polygon layers with census tract so that presence within boundary counts for one safety improvement measure*	
San Francisco	Protected bike lanes	*SFMTA Bikeway Network (2018) (line)*	*Create new feature class consisting of Class I and IV protected lanes*	*DataSF (San Francisco Municipal Transportation Agency, 2016, 2017, 2018a, 2018b)*
	Safety improve-ment	*-Painted Safety Zones (July 2017) (point)* *-Traffic calming features (Aug 2016) (point)* *-Bikeway point features (2018) (point)*	*Merged point datasets to create safety improvement dataset*	

Table 4.4: Census datasets used for all cities

Dataset	Unit or data type	Source
American Community Survey Five-Year Estimates 2012-2016: Median household income	Inflation-adjusted 2016 dollars (US)	U.S. Census Bureau (2016a, 2016b, 2016c)
Census tracts and TIGER Road lines	Shapefile	U.S. Census Bureau Geography Division (2016, 2017)

To start, I associated the census information to the blocks themselves, so that each census block contained attribute information about the median income level within. I assigned a centroid, representing the spatial average, to each census tract.

I used ArcGIS software to create datasets representing protected bike lanes and safety improvement interventions for each city. For protected bicycle lanes, this meant using attribute information about the infrastructure in order to extract the lane infrastructure that was protected from the larger dataset, which also included unprotected lanes. Following studies that suggest that protected bicycle lanes are the most effective at increasing cyclist comfort and attracting new riders, and understanding that one of Vision Zero's key tenets is the separation of vulnerable road users from those moving at higher speeds (Johansson, 2009; NITC, 2014), this analysis focused only on separated lanes. Following the creation of a protected lane dataset, I applied a buffer of ¼ mile, or 400 meters, which the literature has suggested is a reasonable standard for considering access to sustainable and active infrastructure (Prelog, 2015; Wolch et al., 2013). In analysis, each census tract whose centroid fell within the buffer was considered to have access and assigned a value of 1; census tracts whose centroid did not fall within the buffer were given a value of 0 representing lack of access.

In order to analyze the number of safety improvement interventions made in each city, I merged all safety improvement-related point layers to create one point dataset representing safety improvement, to which I added a 'count' column that I populated with a value of 1 for each feature. I then performed a spatial join of this dataset with the census tract boundary layer, which allowed for the count of features within each census tract to be simultaneously summed. For the line and polygon data I included for Boston and New York, I added a 'count' column populated with the number 1, and clipped these datasets to the census tract layer. I then performed a relational join with the complete census tract layer, already containing income information and

the number of point-based safety improvement measures. For the final number of interventions, I added the columns from the point and line/polygon datasets. The values within this column ranged from a minimum of zero to a maximum of 30, as was found in one San Francisco census tract.

This spatial analysis resulted in, for each city, a data table organized by census tract that contained the population, census tract median household income, total number of safety improvement measures, and a binary value representing access to protected bicycle infrastructure. This was converted into a spreadsheet and imported into Stata, a statistical analysis software.

The relationship between median household income and access to safety improvements was analyzed with a chi-square test. First, each city's census tracts were sorted into quintile 'bins' based on their median household income value. This resulted in a new 'income quintile' variable, which divided the census tracts and all their associated information equally between the five quintiles.

I tabulated the income quintile variable with the results of the spatial analysis and performed the Pearson chi-square test. For the protected lane variable, this resulted in a tabulation of the number of census tracts with access in each income quintile. I calculated a percentage representing access by dividing the number of tracts in each quintile with access, by the total number of tracts. I performed the same tabulation with the safety improvement dataset, and used the number of interventions within each quintile and the total number of interventions to calculate a percentage representing the share of safety improvement improvements held by each income quintile.

CHAPTER 5: RESULTS

This chapter provides an overview of my findings, including those of both the content analysis as well as the spatial and statistical analyses.

5.1 Content analysis findings

5.1.1 Boston

Framing its commitment to Vision Zero

Boston announced its commitment to Vision Zero as part of its most recent city-wide transportation and general plans, Go Boston 2030 and Imagine Boston 2030. The initiative is carried out by the Vision Zero Task Force, itself led by the Boston Transportation Department but including 10 government departments and two advocacy groups (WalkBoston and the Boston Cyclists Union) (Boston Transportation Department, 2016). Plans and documents relating to Vision Zero are released by the Boston Mayor, Martin Walsh.

In 2016's Vision Zero Action Plan, Walsh writes in his introductory letter that "IT'S TIME FOR VISION ZERO" (Boston Transportation Department, 2016, p. 5). The plan goes on to say that "We have the tools with which to act; we clearly have the need to act quickly," (24) echoing the sentiment of inevitability and expediency expressed by Walsh. However, the Action Plan also frames Vision Zero as the next challenge, an ambitious initiative in continuity with Boston's history of innovation and transportation 'firsts'—just as Boston was the first city in the United States to have an underground subway, the comparison suggests, it may also be the first city to get to 'zero' (Boston Transportation Department, 2016, p. 8).

In this case, however, the toolkit proposed by the City is not particularly innovative, and instead maintains significant continuity with the original Swedish vision originating in the 1990s, even including a numerated overview of the philosophy that strongly hearkens back to the format and language seen in the manifesto (Boston Transportation Department, 2016, p. 6).

Implementation plan and strategies for zero

Other aspects of the implementation strategy are similarly traditional. In the original Action Plan, the Task Force delineates its four main strategies: reducing speeds and building safer streets, "tackling distracted and impaired driving," engaging Bostonians with Vision Zero, and "holding ourselves accountable" for the results. Of the programs and goals for "tackling distracted and

impaired driving," seven out of the twelve relate specifically to educating cyclists and pedestrians or encouraging helmet use (Boston Transportation Department, 2016, p. 23). Regardless of how the City defines its strategies, they easily fall into the categories that can be used to classify most Vision Zero implementation approaches: engineering, education, evaluation and analysis, and enforcement, with strategies related to participation, outreach, and policy also featuring. However, the strategies defined, and the process undertaken to define them, vary between the plans analyzed.

The Neighborhood Slow Streets plan (Boston Transportation Department, 2017a) stands out as relying largely exclusively upon speed reduction, with traffic calming and speed limit reduction. The Vision Zero Action Plan and Go Boston 2030 plans also highlight engineering measures, largely in the form of intersection improvements, safer crossings, and corridor improvements, including improved bicycle infrastructure. Specific interventions include restricting right turns on red, 'daylighting' intersections to improve pedestrian visibility, leading pedestrian interval traffic signals, and wider sidewalks with shorter crossing distances (Boston Transportation Department, 2017c). The Vision Zero Action Plan, however, proposes the most varied strategies, encompassing data collection (through a partnership with the WAZE app, with cameras, by a rapid response team responding to fatal crashes), enforcement (targeted at 10 high-crash intersections), and education (of motorists, cyclists, pedestrians, police departments, and vulnerable road users). These include specific goals, including some that have been quantified, but no specified performance indicators. This plan pulls in existing BTD initiatives, such as Green Links, which seeks to connect the city to open space with active transportation infrastructure, and Connect Historic Boston, which seeks to do the same for historic sites, while also highlighting new BTD initiatives, associated with Vision Zero, such as the Neighborhood Slow Streets program (Boston Transportation Department, 2016).

Go Boston 2030 (2017c), on the other hand, presents a bold, innovative, and integrated vision, supplemented with quantified goals and 35 performance indicators encompassing goals of sustainability, engagement, mode share, equity, and beyond. (However, even Go Boston 2030 becomes less ambitious when it gets to the concluding section on actual projects to be implemented in the near-term: many Complete Streets projects have timelines of 15 years, and one 9-mile bikeway having a design timeline of five years and an implementation timeline of

15—putting it well beyond the titular ‘2030’ (2017c, pp. 152-160).)

Decision-making process

While the plans vary in their proposed methods for reaching zero, they may exhibit even larger variation in how they present the decision-making process.

The Neighborhood Slow Streets plan (Boston Transportation Department, 2017a) again represents a simplistic elegance of vision, albeit a rather innovative one, in its completely transparent project prioritization process. Neighborhoods must apply to become featured neighborhoods that receive traffic calming. Applications are assessed on a number of criteria, each carrying a specified number of points: community support; percentage of households with children under 18; population percentage age 65 and above; presence of schools, parks, community centres, libraries, and public housing; proximity to rail transit and bus routes; proximity to walking and cycling routes to school or those identified in city plans; and crash history. Top-scoring neighborhoods are further assessed according to strong neighborhood boundaries, geographic diversity among featured neighborhoods, and feasibility (Boston Transportation Department, 2017a).

The other documents do not present such a clear-cut process. The Vision Zero Action Plan outlines the process as starting with the collection and analysis of data, selection of areas based on this data, followed by safety audits with the community and project definition from there, with community engagement occurring throughout the process (Boston Transportation Department, 2016, p. 22). The document does not provide further detail or an idea of how much the process may vary. Go Boston 2030 provides a detailed outline of the marathon citizen participation process undertaken to prepare the plan itself. This included a visioning phase (consisting of three intermediary phases), an action plan phase containing seven initiatives, before a public selection of projects to prioritize with a paper ballot and online survey (which was reweighted by zip code for proportional representation of each neighborhood) (Boston Transportation Department, 2017c). Projects were added to this final list through “detailed needs assessment” which considered what needed to be done to meet the plan’s targets and support expected growth (p. 123). When it comes to more local, less long term, less visionary projects, however, the role of participation is not as clearly defined. For one Vision Zero project, an interactive safety map guided intersection prioritization; in other cases, there is no clear place for public participation or input, nor is the method of project prioritization or selection defined. This

is the case with the Better Bike Corridors project, where projects often have time frames defined as “Ongoing and over 15 years in conjunction with local community process” (Boston Transportation Department, 2017c, p. 152).

Place of equity in plan

Go Boston 2030 lists equity as a guiding principle and one of its “three pillars,” along with economic opportunity and climate responsiveness (Boston Transportation Department, 2017c, p. 8). This plan notes disparities in access that are affected by income, and lists its number-one vision to be expanding access. It also discusses the inequitable distribution of ‘walkability’ and resulting health implications (p. 48), as well as the concern of gentrification associated with transport improvements (p. 76). With an eye to these concerns, the plan proposes proactive project selection and low-barrier outreach to counteract the “many decades of uneven investment” towards populations that have been “chronically underserved” (p. 123). The vision of Boston in 2030 is one with “innovative ways to fund and subsidize transportation for historically underserved,” (p. 72) which will be preceded by a shift to public officials considering “the mobility, housing, and employment needs of historically marginalized groups including youth, seniors, low-income residents, and people of color,” when making decisions about transportation projects and funding (p. 76). To secure this vision, there are quantified goals and performance indicators, including, among others: reaching 100% accessibility with regard to protected bike lanes (from 20%) (p. 35), ensuring “A larger share of capital improvement dollars will be assigned to underserved communities to achieve equitable distribution of investment in transportation infrastructure” , making sure that “participants in transportation planning processes will be representative of the demographic make-up of neighborhoods affected by the project” (p. 77), and reducing the “transportation cost burden for very low income individuals to the citywide average for a median household [“from 33% of income spent on transportation to 13%”]” (p. 73).

The Neighborhood Slow Streets plan also exhibits a foundational commitment to equity, particularly in the way that criteria representing vulnerability are weighted first and most highly in the process. While the quantification of equity in Go Boston 2030 is with targets and indicators to gauge and improve performance down the line, in Neighborhood Slow Streets, the process begins and ends with this (as there is no indication that performance, of any sort, will be monitored following traffic calming) (Boston Transportation Department, 2017a). The Vision

Zero Action Plan, on the other hand, only references equity, without defining it, as when Mayor Walsh writes that "our most vulnerable road users […] are suffering disproportionately because of speeding traffic and distracted drivers" (Boston Transportation Department, 2016, p. 5). The document notes that outreach should be multilingual and focus on high-crash corridors "with a special emphasis on reaching vulnerable and underserved populations" (p. 20), and notably uses people-first language with regard to transit mode choice ('people who bike' instead of cyclists, for example). Beyond this, however, the most it does to operationalize equity is hope that "Vision Zero Boston Task Force members [will] be ambassadors for the initiative and use Healthy Community Champions to reach populations who are often unable to attend community meetings" (p. 20) and create the goal of undertaking more detailed demographic analysis of crash data in the future.

5.1.2 New York

Framing its commitment to Vision Zero

By and large, plans for the City of New York position Vision Zero as a new framework through which the city will be planned and governed. The initiative is ultimately led by the Mayor's Office of Operations, but changes are implemented through a Task Force which includes the City Police (NYPD) and Transportation (DOT) Departments, Taxi & Limousine Commission (TLC), the Department of Health and Mental Hygiene (DOHMH), the Department of Citywide Administrative Services, (DCAS), and potentially other agencies (City of New York, 2014). The Manhattan-specific Pedestrian Safety Action Plan, introduced jointly by the Transportation and Police Commissioners, suggests that much of the planning and responsibility come from the DOT and NYPD; NYC DOT's Strategic Plan notes that while Vision Zero is a "cooperative effort among city agencies," DOT has a "leading and critical role" (New York City Department of Transportation, 2016; Viola et al., 2015).

The plans frame Vision Zero itself as necessary and inevitable, because the "primary mission of government is to protect the public" and the "status quo [of injury and fatality on our roads] is unacceptable" (City of New York, 2014, p. 7). While the point of government responsibility is strongly made, New York also understands Vision Zero to be a collaborative process and a "collective responsibility" (City of New York, 2014, p. 3). Documents suggest that 'zero' can only be achieved with "constant input and feedback from citizens and civic organizations," echoing the approach first laid out in Sweden (City of New York, 2014, p. 7).

The Action Plan even suggests a cultural shift may be necessary for success, as the initiative "needs each and every New Yorker to become aware of the new public discourse on street safety, to appreciate the consequences of careless and dangerous behavior and to do their part to lend civility and consideration to the daily life and rhythm on the streets of our City" (City of New York, 2014, p. 7). However, as with the original Swedish approach, not only does Vision Zero place responsibility and action on citizens and government bodies, but also industry. The documents also note that companies and organizations that operate and manufacture vehicles have a responsibility to improve safety using both technology and education (City of New York, 2014).

The Transportation Department's Strategic Plan (2016) displays clear integration of Vision Zero into the agency and larger city's goals, naming the continuity of the Vision Zero planning documents with the DOT's strategic plan, the city-wide mid-range plan One NYC and the 80x50 plan to reduce greenhouse gas emissions (New York City Department of Transportation, 2016). Indeed, Vision Zero or pedestrian/bicycle-oriented improvements are incorporated into the DOT's larger goals regarding mobility, freight, the public realm, sustainability, and organizational excellence (New York City Department of Transportation, 2016). This suggests that the initiative is, rather than a simple buzzword or side project, a new structure affecting decision making throughout New York City.

Implementation plan and strategies for zero

The plans lay out a specific implementation plan for reaching 'zero,' each representing the same strategies but offering differing levels of detail. New York City's approach is based in engineering, education, and enforcement and analysis (City of New York, 2014; New York City Department of Transportation, 2016; Viola et al., 2015). The 2014 Action Plan offers the most detail, with specific actions to be taken by various city departments, including quantified goals. City Hall, the Police Department, the DOT, the Taxi & Limousine Commission, the Department of Citywide Administrative Services, and the Department of Health and Mental Hygiene are all named with specific actions to be taken, as single departments as well as in partnerships and coalitions. For example, the Police Department (NYPD) will independently increase enforcement against dangerous driving behaviour and enhance training so that officers can better record and preserve evidence and details of crashes, while the NYPD and NYC DOT will together perform outreach and enforcement in areas with history of crashes and create and release borough-wide

safety plans (City of New York, 2014). A key part of New York City's strategy, however, is data collection and analysis. This is exhibited in goals to improve data quality and collection (including of crash data through surveillance, training of police officers, and monitoring of traffic-related hospitalizations) as well as dissemination and evaluation of the data (including crash data, DOT project performance, NYPD traffic citations, 'chronic' road conditions) (City of New York, 2014).

Decision-making process

Indeed, one document proclaims that "Data analysis informs every aspect of the City's response to the Vision Zero challenge" (City of New York, 2014, p. 16). The decision-making process is largely based in these data, which is used to identify problematic sites to which to focus investment (City of New York, 2014; Viola et al., 2015). In one case, a "heat map" of the number and locations of traffic-related deaths and severe injuries (those killed or severely injured, KSI) per year revealed that high exposure of pedestrians to trucks had led to high KSI and informed DOT's response of introducing new regulations limiting truck deliveries and double parking during the day, incentivizing this during night instead (Viola et al., 2015). To prioritize limited funding, the City ranked streets and intersections based on KSI rate per mile. To delineate Priority Corridors and Intersections in Manhattan, DOT selected the most dangerous corridors and intersections and moved down the list until the selected sites accounted for at least 50% of the borough's total KSI—in the end, less than 2% of Manhattan's intersections accounted for 15% of KSI. A similar approach was taken to define Priority Areas; the selected areas contained 50% of all borough pedestrian KSI, yet made up only 26% of its land area (Viola et al., 2015).

Community input is also integrated into the decision-making process. DOT notes that "While DOT utilized quantitative crash data to determine Manhattan's highest-priority corridors, intersections, and geographic areas, qualitative feedback from community members deeply enriches DOT's understanding of these priority locations" (Viola et al., 2015, p. 27). In preparing for the Manhattan Pedestrian Safety Plan, outreach occurred both online (with an interactive map that could be used to log safety complains) as well as with public events and workshops. Public events were geographically dispersed and had Mandarin and Spanish interpreters available in order to encourage diverse participation (Viola et al., 2015). Proactive outreach includes visiting senior centres and community boards in order to solicit feedback from locals on "senior

pedestrian issues" (Viola et al., 2015, p. 7).

Place of equity in plan

The degree to which equity is noted in plans varies dramatically, as can be seen in *Table 5.1*. While the two Action Plans reference an awareness of the equity issues embedded in traffic safety, as above with notes of outreach to senior centres and proffering of translation services, planners neither explain it nor do they use the word "equity". Starting with the 2016 Strategic Plan, however, equity moves from a footnote to a key concern and challenge for a city where the "benefits of […] growth have not been equally shared and rising housing costs have pushed many workers to live farther from their jobs" (New York City Department of Transportation, 2016, p. 7). Indeed, the 2015 and 2016 documents note the Borough Commissions whose sole purpose is outreach and engagement, and highlight the recently-implemented Street Ambassador Program, which specifically seeks to engage "traditionally underrepresented groups … [including] bus riders, non-English speakers, and low-income residents" by setting up mobile information stations (New York City Department of Transportation, 2016, p. 81; Viola et al., 2015). This is based in an understanding that "areas in Manhattan that have the highest incidence of pedestrian fatalities and severe injuries are not always the loudest voices providing input for transportation improvements"; the DOT proposes a series of actions to address this:

> *"including full-fledged planning workshops and charrettes; streamlined, mobile meetings at places where community members already gather (libraries, community centers, parks, etc.); community walk-throughs; and direct communication with elected officials and community leaders in Priority Areas. To further facilitate and institutionalize this effort, DOT will hire a dedicated staff member in their Manhattan office. This staff member will be assigned to neighborhoods that have historically been less engaged with the planning process." (Viola et al., 2015, p. 40)*

The Strategic Plan suggests an understanding of equity that is based in both environmental 'goods' (access to quality public space) and 'bads' (exposure to the negative effects of freight), but it most engages with the concept as a question of access for various groups with differing needs and experiences. Particularly, providing access to "jobs and essential services for low- and moderate-income New Yorkers and people with disabilities" is described as a core mission of NYC DOT (New York City Department of Transportation, 2016, p. 7).

Table 5.1: Documents' inclusion of various factors

City	*Title*	*Year published*	*Specific goals*	*Evaluation & assessment*	*Use of indicators*	*Multiple depart-ments*	*Define equity*
Boston	Vision Zero Boston Action Plan	2016	✓	✓	-	✓	-
	Neighborhood Slow Streets	2017	✓	*	*	-	**
	Go Boston 2030	2017	✓	✓	✓	✓	**
New York	Vision Zero Action Plan	2014	✓	✓	✓	✓	-
	Pedestrian Safety Action Plan - Vision Zero - Manhattan	2015	✓	✓	✓	✓	**
	Strategic Plan	2016	✓	✓	-	✓	✓
San Francisco	Vision Zero San Francisco: Two Year Action Strategy	2015	✓	✓	✓	✓	**
	Vision Zero San Francisco: Two Year Action Strategy 2017-2018	2017	✓	✓	✓	✓	✓

* Applies data and various indicators in decision-making process, but do not indicate plans to monitor or measure after changes implemented.
** Promotes equity without defining it.

5.1.3 San Francisco

Framing its commitment to Vision Zero

San Francisco, like Boston and New York both, frames Vision Zero as inevitable, and a moral imperative: "Zero traffic deaths is indeed ambitious, but zero is the right goal to have" (Vision Zero SF, 2017, p. 2). Also in line with Boston and New York is San Francisco's commitment to the original principles of the initiative. Similarly to Boston, San Francisco presents its understanding of Vision Zero in a five-item list that, like Boston's mirrors the original and preserves the key tenets. Vision Zero San Francisco (VZSF) categories its response into the following five categories: engineering, education, enforcement, evaluation and policy (Vision Zero SF, 2015).

In a similar format to those seen in the other cities, in San Francisco, Vision Zero exists in the form of a Task Force, in this case chaired by Municipal Transportation Agency (SFMTA) and the Department of Public Health (SFDPH), that includes a number of agencies, including the Police department, Public Works (SFPW), Planning Department, and counterparts from county and regional agencies. There is also a Vision Zero steering committee that meets monthly, with a subcommittee for each response category. Task Force meetings are open to the public and attended by the steering committee, representatives of city agencies, and members of the Vision Zero Coalition (Vision Zero SF, 2015).

Implementation plan and strategies for zero

While VZSF's key method to reaching zero is speed reduction, traffic fatalities are seen as a "multi-pronged issue requiring a multi-pronged solution" (Vision Zero SF, 2015, p. 7); as such, additional strategies include improving visibility on the street and awareness of the initiative, with the hope that these strategies will "empower people to make safer decisions and inspire a culture change emphasizing traffic safety" (Vision Zero SF, 2015, p. 7). This is one of many mentions of the hoped-for 'culture change'; VZSF proposes a mixed set of strategies for attainment.

On the engineering side, this includes applying safety improvements along a minimum of 13 miles of road within the High Injury Network (HIN) each year (Vision Zero SF, 2015). The first Action Strategy also calls for pedestrian safety upgrades at 170 intersections on the HIN over five years; an additional 24 safety projects were designated as 2-year action items (Vision Zero SF, 2015). This quantified approach is supplemented with a call for new standards citywide, including "Implement[ing] project integration and project delivery process to ensure all projects are appropriately scoped with respect to safety" (p. 5) as well as "universally beneficial treatments citywide (e.g. daylighting, signal timing, high visibility crosswalks, and proper bus stop lengths)" (p. 13). The vision also includes education in the form of a citywide strategy, reaching drivers of large vehicles, police officers, and commercial and transit operators, as well as elementary and middle school students (Vision Zero SF, 2015, 2017). The collection, integration, and evaluation of data is also at the core of VZSF's approach: not only does the initiative enlist several agency partners to collect and share data which can be analyzed, VZSF has also made it a key goal to develop new methods of collecting and evaluating data; all data is updated regularly and made available to look at or download. Enforcement has also become a

key strategy, as the SFPD have initiated campaigns directed at routine violations associated with injury and fatality, as well as explored automatic monitoring and citation systems for speeding and other infractions.

Core to VZSF's datacentric approach is the use of performance indicators. This has included the number of traffic citations given by type, officer, and district, as well as number of engineering projects implemented and average street speeds. The first Action Strategy also includes milestones by which goals should be reached, at the level of the year and quarter (Vision Zero SF, 2015). The 2017 Action Plan seeks to establish baseline values to use with performance indicators in the future (Vision Zero SF, 2017).

Decision-making process

VZSF's key strategy, however, was its development and use of the High Injury Network (HIN). The City sought to know how best to prioritize funding and direct improvements, and used crash data to develop a map marking high-injury sites forming a network that, despite making up a just 12% of the overall road network, accounted for 70% of severe and fatal injuries. The HIN informs VZSF's decision-making process, as improvements are prioritized along the 125 mi identified as part of the HIN (Vision Zero SF, 2015). Coincident to this approach is the definition and use of "Communities of Concern" (COC), defined as "historically disadvantaged," "low-income communities, communities of colour, and areas with high concentrations of seniors and people who rely on walking and transit as their primary means of transportation" (Vision Zero SF, 2015, p. 9). When the HIN is overlaid upon the COC, patterns emerge, gaps become clearer, and it is easier to prioritize projects and particularly those that will benefit the most vulnerable.

Place of equity in plan

From the late Mayor Edwin Lee's introductory letter in the first Vision Zero Action Strategy, San Francisco identifies equity as the core of its approach: "By working to equitably protect our most vulnerable road users, we strive to create a better culture for our residents, workers and visitors to prioritize traffic safety and reduce collisions that happen on our streets (Vision Zero SF, 2015, p. 3). What follows supports this statement. The use of the HIN and COC systematically ensures prioritization of the most vulnerable, while other initiatives, such as diversion programs for non-financial consequences for infractions like speeding, display an attempt to fully integrate equity. Equity is operationalized with targets, as with the 2018 target that "Safety treatment miles implemented in Communities of Concern [are] equal to or greater

than the proportion of the HIN falling within those communities" (Vision Zero SF, 2017, p. 14). For future evaluation of equity, the plan also seeks to establish a "baseline percentage of citations/warnings issued for traffic violations by race/ethnicity for ongoing monitoring" (p. 12). Other approaches to equity include "proactive community engagement" by collaborating and working with vulnerable populations and community leaders as well as focusing outreach "through existing events that historically underrepresented communities attend" (Vision Zero SF, 2017, p. 14).

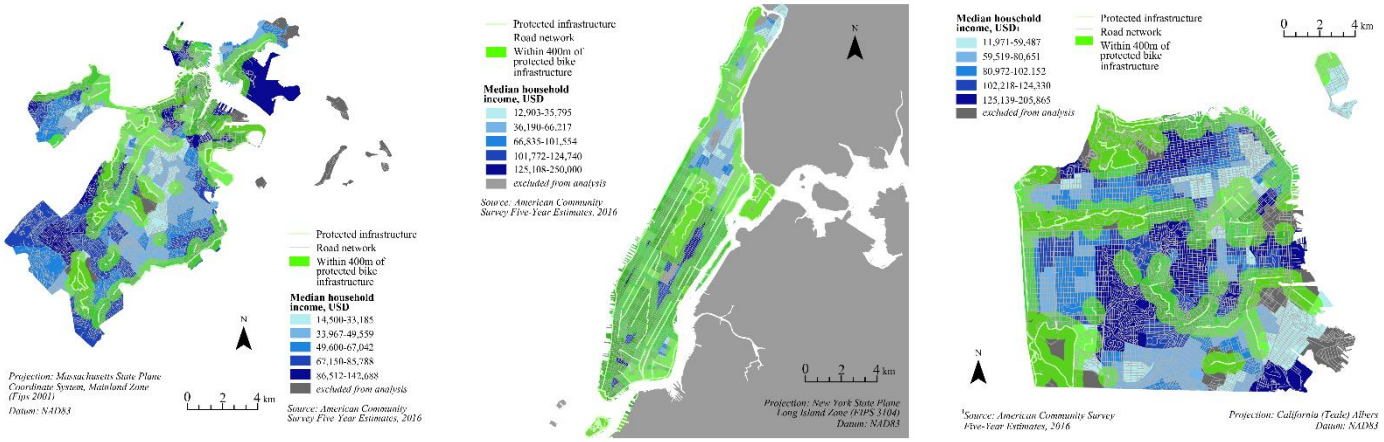
5.2 Quantitative analysis findings

5.2.1 Boston

The relationship between access to protected cycling infrastructure and income was found to be statistically significant (chi-square 4, N = 167, 15.85, p = 0.03). The chi-square value of 15.85 exceeded the critical value of 9.49, meaning we can reject the null hypothesis that the spatial pattern of interventions is equitable across groups. The results, seen in *Table 5.3* and *5.4* suggest that the lowest income quintile has, by a significant margin, the best access to protected infrastructure, followed by the two highest-income brackets.

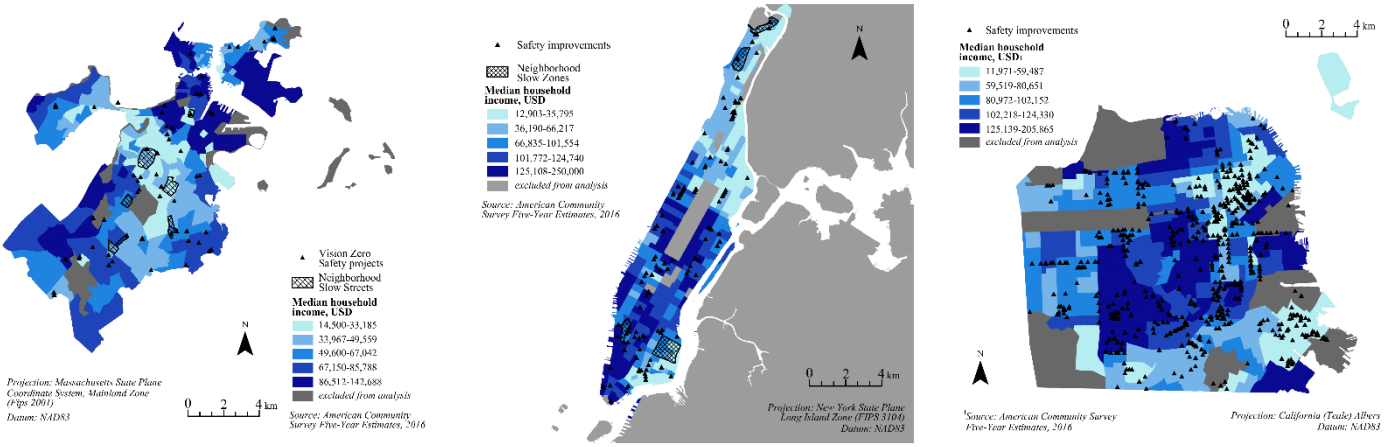
The analysis of safety improvement versus income quintile, with a p-value of 0.184, was not statistically significant. However, the tabulation process reveals that the share of safety improvement measures is distributed relatively equally throughout income quintiles, with a little more than 20% of all interventions occurring in census tracts falling into the first four brackets, while census tracts falling into the highest-income bracket had a share of about 14% of all interventions, as is seen in *Table 5.5*.

These findings are discernable in *Maps 5.1* and *5.2*, below. Considering the distribution of protected bike infrastructure (*Map 5.1*), it is clear that there is limited access across the city, but that access is best within the central city, comprising both upper- and lower-income areas. The pattern of safety improvements is similarly limited, but visually appears distributed across the entire geography.



Boston **Manhattan, New York** **San Francisco**

Map 5.1: Protected bicycle infrastructure access and median household income by city



Boston **Manhattan, New York** **San Francisco**

Map 5.2: Safety improvements and median household income by city

5.2.2 New York

The chi-square value relating protected infrastructure access to income quintile (found under section B.2 in Appendix B), was statistically significant (chi-square 4, N = 275, 19.77, p = 0.001). The chi-square value of 19.77 was higher than the critical value of 18.47, leading us to reject the null hypothesis of an equitable spatial pattern across income groups. From this, it is possible to calculate the percent of access to protected infrastructure by income quintile. The results (seen in *Table 5.3*) show that the two lowest-income brackets have the lowest share of access, at roughly 17.5 and 16% access respectively, whereas the two highest-income brackets have a larger share at about 22.5% of all infrastructure each. This pattern holds out when looking

at the percentage of census tracts within each quintile that have access, seen in *Table 5.4*, where the two lowest income quartiles have the correspondingly lowest values of access at about 71 and 65.5% compared to the top income quintiles' values of over 90%.

The analysis of safety improvement measures was not statistically significant, yielding a p-value of 0.180. The tabulation process, however, revealed an interesting relationship, wherein the lowest shares of all safety improvement measures were found in the lowest and highest income quintiles, at about 12 and 13% of all measures found in each, respectively, as can be seen in *Table 5.5*. Meanwhile, the second-lowest income quintile had the largest share, at over one-third of all measures found in census tracts whose median household income fell within this quintile. The middle-income bracket and second-highest income bracket, respectively, held the second-most and third-most number of safety improvement measures at 23 and 18.5%.

Map 5.1 illustrates high coverage of access to protected bike infrastructure across Manhattan, effectively highlighting the gaps in access. Visually, it is clear that these main gaps are lower income census tracts. *Map 5.2* shows that safety improvements seem to appear in clusters across the island, which likely illustrates an approach to address problematic corridors rather than unconnected point improvements.

5.2.3 San Francisco

Neither the analysis of access to protected infrastructure nor that of safety improvement measures compared to income quintiles proved statistically significant, as the former had a p-value of 0.064 and the latter had one of 0.667 (as can be seen in Appendix B, B.3). However, the tabulation of infrastructure investment by income quintile still yielded interesting results. As can be seen in *Tables 5.3* and *5.4*, the census tracts falling into the second-highest income quintile had the largest share and the most access to protected infrastructure, while the highest income bracket had the lowest. The rest of the quintiles fell within these extremes, although the lowest-income quintile had a lower share.

This pattern is not repeated in the distribution of safety improvement measures. The largest share of interventions was placed in census tracts falling within the lowest-income quintile (as can be seen in *Table 5.5*), followed by the middle and second-highest-income quintile.

Map 5.1 shows access to protected bike infrastructure is higher in San Francisco than in Boston, but still lags that in Manhattan. A degree of the protected infrastructure is in park areas

which were excluded from the analysis, with the rest showing limited connectivity across the city. *Table 5.2* shows San Francisco's number of safety improvements easily exceeds that of Boston or Manhattan. Visually, safety improvements also exhibit a degree of clustering along corridors, with several low-income areas hosting clusters of interventions.

Table 5.2: Income ranges per quintile, USD

City	*Quintile 1*	*Quintile 2*	*Quintile 3*	*Quintile 4*	*Quintile 5*
Boston	14,500-33,185	33,967-49,559	49,600-67,042	67,150-85,788	86,512-142,688
New York	12,903-35,795	36,190-66,217	66,835-101,554	101,772-124,740	125,108-250,000
San Francisco	11,971-59,487	59,519-80,651	80,972-102,152	102,218-124,330	125,139-205,865

Table 5.3: Share of overall access to protected infrastructure by income quintile

City	*Quintile 1*	*Quintile 2*	*Quintile 3*	*Quintile 4*	*Quintile 5*
Boston*	29.63	13.58	12.35	20.99	23.46
New York*	17.57	16.22	21.17	22.52	22.52
San Francisco	16.67	22.22	22.22	29.63	9.26

**Result is statistically significant at the $p < 0.05$ level.*

Table 5.4: Percent with access to protected infrastructure, by quintile

City	*Quintile 1*	*Quintile 2*	*Quintile 3*	*Quintile 4*	*Quintile 5*
Boston*	70.59	33.33	29.41	51.52	57.58
New York*	70.91	65.45	85.45	90.91	90.91
San Francisco	23.68	32.43	32.43	43.24	24.24

**Result is statistically significant at the $p < 0.05$ level.*

Table 5.5: Share of safety improvement measures within each income quintile

City[1]	*Quintile 1*	*Quintile 2*	*Quintile 3*	*Quintile 4*	*Quintile 5*
Boston	20.69	21.84	20.69	22.99	13.79
New York	12.04	32.87	23.15	18.52	13.43
San Francisco	26.22	14.63	21.64	20.43	17.07

[1]*No results were statistically significant at the $p < 0.05$ level.*

CHAPTER 6: DISCUSSION AND CONCLUSION

This research sought to understand each city's approach in transportation planning associated with Vision Zero; specifically, this included methods for improving safety, conceptions of equity, and implementation strategies, drawn from planning documents. The results of statistical analysis provide a quantification of equity with regarding to infrastructure and safety improvement projects across income quintiles. Here, I discuss the results of my content and statistical analysis and consider policy implications. I draw conclusions about successes and challenges in Vision Zero-related transportation planning, and make suggestions about best practices as well as topics for future research.

6.1 Analysis of findings

6.1.1 Boston

Boston's planning documents represented an uneven approach to Vision Zero; implementation methods and the role of equity were not addressed consistently across documents. The three plans, all from similar timeframes, and all connected to Vision Zero, found agreement in road design solutions, but lacked cohesion with regard to methods for the integration of equity, and other than the Neighborhood Slow Streets plan, failed to clearly illustrate what the planning process might consist of.

Nonetheless, there were successes. The Neighborhood Slow Streets plan (Boston Transportation Department, 2017a), in its simplicity, transparency, and formal integration of equity measures, represents an interesting and potentially successful planning method for the City moving forward. However, while the process is clearly based in community engagement, it is worth noting that the act of 'engaging' is left entirely up to the community itself, which would present additional barriers to neighborhoods that already lack strong groups to advocate for their needs. Go Boston 2030's (Boston Transportation Department, 2017c) approaches to engagement and equity are ambitious, and the integration of quantified goals and measurable indicators, particularly with regard to equity, set it apart in a positive way.

The approach laid out in the Vision Zero Action Plan also can be considered notable in a few senses. For one thing, the integration of two prominent local advocacy groups into the Vision Zero Task Force (WalkBoston and the Boston Cyclists Union) invites increased

accountability and transparency. The City's data collection agreement with the WAZE app represents a novel method of collecting data that can be used to evaluate design changes. The City's quantified goal of adding 10 miles of "high-priority projects on the Boston Bike Network" is also an easily-measurable indicator of action towards goals (Boston Transportation Department, 2016, p. 16). However, several of the plan's approaches should be regarded with skepticism. For example, the plan, in several of its goals, puts what some may consider a problematic focus on pedestrians and cyclists, the alleged vulnerable users at the focus of Vision Zero. For example, of twelve programs meant to "tackl[e] distracted and impaired driving," seven include or are focused on educating cyclists and pedestrians or encouraging helmet use. Indeed, part of the campaign to reduce distracted and impaired driving is providing helmets to cyclists. The plan also includes "Hard-hitting Public Service Announcements and media campaigns to … address [the dangers of] walking and riding a bike while distracted or under the influence of drugs or alcohol," to be released alongside similar campaigns aimed at motorists (p. 18). While there is some basis for this line of thought, these measures arguably put inordinate responsibility on vulnerable users for threats to their own safety that are nonetheless posed by motor vehicles.

The results of the content analysis are belied by those of the quantitative analysis, however. The lowest-income quintile had the best access to protected infrastructure of any at about 70.5%, with next-best access being to those in the highest-income quintile, with 57% of census tracts within this range having access to protected infrastructure. The middle and second-lowest income quintiles had similar values of access, about 30%, while census tracts in the second-highest income quintile had access about 51.1% of the time. These results, statistically significant, resist easy interpretation, but likely have something to do with the concentration of poverty in Boston's "inner city" urban neighborhoods. The analysis of safety improvement measures did not lead to statistically significant results, but the analysis reveals that these interventions are distributed between income quintiles with relative equality (see *Table 5.5*). Given that the safety improvement data employed in this analysis includes solely Vision Zero-specific interventions (unlike the bicycle lane data, which includes a significant amount of infrastructure pre-dating Vision Zero), it could be that Boston's approach has been successful from an equity perspective. Further research is necessary to understand the significance of, and explanation behind, these findings.

6.1.2 New York

Despite the lack of discussion of equity in the Vision Zero Action Plans (City of New York, 2014; Viola et al., 2015), the approach mentioned throughout the plans gives reason for hope. The Street Ambassador Program is a significant step towards ensuring that all voices are heard, as are outreach activities specifically with groups particularly vulnerable to traffic violence through activities at schools and senior centres. DOT's readiness to adopt alternate forms of community engagement, beyond workshops and even beyond online methods, suggests a commitment to equitable representation in the planning process. Hiring a dedicated staff member to manage this process suggests further commitment to this goal. On the other hand, while the plans all note the vitality of community engagement, the form and extent to which these processes are institutionalized in the planning process is unclear. The plans also suggest a data-based analysis of crash sites will allow for the targeting of interventions to the areas that need them most, and while this may well be the case, there is no indication that socioeconomic data has been integrated into this process (Viola et al., 2015). The implications of this for site identification are unclear, but what is clear is that the prioritization process does not seek to account for interlocking forms of vulnerability, which is limiting and potentially problematic.

Nonetheless, New York's Vision Zero implementation finds strength in the clear and in many cases quantified goals and indicators present throughout the plans. The initiative's data collection and dissemination practices are also highly commendable, in providing for routine evaluation both internally and by the public, as all crash data, reports, and project details and locations are easily available to download in accessible formats on the Vision Zero website and in most cases updated monthly. The city also finds notable success in the degree to which Vision Zero is undertaken as an integrated effort, going beyond just the DOT to become a framework of action directing the Police Department, Taxi and Limousine Commission, Citywide Administrative Services, City Hall, and Health and Mental Hygiene (City of New York, 2014).

The spatial and statistical analysis show that throughout Manhattan, wealthier census tracts do, overall, have better access to protected bicycle infrastructure at a statistically significant level, with residents of the two highest-income quintiles overall having at least 25% more access in their neighborhoods than those in the two lowest-income quintiles, and holding a larger share of all census tracts with access. This being said, however, even Manhattan's lowest level of access to protected infrastructure, 65.5% in the second lowest-income quintile, is

nonetheless an appreciable level of access. That over 70% of census tracts in the lowest-income quintiles have access to protected infrastructure is likewise impressive and would make a highly ambitious goal for many cities and towns throughout the United States. Nonetheless, the gaps in access between lower- and higher-income neighborhoods, even in a place as dense as Manhattan, suggest that the city has farther to go before reaching its goal of transportation equity.

This pattern is not so clear cut, however, when it comes to the distribution of safety improvement measures. While the results were not statistically significant, the analysis revealed that the lowest shares of all safety improvement measures were found in the lowest-income and the highest-income quintiles, and the highest share, at nearly one-third of all interventions, was found in the second lowest-income quintile. This reason for this distribution is unclear, but may have something to do with income quintiles varying in their position in residential neighborhoods versus along major roads, which call for different types and distributions of response.

6.1.3 San Francisco

San Francisco's Vision Zero Action Strategies displayed ambition, accountability, and comprehensiveness. While the first Action Strategy failed to define equity, it and its subsequent plan show a commitment to the collection, evaluation, and application of data, and strategies for innovation in this regard. Indeed, of all the plans, San Francisco had the most comprehensive set of performance indicators, by sheer number as well as topic.

It is worth noting, however, that the City's aggressive and data-centred approach appears to be moving in the direction warned about by Elvebakk, who wrote that to truly reach zero, governments would have to make infringe upon the autonomy of road users (2007). The move to monitor and record data like speed and other driving behaviours, in ways that residents may or may not be aware of, could prove to be an overreach and invasion of privacy. This is even more of a concern if this is done in partnership with the private sector, as is suggested in the 2015 Action Strategy, as privacy becomes even less assured.

Overall, however, San Francisco presents a plan that is both vitally focused on human issues of equity and access, while simultaneously planning in a way that facilitates self-evaluation and transparency, as well as accountability for goals.

The results of the quantitative analysis paint a complex picture. While neither section of the analysis led to statistically significant results, the distribution of infrastructure and

improvements that is neither clearly equitable nor inequitable; while there are differences in each income quintile's share of investments, the differences do not appear to follow any intuitive pattern. Further research, for example, into the location of these quintiles, what infrastructure is already in place, and the distribution of crashes, is needed to understand and interpret these results.

6.2 Discussion

6.2.1 Implications and recommendations

This analysis considers three major U.S. cities' approach to implementing Vision Zero. As more cities in the U.S. and beyond begin to implement this initiative, analysis of this sort will be useful in determining best practices.

These three case studies represent various approaches of various strength and weakness. San Francisco and New York's datacentric approach, and particularly San Francisco's development and application of the High Injury Network as a means through which to prioritize projects, improve accountability, and facilitate more effective planning and decision-making. Part and parcel to this approach are the need for effective mechanisms for data collection, analysis, and dissemination. In this regard, both San Francisco and New York City suggest a way forward, as both seek to improve the quality and increase the amount and variety of data collected, which can be used in evaluation and decision-making. In this sense, the methodology seen in the Boston Slow Neighborhood Streets represents an intriguing innovation, in the sense of creating a completely transparent and legible planning process, that still integrates a formal weight for equity concerns.

Areas of weakness include a lack of specificity, both in creating plans but also in drafting internal policy and practice. Without a clearly defined process for decision-making, integrating considerations of equity, and integrating the concern of the public, the planning process becomes illegible to anyone trying to analyze, evaluate, or navigate it. Along this line of thought, all three cities were inconsistent in their attempts to define equity, with none integrating a definition of what equity or equitable transportation meant to them throughout all plans. Similarly, outside of San Francisco, there was an inconsistent application of performance indicators. While some were integrated into New York and Boston plans, the integration of high-quality indicators must be a priority in an undertaking of this sort. Concerns also follow all three cities' reliance on 'enforcement' as a key implementation method, and their lack of rationale or methods to ensure

that people of colour are not disproportionately affected, as has been the case historically as with the disproportionate citations and tickets given to people riding bikes as people of colour (Hoffmann & Kmiecik, 2016). Uncritical reliance on the enforcement approach could easily present an equity problem of its own.

The results of the quantitative analysis revealed patterns of access that varied throughout the cities, as well as between protected bicycle infrastructure and to safety improvement categories. Further analysis is needed in order to draw useful conclusions at the city level. Of note, however, is the fact that San Franciscans across the board have lower access to protected bike lanes than was seen in the other areas of study, despite having the highest cycling rate of the three cities. While the study of safety improvement measures did not yield statistically significant results, tabulating the distribution of these interventions between income quintiles represents a good indicator of each city's application of Vision Zero, as most of the data and interventions occurred specifically as part of the initiative. (This is not the case with regard to bike infrastructure, as significant parts of the network reflected in the data predate Vision Zero.) As such, it is notable that in Boston, these interventions are distributed relatively evenly between the first four income quintiles, with only the wealthiest quintile having notably fewer interventions. The distribution is not so even in other cities, but they too demonstrate that such interventions are, at the least, not overrepresented in the highest income quintile. Further research could evaluate how well this distribution of investment follows social need, with use of crash data, for example.

6.2.2 Limitations

This being said, there are limitation to this analysis. Cities' datasets varied in terms of how up to date they were and the feature types and attribute information that they included. This research did not seek to confirm where infrastructure was placed or add features to the map that were not in the datasets available, meaning that the accuracy of the assessment is dependent upon the accuracy of the data available. Specifically, Boston had the lowest amount of data on design interventions and seems to be updated the least regularly; this could mean it appears that Boston has made fewer physical interventions than it actually has. This is associated with the larger limitation that this study relies fully on documents and data sets released by the cities themselves; accuracy and comprehensiveness of data could be improved with interviews and on-the-ground study. This study also did not incorporate injury or fatality crash data. The inclusion

of this data would allow for a better evaluation of the placement of infrastructure investment, as such investment should theoretically follow the places with the highest degree of traffic injuries and fatalities. However, this data was not available or comparable for all three cities and such additional analysis would lay outside the scope of this project. Finally, in setting the start of analysis to coincide with the implementation of Vision Zero, this study does not address the larger trends and actions taken by each city up to the point of Vision Zero, leaving out a larger story.

6.3 Conclusion

This research was concerned with application of the Vision Zero initiative in three U.S. cities, and particularly the role of equity in the process. To understand both the planning practices and their results, the analysis included document review as well as a spatial and quantitative analysis of interventions made. Recommendations were made for cities seeking to undertake this initiative in the future. Specifically, use and collection of data provides a means of prioritization of sites for safety improvements. Additionally, the use of quantified goals, effective indicators, and milestones is key to ensuring accountability and facilitating adherence to goals. Importantly, indicators must include a focus on equity, in participation as well as access to safety improvements and infrastructure. Implementation suffers when the planning process is illegible to members of the public, as well as when methods, processes, and goals are vaguely defined. Avenues for future study of Vision Zero and equity in transportation include analysis of funding and policy, the role of advocacy and community groups, and the tracking of progress made compared with goals set.

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APPENDIX A: DATASET SUMMARY STATISTICS

A.1: Boston

Summary statistics
n = 167

Variable	Mean	Standard deviation	Min	Max
Area (m2)	6069333.2	543968.1	43381	4345488
Population	3700.605	1374.338	1203	8287
Median household income	61911.69	30140.69	14500	142688
Number safety improvement	0.5210	0.9368	0	5
Access to infrastructure	0.4850	0.5013	0	1

Quintiles

Quintile	Observations	Mean	Standard deviation	Min	Max
1	34	25131.88	5575.958	14500	33185
2	33	42003.55	4892.967	33967	49559
3	34	58108.74	5775.84	49600	67042
4	33	76260.45	6214.652	67150	85788
5	33	109283.6	13988.5	86512	142688

A.2: New York

Summary statistics
n = 275

Variable	Mean	Standard deviation	Min	Max
Area (m2)	1938358	974635.1	447807	10715792.246
Population	5937.185	2999.094	120	16039
Median household income	85925.85	48105.37	12903	250000
Number safety improvement	1.5652	13.0707	0	12
Access to infrastructure	0.8073	0.3952	0	1

Quintiles

Quintile	Observations	Mean	Standard deviation	Min	Max
1	55	27487.82	6347.099	12903	35795
2	55	49384.84	8623.492	36190	66217
3	55	82811.27	9934.92	66835	101554
4	55	114168.1	7410.107	101772	124740
5	55	155777.2	29046.99	125108	250000

A.3: San Francisco

Summary statistics
n = 186

Variable	Mean	Standard deviation	Min	Max
Area (m2)	513464	381332.7	56564	2772873
Population	4456.102	1576.649	1562	13057
Median household income	91073.09	37894.14	11971	205865
Number safety improvement	3.5269	4.7399	0	30
Access to infrastructure	0.2903	0.4551	0	1

Quintiles

Quintile	Observations	Mean	Standard deviation	Min	Max
1	38	38216.42	14638.42	11971	59487
2	37	71754.41	6517.816	59519	80651
3	37	90343.89	6051.424	80972	102152
4	37	111906.1	6794.073	102218	124330
5	37	144573.2	17685.28	125139	205865

APPENDIX B: FULL QUANTITATIVE ANALYSIS RESULTS

B.1: Boston

Infrastructure access

Quintile	0	1	Total
1	10	24	34
2	22	11	33
3	24	10	34
4	16	17	33
5	14	19	33
Total	86	81	167

Pearson chi2(4) = 15.8485
Pr = 0.003

Safety improvement

Quintile	0	1	2	3	4	5	Total
1	22	8	2	2	0	0	34
2	18	11	4	0	0	0	33
3	27	3	1	0	2	1	34
4	23	4	3	2	1	0	33
5	23	8	2	0	0	0	33
Total	113	34	12	4	3	1	167

Pearson chi2(20) = 25.4764
Pr = 0.184

B.2: New York

Infrastructure access

Quintiles	0	1	Total CT
1	16	39	55
2	19	36	55
3	8	47	55
4	5	50	55
5	5	50	55
Total Access	53	222	275

Pearson chi2(4) = 19.7731
Pr = 0.001

Safety improvement

Quintiles	0	1	2	3	4	5	6	7	8	9	12	Total CT
1	44	4	2	3	1	1	0	0	0	0	0	55
2	39	1	5	2	2	0	3	1	0	1	1	55
3	41	4	3	1	2	1	0	0	3	0	0	55
4	36	9	4	3	2	0	1	0	0	0	0	55
5	40	7	4	3	0	1	0	0	0	0	0	55
Total TC	200	25	18	12	7	3	4	1	3	1	1	275

Pearson chi2(40) = 48.0135
Pr = 0.18

B.3: San Francisco

Infrastructure access

Quintiles	0	1	Total CT
1	29	9	38
2	25	12	37
3	25	12	37
4	21	16	37
5	32	5	37
Total Access	132	54	186

Pearson chi2(4) = 8.8943
Pr = 0.064

Safety improvement

Quintiles	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*14*	*15*	*16*	*17*	*18*	*30*	Total CTs
1	8	7	3	6	3	2	1	0	1	1	1	0	2	1	0	0	0	1	1	38
2	12	9	5	2	3	1	0	1	0	2	0	1	0	0	0	0	0	1	0	37
3	11	4	5	3	2	3	0	3	0	0	0	2	3	0	0	0	1	0	0	37
4	14	4	3	3	0	3	2	1	1	0	2	2	0	1	0	0	1	0	0	37
5	14	6	4	2	3	2	1	0	1	0	0	1	0	1	1	1	0	0	0	37
Total TC	*59*	*30*	*20*	*16*	*11*	*11*	*4*	*5*	*3*	*3*	*3*	*6*	*5*	*3*	*1*	*1*	*2*	*2*	*1*	186

Pearson chi2(72) = 66.3175
Pr = 0.667