

Calming New York: An Examination of Neighborhood Slow Zones

Jonas Xaver Hagen

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ABSTRACT

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Road traffic crashes are a leading cause of death and injury worldwide and in the US. In New York City, there are about 60,000 annual traffic casualties, including over 200 deaths. Area-wide traffic calming can improve traffic safety, pedestrian and cyclist comfort, and quality of life in neighborhoods (Elvik, 2009). This dissertation examines an area-wide traffic calming program, New York City's "Neighborhood Slow Zones" (NSZs), in terms of environmental justice, traffic safety, and street design.

The dissertation consists of three distinct but interrelated empirical studies. The first one asks if the NSZ program furthers environmental justice in New York City. It examines the locations of the 28 zones in terms of minority and low-income areas, as well as the inclusion of these populations in the process that led to the siting of the zones. This chapter concludes that the NSZ program improves environmental justice in New York City, both because the zones are equitably distributed in poor and minority areas, and because the planning process that led to the siting of the zones was inclusive of these populations.

The second study examines the effectiveness of the zones at reducing traffic casualties. This analysis uses a quasi-experimental, before and after research design, with a treatment group (the Neighborhood Slow Zones) and a comparison group (similar zones that did not receive the treatment). The analysis does not detect statistically significant reductions in traffic casualties associated with the NSZs.

The final empirical uses a policy transfer approach to compare street design in New York City's 20-mph zones to similar zones in London. London's "Slow Zones" were found to be

effective at preventing traffic casualties (Grundy et al., 2009), and were the inspiration for New York's Neighborhood Slow Zones. This study analyzes the traffic calming devices transferred from the zones in London to those in New York. While street designs in London's 20-mph zones included a robust implementation of traffic calming devices, New York's NSZs had a much more skeletal implementation of these devices. This suggests that the nature of the transfer of street design from London to New York City contributed to the disappointing results of 20-mph zones in the latter city. Despite these findings, I argue that the NSZ program has had partial success.

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For Christine Rosemarie Hagen, in loving memory

“Wer im Herzen seiner Lieben lebt, ist nicht tot.”

Chapter One

Introduction

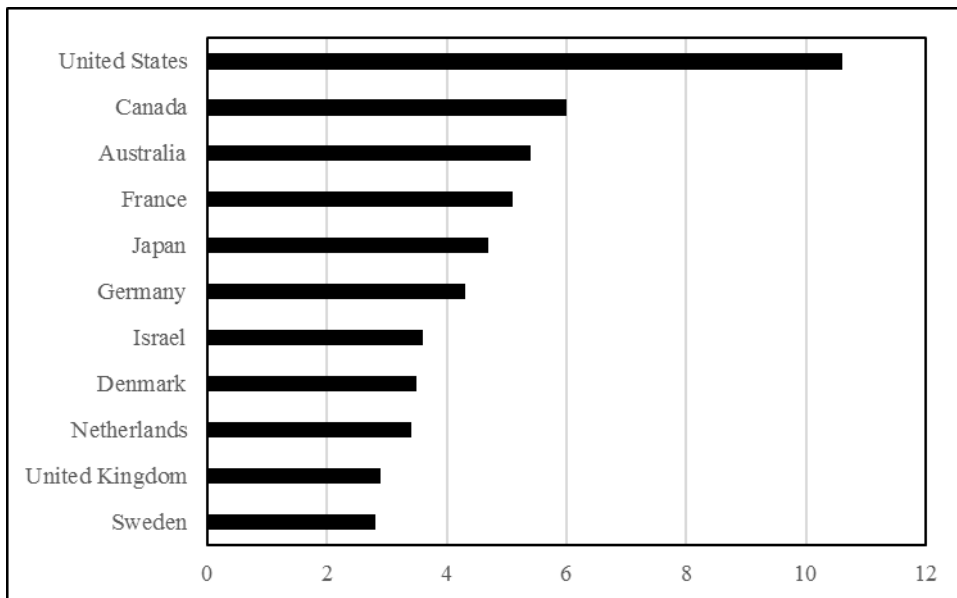
1 Traffic Safety: The US Underperforms

Road traffic injury is one of the most serious public health problems worldwide. The road transportation system causes over 1.25 million deaths and tens of millions of injuries each year (World Health Organization, 2015). Road traffic injury was one of the ten leading causes of death for the first time in 2015 (World Health Organization, 2017). Among people aged 15-29, road traffic injuries are the leading cause of death, and the third-leading cause for those aged 30-49. This contributes to the heavy burden that the lack of road safety places on household and national economies and broader development goals.

For much of the twentieth century, the United States was at the forefront of traffic safety. The Federal government showed leadership by developing the National Highway Safety Bureau (NHSB, later became the National Highway Traffic Safety Administration, NHTSA) in 1966. The US was the world's "safest environment for motoring" in 1978 (Motor Vehicle Manufacturers Association of the United States, 1981, p. 52), with the lowest rates of deaths per registered vehicle and 100 million vehicle miles travelled. The United States saw large reductions in traffic fatalities since its maximum of about 55,000 annual deaths in 1972 (Evans, 2014). Leading public health institutions and researchers in the US consider the improvement in motor vehicle safety in the United States to be one of the ten greatest achievements in public health of the twentieth century (Centers for Disease Control and Prevention, 1999; Warner & Chen, 2012).

However, in the late 1970s and early 1980s, US traffic safety policy began to diverge from its peers, and its relative performance on traffic safety worsened. From its leadership position in terms of safety per registered vehicle and the same distance travelled in 1978, it fell to 16th and 10th place, respectively, in 2002 (Evans, 2004). While traffic deaths in the US fell 16% from 1979 to 2002, Canada, the UK and Australia witnessed an average reduction of 49% in the same period (Evans, 2014). Versus the Netherlands, these changes are even more dramatic; US traffic fatalities declined 41% from 1972-2011, and 81% in Holland. Recent figures show that road traffic fatality rates in the US are much higher than in ten other wealthy countries (see Table 1 below). For example, fatality rates are about four times higher in the US than in Sweden and the UK, and Canada's rate is about 40 % lower than the US'.

Table 1 Road Traffic Fatalities Per 100,000 Population



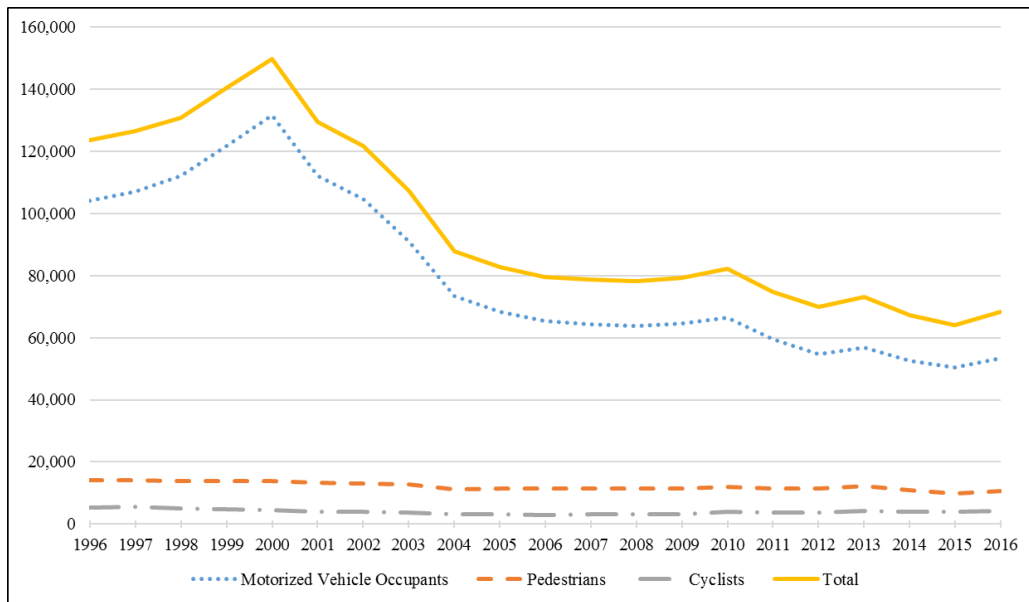
Data: World Health Organization, 2015

1.1 New York: Improving the US' Safest City

In the context of the US, New York is an extreme outlier regarding both its transportation system and traffic safety. Among major US cities, it has by far the highest percentage (57%) of trips to work made by public transportation. Washington D.C., Boston, and San Francisco trail far behind New York with 37%, 34% and 33%, respectively, while only 5% of travel to work nationwide is made by public transportation (Freemark, 2016). Among the 15 largest cities, the percentage of trips to work made on foot in New York (10%) was only equaled by San Francisco, versus 3% for all of the US.

New York City has worked hard in the last decades to improve traffic safety and has achieved large reductions in road traffic casualties (injuries and deaths). From 1996 to 2016, total traffic casualties declined 58% from their highest point in 2000 to their lowest in 2015 (see Figure 1 below). The city's fatality rates (3.5 fatalities per 100,000 inhabitants) are a quarter of the national rate (12.2), and less than half the rate of the ten other largest cities in the US (Viola, Roe, & Shin, 2010). The traffic fatality rate in New York is comparable to those of European cities; at 3.5 deaths per 100,000 inhabitants, it is below that of Copenhagen (3.9), but higher than Paris (3.1), London (2.7), Berlin (1.6) and Stockholm (1.2).

Figure 1 Annual Traffic Casualties in New York City, 1996-2016 Annual Traffic Casualties in
New York City, 1996-2016



Data: New York State Department of Transportation, 2017

The New York City Department of Transportation (DOT) credits its traffic safety programs for the safety improvements in recent decades (New York City Department of Transportation, 2007). These include pedestrian safety programs such as Safe Routes to School, Safe Routes for Seniors, and the speed hump program. The DOT has also pedestrianized public spaces throughout the five boroughs, including the iconic Times Square in Manhattan. Other safety programs target high risk corridors, such as Grand Concourse (the Bronx), and Queens Boulevard (Queens). The DOT also continues to build out the city’s cycle network. The network currently encompasses over 1,000 miles of bike routes, and the city has supported a bike sharing scheme that was launched in 2013 (New York City Department of Transportation, 2018).

Despite New York's impressive record, there is much room for improve traffic safety. The overall reductions in traffic casualties from 1996 to 2016 were mainly driven by reductions in motorized vehicle occupant casualties, which fell 62% from a high point in 2000 to a low in 2015. However, pedestrian casualty reductions were much smaller during the same period; they fell 31% from a high in 1996 to a low in 2015. Further, vulnerable road users (pedestrians and cyclists) are overrepresented in traffic fatalities. Although only 11% of commuters used walking and cycling as their primary mode in 2015, 64% of traffic fatalities were vulnerable users that year (Mayor's Office of Operations, 2016). Recognizing the need to improve traffic safety, the City launched Vision Zero, the goal of zero deaths or serious injuries from road traffic, in 2014.

New York City's government also seeks to expand walking, cycling and public transportation to meet goals of environmental sustainability and social equity. PlaNYC, the city's first overall sustainability plan (City of New York, 2007) announced efforts to reduce greenhouse gas emissions by improving conditions for walking, bus and rail service, and expanding the cycling network. A more recent citywide planning document, OneNYC (City of New York, 2015), reiterated these goals, and reinforced the need to improve traffic safety to increase travel by sustainable modes. The latter document also emphasized the potential gains in social equity of improving sustainable transportation networks, e.g., by enabling New Yorkers to reach 25% more jobs via public transportation.

This dissertation examines a traffic safety program in New York City: Neighborhood Slow Zones (NSZs). The NSZ program is the first systematic area-wide traffic calming program in a major US city. Area-wide traffic calming has been effective in improving traffic safety and pedestrian and cyclist comfort in European cities, and is a favored tool there (Bunn et al., 2009; Elvik, 2001). The NSZ program was launched in 2011 as part of an effort to improve pedestrian

safety. The program has generally been popular with the public, and 28 zones have been implemented throughout the five boroughs of the city.

The potential for area-wide traffic calming to improve safety and the NSZ program's success in delivering this policy tool in a relatively short time make this examination of the program particularly important. This dissertation finds that the program has attained some social equity goals but fallen short of the desired traffic safety impacts. It also finds that a possible contributing factor to the disappointing results was lack of street designs that could effectively slow traffic in the zones. However, I argue that the program cannot be considered an implementation failure, but rather, an incremental step toward a safer, more equitable and environmentally sustainable New York City.

2 Streets, Speed and Safety

2.1 Streets and the Automobile

The desire for increased travel speed drove the technological advancements that helped create the transportation networks and built environment that we inhabit today. For example, railways provided faster travel than walking or horses, automobiles provided faster and more direct travel than railways, and air travel provided faster travel than all of these modes, especially for long distances.

Until the emergence of the automobile in the first decades of the twentieth century, most street users proceeded at relatively low speeds (under 15 mph). Slow-moving traffic allowed streetcars, horse-drawn carriages, and pedestrians to share the roads with peddlers and children at play. When automobiles appeared in cities after the turn of the century, much of the urban public

was understandingly frightened, as these heavy, fast-moving vehicles represented a very real threat to the safety of all street users (Norton, 2008). Speed was seen as the most dangerous aspect of automobiles and speed limits were very low. The median speed limit for states was 10 miles per hour in 1906, and local authorities could (and often did) impose lower limits.

However, in the 1920s, a new type of professional, traffic engineers, joined forces with other pro-automobile interests to emphasize the streets as thoroughfares for cars, rather than places for pedestrians, streetcars, or children's play. Although traffic casualty rates and congestion were worse than ever, these engineers argued that increased auto speeds also improved safety. The solutions included pedestrian control, safety instruction in schools, and wide urban roads. Traffic engineers continued to be the dominant force in city planning in the coming decades, and their efforts to increase capacity and speed for cars in cities were largely unquestioned after the 1920s, even in residential areas (Southworth & Ben-Joseph, 1995).

The autos domination of cities was strengthened by the post-WWII development of the highway system, which established cars as the default mode of transportation and introduced freeways into city centers (DiMento & Ellis, 2013). The system and hegemony of auto travel, or "automobility," (Burnham, 1961, p. 435) was solidified in the post-war US and the highway system, financed by gas taxes, was built out. During this period, travel by public transportation, walking and cycling fell precipitously with respect to the faster option of car travel. At the same time, the built environment was configured to accommodate auto-centric suburban lifestyles (Jackson, 1987), further solidifying the dominant role of the car in the US's transportation system.

2.2 The High Cost of Fast Streets

Although automobility came to dominate transportation since the 1920s, dissident voices questioned the logic of fast-moving traffic on urban streets. Lewis Mumford (1958) had scathing criticism of the plan for the interstate highway system, and particularly its plan for urban freeways, which he thought would destroy the fabric of historic downtowns and surrounding neighborhoods. Jacobs (1961) showed the value of places that were good for walking and allowed vibrant city life, describing sidewalks bustling with people walking and children at play in Boston's South End or Greenwich Village. Similar to Jacobs, Lynch (1960) praised the "imageability" (1960, p. 9) of narrow Boston streets with historical buildings that were congested with pedestrians and cars, but had no place for parking. In contrast, Los Angeles, the quintessential car city, was "formless" and "without centers" (Lynch, Kevin, 1960, p. 40). In their seminal work on livability in a San Francisco neighborhood, Appleyard & Lintell (1972) supplied quantitative empirical data for the theories that praised walkable cities and streets. They found traffic speed, accidents and noise on residential streets increased with traffic volumes, while residents' relationships with neighbors decreased.

More recent research claims that higher auto speeds discourage walking and cycling trips, as these modes become relatively slower, less comfortable, and more dangerous (Jacobsen et al., 2009). This notion is supported by Ishaque and Noland's (2008) findings that longer signal cycle timing for autos creates less favorable condition for pedestrians. Buehler (2011) contends that, among other factors, roads that allow high travel speed facilitate auto travel in the US. Compared to the US, auto use is expensive and slow in German cities, whereas public transportation, walking and biking are safer and more convenient. This results in higher proportions of trips made by cleaner, safer modes in German cities.

Scholars have shown that transportation planning has prioritized the speed and volume of automobile traffic flows, often referred to as “mobility,” over other concerns, including traffic safety, and particularly pedestrian safety (Ben-Joseph, 1995; Black, 1990; Dumbaugh & Li, 2010; Henderson, 2011; Noland, 2013; Norton, 2011; Southworth & Ben-Joseph, 1995). Many scholars challenge this orientation, proposing transportation systems that subordinate concerns of “mobility” to goals of “access.” The latter concept centers on peoples’ ability to reach destinations that are of value to them, which is in fact the main goal of transport (Handy, 1993; Metz, 2008; Sclar & Schaeffer, 1980). Other scholars have proposed that transportation should focus on improving energy efficiency and other environmental outcomes, including reducing emissions of pollutants (Banister, 2008, 2011; Illich, 1974; Newman & Kenworthy, 2006). These scholars argue for transportation systems with reduced tripmaking by auto and increased travel by the sustainable modes of walking, cycling and public transportation. Both of these approaches to transportation (access and environmental concerns) highlight the gains in traffic safety that planners could achieve by prioritizing vulnerable street users (pedestrians and cyclists) over the speed and volume of motorized traffic.

2.3 Slower, Safer Streets Through Traffic Calming

Approaches to manage auto speed in cities include education, enforcement, and traffic calming. The Institute of Traffic Engineers defines traffic calming as “the combination of mainly physical barriers that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized streets users” (Lockwood, 1997, p. 22). Traffic calming slows traffic with physical measures placed in the roadway, such as speed tables, curb extensions, median islands, chicanes, and traffic circles. While other safety measures separate motorized

traffic from vulnerable street users, e.g., sidewalks for pedestrians, and bikeways for cyclists, traffic calming aims to slow motorized vehicles to speeds that ensure the safety of pedestrians and cyclists in the roadway.

Although these measures can be implemented in an isolated fashion on individual streets, in area-wide traffic calming, they are introduced in an entire area systematically, with the aim of slowing traffic throughout that area. In addition to improving traffic safety by lowering speeds and reducing through traffic in neighborhoods, these zones can create a more pleasant environment, and make outdoor play safer (Elvik et al. 2009). Scholars and practitioners also associate this measure with improved mobility and comfort for pedestrians and cyclists (Pucher & Dijkstra, 2003).

Traffic calmed areas often have speed limits of 20 mph/30 kmph, although lower speeds (e.g., 20 kmph/12 mph, or walking speed, about 5 kmph/3 mph) are common in cities in Europe and the UK. Researchers have carried out numerous empirical studies on the effects of area-wide traffic calming (Bunn et al., 2003; Cairns, Warren, Garthwaite, Greig, & Bamba, 2015; Elvik, 2001; Elvik, Vaa, Erke, & Sorensen, 2009; Ewing, Chen, & Chen, 2013; Grundy et al., 2009; Vis, Dijkstra, & Slop, 1992). Many of these studies show significant reductions in traffic casualties. A meta-analysis found an average reduction of injury accidents after introduction of the schemes of about 25% on residential streets, and about 10% on main roads (Elvik, 2001). Two other meta-analyses found traffic calming to be an effective policy tool for reducing traffic casualties (Bunn et al., 2009; Cairns et al., 2015). Findings from individual studies of the safety benefits of traffic calming included a 42% reduction in road casualties for London's Slow Zones (Grundy et al., 2009); a 25% reduction in injuries for traffic-calmed areas in Holland (Vis,

Dijkstra, & Slop, 1992); and no detected effects for speed humps in New York City (Ewing, Chen, & Chen, 2013).

Area-wide traffic calming can also further social equity and promote environmentally-friendly modes of travel. Researchers studying traffic-calmed zones in London found that numbers of traffic casualties decreased most in poorer areas of the city, thereby helping reduce the socio-economic inequality of road traffic injury in that city (Steinbach, Cairns, Grundy, & Edwards, 2013). Walking increased in a neighborhood in Glasgow (Scotland) after the implementation of area-wide traffic calming (Morrison, 2004). Further, the measure contributes to higher levels of walking and cycling in Germany and Holland versus the United States, because of the added safety and comfort it affords vulnerable users (Pucher & Dijkstra, 2003).

2.3.1 Neighborhood Slow Zones

Under the NSZ program, New York City's Department of Transportation (DOT) implemented a speed limit of 20 miles per hour and traffic calming devices on streets in 28 areas of approximately five square blocks. These zones were one of the action items of the DOT's *Pedestrian Safety Study & Action Plan* (Viola et al., 2010). The first zone appeared in Claremont, in the Bronx, in 2011, and the DOT implemented the remaining 27 zones between 2012 and 2016. About 540,000 New Yorkers live within the borders of the NSZs.

As previously mentioned, the NSZ program is the first systematic area-wide traffic calming program in a major US city. Ewing (1999) reports that area-wide traffic calming had previously been implemented systematically in the US in smaller cities (including Sarasota and Boulder) and in a sporadic way in a larger city (Seattle). To use terminology of diffusion of innovations, this makes New York City an "early adopter" of this policy tool (Rogers, 2010).

The potential of area-wide traffic calming to improve traffic safety, reduce social inequality and contribute to environmental goals make an examination of this program important in the US context.

3 Theoretical Framework

The idea that transportation systems and streets can be modified to improve equity, public health and environmental outcomes underlie this dissertation. Although the three empirical chapters draw upon different theories, the notion that slower speeds on city streets through area-wide traffic calming can lead to more favorable outcomes is a common thread. This section outlines the theoretical underpinnings of the dissertation.

The overarching theory guiding this research is that streets are the result of, and can be modified through social interactions. As research that seeks to contribute to creating safer streets, this dissertation is part of a movement that seeks to bring public health concerns back to the core of urban planning. The dissertation also draws upon environmental justice theory, seeking to create more equitable cities by equitably distributing environmental risk and including low-income and minority populations in planning processes. Finally, the dissertation uses a policy transfer approach to examining street designs in 20-mph zones in London and New York City.

3.1 Streets as a Social Construction

In its examination of an area-wide traffic calming program in New York City, this dissertation adopts a social constructivist view of streets. Social constructivism emphasizes that reality is socially constructed; culture and context create the knowledge of what occurs in society (Berger & Luckmann, 1966). In this theory, the dominant definition and understanding of artifacts,

including streets, arise through social interactions. Currently, the street is primarily conceived of as space that people use to travel in autos and store autos (parking). Norton (2011) showed that pre-automobile streets were places for commerce, child's play, and walking, and that the redefinition of streets as places for auto travel and storage was won by automobile interests only after hard-fought battles with civic groups interested in protecting streets as places for pedestrians. If streets were redefined for autos in the 1920s through social interactions, it follows that society can also redefine streets as spaces that cars share with people walking and on cycles.

Just as the "machine ensemble" (Schivelbusch, 1986, p. 16) of the railroads consisted of the locomotive and the track, the proliferation of the automobile depended upon the creation of high-quality streets (McShane, 1994). Social interactions defined existing streets as spaces for autos and created new extensive networks exclusively for cars, creating auto-centric streets and cities. Traffic calming stems from an understanding that pedestrians and cycles also require artifacts to create an ensemble that allows safe and comfortable use of these modes, and that these modes can play an important role in a city's transportation system. Proponents of traffic calming also believe that the ensembles for autos and vulnerable street users can coexist harmoniously in the same space. However, safer streets and more sustainable transportation systems require restrictions on auto use and improved infrastructure for walking and cycling (Banister, 2008; Kemp, Avelino, & Bressers, 2011).

This dissertation examines a program that sought to redefine streets in favor of vulnerable users, and identifies some of its successes, shortcomings and possible reasons for the program's partial success. Irrespective of the successes or failures of the NSZ program, the research in this dissertation is premised on the notion that streets are a product of social interactions, and

therefore malleable artifacts that can be modified to create healthier, more equitable and environmentally sustainable cities.

3.2 Public Health and Urban Planning

This dissertation draws from theories and methods from both urban planning and public health and contributes to scholarship that seeks to reconnect these two fields. Scholars have argued that solving the environmental and public health challenges of today's cities call for public health concerns to be put at the center of urban planning research and practice (Corburn, 2007; Garau, Sclar, & Carolini, 2004; Northridge, Sclar, & Biswas, 2003; Rosenthal et al., 2007)). This dissertation is a small contribution towards this larger goal.

Despite the present separation of the two disciplines, the field of urban planning largely arose from tackling public health crises in industrializing cities in North America. Perhaps the most important challenge facing U.S. cities in the 19th century was to reduce deaths from communicable diseases, including cholera, typhoid and diphtheria. Engineers worked with municipalities, first to provide potable water to cities and then to create sewage systems. These professionals, as well as landscape architects and “sanitarians” (urban public health professionals that advocated for sanitary cities, (Schultz & McShane, 1978), were precursors to urban planners. Between the 1850s and 1890s, these efforts dramatically lowered disease and mortality rates in US cities.

Landscape architects and engineers were the best represented professions in the nascent discipline of urban planning during the beginning of the 20th century, and at this time, urban planning was directly linked to public health. However, urban planning and public health soon diverged (Corburn, 2007). Increasing professional specialization since the 1930s, with separate

municipal departments for different competencies (such as sanitation, housing, and traffic planning), further separated urban planning and public health. Particularly since the turn of the last century, research has brought these fields together to tackle problems such as traffic safety (Frank & Engelke, 2001; Frumkin, 2002; Pucher & Dijkstra, 2003) and local air quality (Lena, Ochieng, Carter, Holguín-Veras, & Kinney, 2002; Minkler, Vásquez, & Shepard, 2006).

Public health and urban planning have different but complementary competencies. Studies of injury epidemiology serve to diagnose the problems of traffic injury and the effectiveness of traffic safety measures. Urban planning research has the potential to compare different approaches to traffic safety and identify opportunities and obstacles to creating safer transportation systems. Working together, these fields can contribute more effectively to creating healthier cities.

3.3 Traffic Injury and Speed

The epidemiological theories of traffic injury of William Haddon Jr. (Haddon Jr, 1970, 1980) bring together the fields of public health and planning. Speed plays a central role in the sustaining of traffic injuries in his seminal works, where the human body's capability to withstand mechanical violence is the basis of strategies to reduce traffic injury. These strategies include: reducing the kinetic energy in the transport system, separating this energy, and creating barriers around energy in the traffic system. Haddon's strategies for preventing traffic injury can guide planners to employ specific measures to improve safety in the transportation system, such as introducing slower speeds, and constructing sidewalks and protective bollards. These theories can help shift the focus in transportation planning from decreasing the frequency of vehicle collisions to preventing bodily injury. As Haddon pointed out: "A vehicle crash, per se, need

necessitate no injury” (1970, p. 2232). The specific measure of traffic calming, which is the focus of this dissertation, aligns with Haddon’s theory of injury prevention. An intervention in the built environment, traffic calming reduces the kinetic energy of the transportation system by slowing traffic, potentially reducing the mechanical violence that leads to injuries.

The centrality of speed in traffic injury severity in Haddon’s is borne out by empirical evidence. Studies describe the relationship between a car’s speed at the moment it collides with a pedestrian and the severity of the pedestrian’s injury (Anderson et al., 1997; Rosén & Sander, 2009). These studies show an exponential increase in injury severity as auto speeds increase. For example, Anderson et al. show an 8 % likelihood of fatal injury for a pedestrian struck by an automobile travelling at 30 km/h (19 mph), a 58 % chance of fatality at 45 km/h (28 mph) and an 85% chance of fatality at 50 km/h (31 mph). The authors also showed that braking distance increases proportionally with the square of speed. This makes it easier to avoid collisions and thereby eliminate injuries at lower speeds or reduce injury severity when collisions occur.

3.4 Equity, Participation, and Environmental Justice

Both participatory and equity planning approaches were created partly in response to perceived deficiencies of the expert-driven, modernist “rational model” of planning, which took shape in the 1950s and 1960s (Beauregard, 1984, 1989). Environmental justice began as a grassroots movement in the 1980s, and research on the topic emphasizes the disproportionate exposure to environmental health burdens of low-income and minority populations. My examination of the NSZ program uses an environmental justice approach that investigates the equitable distribution of the zones, as well as whether the planning process that led to the siting of the zones was participatory and inclusive of poor and low-income populations.

While rational planning seeks efficiency through top-down, centralized planning, participatory planning emphasizes understanding, public debate and consensus building (Forester, 1999; Healey, 1997; Innes & Booher, 2004). While some scholars have been skeptical of the possibility of changing planning outcomes through participation and communicative approaches (Abram, 2000; Arnstein, 2007; Fainstein, 2000; Flyvbjerg, 2003; Huxley, 2000), others have examined the difficulties surrounding participation of historically oppressed, low-income and minority populations in planning processes (Healey, 1997; Umemoto, 2001; Umemoto & Igarashi, 2009; Yiftachel, 1998; Young, 1986, 1989, 2002).

In contrast to participatory planning's emphasis on public debate, advocacy planning (Davidoff, 1965) is more directly related to achieving greater equity by using planning processes to redistribute resources to poor and minority citizens. This approach was put into practice as "equity planning" in Cleveland (Krumholz, 1982), where the municipal government's policies sought to improve services for poor residents by, for example, upgrading bus service. Similarly, planners in Clavel's "progressive cities," (Clavel, 1986, 1994) such as Hartford, Boston, Chicago and Burlington, practiced equity planning that emphasized participatory methods to achieve redistributive goals.

The equity and participatory planning approaches outlined above are reflected in the concept of environmental justice, which seeks to redress the disproportionate burden of environmental health-related disease borne by minority and low-income populations. The environmental justice movement began as a grassroots movement in 1982, when the state of North Carolina attempted to dump more than 6,000 truckloads of the toxin polychlorinated biphenyls (PCBs) in Warren County, a rural and majority African American community (Faber & McCarthy, 2001). Minority and low-income communities created hundreds of grassroots

environmental justice organizations in the 1980s. These organizations pressured the Environmental Protection Agency (EPA) to become more responsive to EJ issues. This pressure led to the 1994 presidential Executive Order that requires the Federal government (and agencies receiving Federal funds) to “make achieving environmental justice part of its mission” (Federal Register, 1994, pp. 1–101). Since the 1990s, an increasing body of research on environmental justice has documented the disproportionate siting of toxic land uses in low-income and minority areas (Been, 1992; Bullard, 2000; Heiman, 1996; Leonard III, 1996) as well as exposure to air pollution (Jerrett et al., 2001) and industrial hazards (Pais, Crowder, & Downey, 2014).

Given the lack of attention of mainstream environmental groups and government to the environmental concerns of minority communities (Lazarus, 1992), much research on environmental justice has highlighted the community-driven processes and the participatory, grassroots nature of the movement (Bullard, 2000; Cole & Foster, 2001; Di Chiro, 2008; D. J. Faber, 1998; Faber & McCarthy, 2001). For some scholars, the concept of environmental justice explicitly includes “participatory justice” (Schlosberg, 2013, p. 40): participatory planning processes that are inclusive of low-income, minority populations (Hamilton, 1993; Lake, 1996).

Critics of the rational school said that its quest for efficiency left out the issue of who are the beneficiaries of plans (“efficiency for whom and for what?” Wildavsky 1973, p. 142). Further, the rational model neglects “the human side of planning” (Friedmann and Hudson 1974, p.13). As Friedmann (1989) points out, when planners apply pure technique, as is the case in rational planning, they tend to “slash blindly into the life of living communities” (p. 128). These criticisms hold true for transportation planning, which has commonly been insensitive to the needs of low-income and minority populations. Cost-benefit analyses for transport infrastructure favored wealthy commuters, autos over transit, disregarded pedestrians, and sought no input

from communities (Black, 1990). Many urban highways were routed through existing working-class, minority neighborhoods, often severing them, and in some cases demolishing them entirely, with the goal of eliminating “blight” (DiMento & Ellis, 2013). Auto-centric transportation planning centering on middle-class suburban populations starves funding for public transportation, excluding vulnerable populations from transport networks; “transportation racism” (Bullard, Johnson, & Torres, 2004, p. 1) exacerbates chronic inequality in US cities. Conventional transportation planning generally continues to disregard the needs of these populations, including traffic safety, as a disproportionate amount of traffic casualties come from poor and minority populations (Deka, 2004).

My analysis of the NSZ program uses the environmental justice approach, where environmental justice is conceived as not only the equitable distribution of hazards or amenities, but also using an inclusive, participatory planning approach. I use demographic and crash data to examine whether zones have been distributed equitably in environmental justice areas and places that could benefit from the zones from a traffic safety perspective. Interviews and policy documents provide data on the participatory processes used to site the zones. I argue that the NSZ program improves environmental justice, with an equitable distribution of the zones and employing an inclusive, participatory planning process.

3.5 Policy Transfer of Traffic Calming

While previous scholarship has noted the diffusion of traffic calming across countries and cities (Ben-Joseph, 1995; Ewing, 1999; Hass-Klau, 2014; Kjemtrup & Herrstedt, 1992), these studies have neither employed a policy transfer perspective, nor provided detailed analyses of the street designs used in the intervention sites. I use a policy transfer approach to examine street designs

of 20-mph zones in London and New York City. I use the zones in London for two reasons. First, London's "Slow Zones" were the inspiration for New York's NSZs (Health Resources in Action, 2013). Second, the zones in London achieved considerable reductions in traffic casualties (Grundy et al., 2009; Li & Graham, 2016; Webster & Layfield, 2003), as opposed to the zones in New York, which I did find to improve traffic safety.

The term "traffic calming" appeared in the 1963 "Traffic in Towns" report of the UK's Ministry of Transportation (Ben-Joseph, 1995). This report described situations where reduced vehicle speeds and volumes permit a mixture of pedestrians and vehicles and do not harm traffic flow. This concept initially gained more traction in continental Europe than the UK, and led to the implementation of traffic calming on individual streets in Holland in the late 1960s. Area-wide traffic calming became a favored tool to improve traffic safety in countries such as Germany, Denmark, Holland, Sweden, and the UK since the 1970s (Kjemtrup & Herrstedt, 1992). Although the policy tool has been implemented in a handful of US cities, it is relatively rare in this country in comparison to Europe.

Traffic calming is a technological development that modifies the "machine ensemble" of automobility, altering the environment that vehicles use to traverse space (streets). It is also a policy tool that has been diffused since the 1960s, widely in Europe, and to a lesser degree in the US. Diffusion literature (Rogers, 2004, 2010) studies how, why and at what rate new ideas (innovations), including products and technological advancements, spread across places and institutions. Policy transfer, a subset of diffusion literature (Mossberger & Wolman, 2003), analyzes the spread of policies among institutions. Because area-wide traffic calming is at once a technology and a policy tool, the policy transfer approach is particularly well-suited to

examining how the transfer of 20-mph zones from London to New York might have impacted the policy's safety outcome.

Policy transfer is defined as “a process in which knowledge about policies, administrative arrangements, institutions etc. in one time and/or place is used in the development of policies, administrative arrangements, institutions in another time and/or place” (Dolowitz & Marsh, 1996, p. 344). Policy transfer can be treated as an independent variable, where researchers seek to explain the policy transfer process, or an independent variable, where the policy transfer framework helps explain policy outcomes.

In its origins, the policy transfer literature was narrow and state-centered. A prominent example of early research in the field was an examination of how US welfare-to-work policy has been used in Britain since the early 1980s (Dolowitz & Marsh, 2000). However, the literature has expanded in scope and now analyzes the diffusion of policy innovations between different types of actors, including states and cities (Benson & Jordan, 2011). Sometimes called “urban policy mobility” (McCann, 2011), the framework has also been used to specifically analyze city-to-city policy movement. Policy transfer has also been previously used to study the diffusion of urban transportation policies among cities (Timms, 2011), including policies that seek to improve safety and accessibility (Marsden, Frick, May, & Deakin, 2011).

However, no previous research has used the policy transfer for an in-depth examination of the diffusion of traffic calming. This approach is well-suited to the analysis of the transfer of street designs for 20-mph zones between London and New York City. The policy transfer framework helps identify exactly what street design elements were transferred from London to New York, possible barriers to the complete transfer of traffic calming street designs between the cities, and reasons for disappointing traffic safety results of the policy in New York.

4 Research Questions, Methods and Data

The three empirical chapters in this dissertation (Chapters Two, Three and Four) use different methods to examine different aspects of the NSZ program. As this is a three article dissertation, the empirical chapters are also stand-alone articles, complete with introductions, literature reviews, background, methods, results, and discussion sections. Each empirical chapter uses the most appropriate method to answer the research question for that chapter. This section briefly outlines those research questions, as well as the chapters' methods and data. The fifth chapter of this dissertation presents conclusions that can be drawn from the research and outlines a research agenda for traffic calming in New York City and the NSZ program.

4.1 Chapter Two

The first empirical chapter investigates if the NSZ program improves environmental justice, both considering the zones' equitable distribution in minority and low-income neighborhoods, and inclusion of these populations in the planning process that led to the siting of the zones.

The research question guiding this chapter is: *Did the NSZ program further environmental justice?* As discussed above, "environmental justice" here refers to both equitable distribution and inclusive, participatory planning.

This chapter uses mixed (both qualitative and quantitative) research methods (Creswell & Clark, 2007). Two analyses, one on the distribution of the zones in terms of demographic characteristics and another on risk to traffic exposure in the areas of the zones, use quantitative methods. A third analysis, examining the participation of environmental justice populations in the planning process, uses qualitative methods.

Qualitative data come from interviews and official documents from the DOT, both in reports and from websites. The quantitative data in the study include demographic data from the 2010 U.S. Census's Summary File 1 (SF1) at the block group level. Data on income came from the 2006-2010 American Community Survey (ACS) at the census tract level. I used crash data for 2005-2010 that I had acquired from the New York City DOT via a FOIL (Freedom of Information Law) request. I extracted the data on demographics and traffic injuries using ArcGIS, and used statistical software (Stata 14) to analyze it. The borders of the NSZs came from a DOT website (New York City Department of Transportation, n.d.).

The chapter includes a chi-square analysis to determine if the NSZs are equitably distributed in minority and low-income areas of the city. The unit of analysis is census tracts (population ~4,000). The second analysis uses a multiple logistic regression to determine if the zones were implemented in places that could benefit from them when considering exposure to risk of traffic injuries. Variables for exposure to risk of traffic injury were population density, and counts of three types of casualties: motorized vehicle occupants, vulnerable users, and total casualties (motorized vehicle occupants and vulnerable users).

Finally, I analyzed the qualitative data to determine if the planning process was inclusive of poor and minority communities in New York. This analysis organized the qualitative data into themes using Creswell's "lean coding" approach (2013).

4.2 Chapter Three

This chapter seeks to determine the effects of the NSZs on road-traffic related deaths and injuries for three types of road users: motor vehicle occupants, vulnerable users (pedestrians and

cyclists), and total casualties (both motor vehicle occupants and vulnerable users). The research question for this chapter is: *Are the NSZs associated with reductions in traffic casualty rates?*

I use quantitative methods and a quasi-experimental research design (Shadish, Cook, & Campbell, 2002) to determine the zones' effects on traffic casualties. The analysis compares traffic casualties before and after implementation, both for the treatment group (the NSZs), and a comparison group (a group of zones with similar characteristics), employing a "difference-in-differences" research design. This approach can determine the impact of an intervention while effectively ruling out alternative explanations observed effects (Meyer, 1995). The chapter includes two types of "difference-in-differences" analyses to determine the impact of the zones: one uses t-tests to determine an "adjusted treatment effect" (Ewing, Chen, & Chen, 2013b, p. 34) and another employs OLS regression and an interaction coefficient as in Freeman (2012).

I chose the comparison zones to match the NSZs as closely as possible given time and resource constraints. A well-matched comparison group increases the likelihood that any observed effect is attributable to the intervention and not other factors, such as "regression to the mean" (Elvik, 2001; Hauer, 1991). I used several criteria in choosing the comparison zones: number of segments in the zones, road width, parking, pre-implementation traffic casualties. In an effort to reduce any differences in casualties due to driver behavior, enforcement of traffic laws, or casualty reporting, I used the same police precinct and community district for each treatment and comparison zone.

The "difference-in-differences" analyses use five financial years of data in the pre-implementation period, and two financial years of post-implementation data for treatment and comparison zones. The data in this paper came from several different sources. The New York City DOT provided the exact implementation dates of the NSZs, including the beginning and end

of the implementation period for each zone (28 zones, implemented between 2011 and 2016). The implementation period was the exact day that implementation began, and the day that it ended. For example, for the NSZ in Norwood, in the Bronx, implementation began on 09 April 2014 and finished on 23 June 2014.

I used a FOIL request to acquire crash data from the New York State DOT. This data originates from police reports. The NY State DOT collects this data from police precincts and departments around the state and consolidates it into a single database. The data includes all collisions involving vehicles that were reported to police and is georeferenced to a street address. It includes the type vehicle(s) involved in the collision of, and if the collision resulted in an injury, the type of street user injured (including motor vehicle occupants, pedestrians and cyclists). I requested the crash data from 2000 to 2016, as this data was available through 2016 at the time of the request (May 2017). Information on the street network, and community district and police precinct boundaries came from the Department of City Planning's open data portal (New York City Department of City Planning, n.d.).

4.3 Chapter Four

The third empirical chapter examines the policy transfer of street design from London to New York City. London's 20-mph zones were the inspiration for New York's NSZs, and while London's zones were associated with significant reductions in traffic casualties, those in New York did not impact traffic safety. The research question guiding this article is: *Did the policy transfer of street design of 20-mph zones from London impact safety outcomes in similar zones in New York?*

This chapter uses mixed methods to examine the policy transfer of street designs for 20-mph zones between London and New York. The analysis uses quantitative data on type and quantity of traffic calming devices implemented in zones in both cities, and qualitative data on the NSZ program and the street designs used in 20-mph zones in New York.

For New York, the data on traffic calming devices came from official planning documents, which was verified and supplemented by the DOT. Because this information was not readily available for London, I used ArcGIS and Google Streetview to collect this data from a sample of the 399 20-mph zones implemented from 1993-2008.

Due to time and resource constraints that did not allow me to collect data for a statistically representative sample of London's 20-mph zones, I used a stratified sample. Stratified samples approximate representative samples by selecting observations based on key variables in the population (Harding, 2006). The 34 sample zones came from 30 of London's 33 boroughs, were evenly distributed according to size, land use and reason for implementation (e.g., reduce through traffic or improve safety around a school) of the zone. The 20-mph zones in New York and the sample zones in London had a similar number of miles of street (149.3 and 147.9, respectively).

The qualitative data on the NSZ program and street designs used in the zones came from interviews, site visits and documents. These data provided information on the policy transfer of 20-mph zones, as well as barriers to implementation of robust traffic calming in New York City.

The data collected allowed me to determine how the policy transfer that occurred between London and New York impacted the effectiveness of the zones at improving traffic safety in the latter city. It also shed light on theories that explain the diffusion of traffic calming

and allowed for the elaboration of a more nuanced theoretical model of the impacts of traffic calming on traffic safety.

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Chapter Two

Traffic Calming and Environmental Justice: New York City's Neighborhood Slow Zones

Abstract: In this paper, I examine New York City's Neighborhood Slow Zones (NSZ) program in terms of environmental justice. The paper uses both quantitative and qualitative methods. Quantitative analyses show that the areas where the zones are implemented are well-represented in terms of environmental justice (low-income and minority) populations, and that risk exposure to traffic injury and traffic casualty counts are similar in NSZ and non-NSZ areas. The qualitative analysis shows that the program was structured in a way that included the participation of environmental justice communities and led to the siting of zones in such neighborhoods. These findings suggest that the NSZ program can address environmental justice's goals to distribute environmental risk more equitably and to including low-income and minority communities in planning processes.

1 Introduction

Environment-related health burdens are disproportionately borne by minority and low-income populations, a reality that the concept of environmental justice seeks to address (Robert Doyle Bullard, 2000). Further, because minority and low-income populations have been historically excluded from decisionmaking that led to the inequitable distribution of environmental hazards, another important aspect of environmental justice is the call to include these populations in participatory planning processes related to the distribution of such hazards (Schlosberg, 2003).

Much of the research on environmental justice is related to toxic land uses. Another environmental hazard that disproportionately affects environmental justice populations is road traffic injury (Cottrill & Thakuria, 2010). One tool that promises to reduce traffic casualties is area-wide traffic calming (Bunn et al., 2009). Under this measure, rather than implementing traffic calming devices on individual streets or intersections, they are implemented in entire areas. In this paper, I analyze an area-wide traffic calming program, New York City's Neighborhood Slow Zones (NSZ), in terms of environmental justice. I examine the zones' spatial distribution (whether they were equitably distributed), as well as the planning process by which they were sited (whether the process included the contributions of minority and low-income residents). The paper uses qualitative and quantitative methods to answer the following research question: *Does the NSZ program further environmental justice in New York City?*

The NSZs consist of 28 areas of approximately five square blocks where the speed limit is reduced to 20 miles per hour and traffic calming measures, physical alterations to the roadway, are introduced to slow auto speeds. The quantitative analysis examines the NSZs' distribution in terms of environmental justice populations, and the qualitative data describes the process that led to the siting of the zones. My analysis shows that the program furthers environmental justice in

New York City, both in terms of their distribution and the planning processes used to site the zones.

This paper proceeds as follows: after reviewing literature on environmental justice and traffic calming, I discuss the methods, and then the results of the analyses. I continue with a discussion of the findings and finally, present policy implications and conclusions.

2 Literature Review

2.1 Environmental Justice

When the environmental justice movement began in the 1980s, it focused on the siting of toxic land uses, such as hazardous waste disposal sites, in minority and low-income areas. Pressure from grassroots organizations led to the 1994 Presidential Executive Order 1298, which required Federal Agencies to “make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations” (1994, p. Section 1-101). Research on environmental justice has examined the siting of Locally Unwanted Land Uses (LULUs) in general in the US (Been, 1992) and specific uses, including solid waste disposal sites (Robert Doyle Bullard, 2000; Heiman, 1996), and nuclear waste facilities (Leonard III, 1996). Researchers have also documented minority populations’ disproportionate exposure to industrial hazards (Pais, Crowder, & Downey, 2014) and particulate air pollution (Jerrett et al., 2001).

In addition to focusing on the more equitable distribution of environmental risks, environmental justice activists and researchers have also emphasized community participation in planning processes (Hamilton, 1993; Lake, 1996; Schlosberg, 2003). Minority and low-income

populations have historically been excluded from mainstream environmental groups and planning processes that locate noxious land uses. Yet, environmental activists and researchers see authentic community participation as a way to help enfranchise such vulnerable populations and lead to more equitable outcomes where minority and low-income populations do not carry a disproportionate environmental burden.

2.2 Environmental Justice and Transportation

The United States Department of Transportation (USDOT) is among the agencies specifically cited in the 1994 Executive Order. The USDOT's directives on environmental justice instruct USDOT-funded agencies to incorporate the following guiding principles into transportation planning: 1) ensure full and fair public participation of minority and low-income populations in transportation decision-making processes, 2) avoid, minimize, or mitigate disproportionate adverse health and human effects on these populations, and 3) ensure that the benefits of transportation systems are delivered equitably and promptly to minority and low-income populations.

Transportation researchers interested in environmental justice have examined issues created by the standard urban transportation planning process, which has “generally ignored” (Deka, 2004, p. 352) the concerns of minority and low-income communities. These issues include disparities in funding for transportation infrastructure, resulting in restricted access to destinations such as jobs, education, health care services and grocery stores in poor, minority areas (Karner & Niemeier, 2013; Sanchez, Stolz, & Ma, 2003). Discrimination in transportation policy and infrastructure, also called “transportation racism” (Robert D. Bullard, Johnson, & Torres, 2004, p. 1), often resulted in the severing or demolition of low-income, minority neighborhoods to make way urban freeways, particularly from the 1950s to the 1970s (DiMento

& Ellis, 2013). Throughout the US, minority and low-income populations live in closer proximity to high volume roads as compared to White and middle- or upper-income populations (G. M. Rowangould, 2013). Researchers have also shown that environmental justice populations have higher exposure to air and noise from roadways (Forckenbrock & Schweitzer, 1999; Jacobson, Hengartner, & Louis, 2005). Efforts to improve the environmental justice of the transportation system have led to evaluations of proposed road construction projects (Chakraborty, 2006; Lane, Hoffeld, & Griffin, 1998).

Research has also examined environmental justice as related to traffic casualties in the US. Nationwide, motor vehicle injuries exact a disproportionate toll on racial and ethnic minorities (McKenzie, 2014) and on low-income neighborhoods (Cubbin, LeClere, & Smith, 2000; Cubbin & Smith, 2002). Further, minorities are overrepresented in pedestrian fatalities in the US (Deka, 2004). Specifically, the incidence of pedestrian-vehicle crashes is relatively elevated in environmental justice areas of the Chicago Metropolitan area (Cottrill & Thakuriah, 2010), and pedestrian fatality rates were significantly higher for African Americans and Latinos in Atlanta (Hanzlick et al., 1999).

2.3 Traffic calming

Standard traffic planning and engineering practices encourage the creation of high-speed roads for autos and increased traffic speeds on road networks, often to the detriment of vulnerable road users (pedestrians and cyclists) (Noland, 2013; Southworth, 2005). Traffic calming seeks to slow auto speeds and discourage fast-moving traffic by introducing physical barriers, such as speed humps, curb extensions, and traffic circles, in roadways. Area-wide traffic calming has been shown to reduce traffic casualties (Bunn et al., 2009; Cairns, Warren, Garthwaite, Greig, & Bamba, 2015) and emissions of local pollutants and greenhouse gases (Baldasano, Gonçalves,

Soret, & Jiménez-Guerrero, 2010; Hedström, 1999; Madireddy et al., 2011). Other motivations for implementing traffic calming include improving comfort for vulnerable road users, neighborhood quality of life (Elvik, Vaa, Erke, & Sorensen, 2009), and social inclusion (Sauter & Huettenmoser, 2008).

Although much research has been published on the effects of traffic calming, there have been relatively few studies on the equitable distribution and siting of traffic calmed streets and zones in terms of socioeconomic characteristics. In my research for this paper I found only two such studies, both from the UK. In those studies researchers also found a higher proportion of traffic-calmed road segments in lower-income areas of England and Wales (Rodgers, Jones, Macey, & Lyons, 2010), and a study of London's 20 mph-zones found that numbers of traffic casualties decreased most in poorer areas of the city (Steinbach, Cairns, Grundy, & Edwards, 2013). This paper represents the first attempt at evaluating the distribution of traffic calming through the lens of environmental justice, considering not only the demographic aspect of this distribution in terms low-income and minority areas, but also in terms of the inclusion of these populations in participatory planning processes.

3 Background

3.1 Environmental justice in New York City

New York City has witnessed several important environmental justice initiatives. The “fair share” criteria, adopted in 1990 by the City Planning Commission, ensure that undesirable land uses are borne equitably by every borough and every community in the city (New York City Department of City Planning, 1995). In addition, in two separate initiatives, community activists and researchers collaborated to document disproportionate exposure to air pollution and asthma

rates in minority, low-income areas due to heavy bus traffic in Upper Manhattan (Minkler, Blackwell, Thompson, & Tamir, 2003; Minkler, Vásquez, & Shepard, 2006) and truck traffic in Hunts Point, in the Bronx (Lena, Ochieng, Carter, Holguín-Veras, & Kinney, 2002).

While previous research has not looked at traffic casualties New York City specifically as an environmental justice issue, researchers have shown that minority and low-income areas are overrepresented in terms of crashes and casualties. The burden of traffic casualties is higher in areas with higher percentages of Black and Hispanic residents (Viola, Roe, & Shin, 2010). Further, poor areas of the city have a higher occurrence of pedestrian-vehicle collisions than in middle- or upper-income neighborhoods (Neckerman et al., 2009).

Researchers have also found that poor areas have a generally less favorable pedestrian environment, including higher crime rates, higher speed limits, and wider streets, and fewer pedestrian amenities (e.g., street trees, landmarked buildings, clean sidewalks) (Neckerman et al., 2009). Further, high-poverty, minority New Yorkers living in areas with fewer pedestrian amenities and higher homicide rates were less likely to engage in active transportation (walking and cycling) than wealthier, non-Hispanic white New Yorkers living in pedestrian-friendly areas (Lovasi et al., 2013). Finally, studies have shown that poor neighborhoods are subject to elevated levels of air pollution from road traffic, resulting in higher asthma hospitalization rates in low-income minority areas of New York City (Claudio, Tulton, Doucette, & Landrigan, 1999; Corburn, Osleeb, & Porter, 2006; Gwynn & Thurston, 2001).

Although environmental justice populations bear the burden of the externalities of motorized traffic, they are less likely to reap its benefits. Workers in minority and low-income areas of New York City were less likely to use a car and more likely to use public transportation

than workers in non-environmental justice areas (New York Metropolitan Transportation Council (NYMTC), 2013).

3.2 The origin of the Neighborhood Slow Zones program

Traffic policy in New York City has increasingly emphasized environmentally sustainable modes (walking, cycling and public transportation) and safety for pedestrians and cyclists in recent years. Since 2007, the New York City Department of Transportation (the DOT) increased efforts to create safer streets by expanding the cycle network and making pedestrian safety improvements such as Safe Routes to School and Safe Routes for Seniors. The *New York City Pedestrian Safety Study and Action Plan* (Viola et al., 2010) proposed a pilot program that would test the safety performance of neighborhood zones with 20 mph speed limits. This led to the creation of the NSZ program in 2011. The DOT implemented 28 zones from 2011 to 2016. Using data from the 2010 Census, about 540,000 New Yorkers (6.6% of the City's population) reside within the boundaries of the 28 zones.

4 Methods and Data

This paper uses mixed methods, a research approach that combines quantitative and qualitative methodologies (Creswell, 2009; Jupp, 2006). Two analyses, those of the spatial location of NSZs in terms of low-income and minority populations, and of the risk exposure and traffic casualties in those zones, use quantitative data and methods. A third analysis, which evaluates the NSZ program in terms of environmental justice & community participation in the planning of the zones, uses qualitative data on the Neighborhood Slow Zones program.

I employed spatial tools to extract data on demographics and crashes in New York City, and statistical software to analyze the data. Population data for race/ethnicity came from the 2010 U.S. Census's Summary File 1 (SF1) at the block group level, and for poverty, from the 2006-2010 American Community Survey (ACS) at the census tract level. The borders of the zones were included in a shapefile downloaded from a DOT website (New York City Department of Transportation, n.d.-b). Data on motor vehicle crashes for the years 2005-2010 came from the New York City DOT, acquired via the Freedom of Information Law (FOIL). This study used data through 2010 because the first NSZ was implemented in 2011.

I gathered qualitative data from interviews and DOT documents. The data includes interviews with two DOT officials and a staff member of a local transportation advocacy group (Transportation Alternatives). The two interviews were semi-structured and about 40 and 20 minutes long, respectively. The documents included the DOT's webpages on the NSZ program, as well as DOT presentations available on the Department's website. I used "lean coding" (Creswell, 2013, p. 143) to organize the content of the interviews, webpages and presentations into themes. In gathering and organizing the qualitative data, I also relied on previous, informal conversations I had with DOT officials and citizen activists regarding the program, which I had been following as a participant observer since February 2013.

4.1 Unit of Analysis and Variables

Following previous research on environmental justice (Cottrill & Thakuriah, 2010; New York Metropolitan Transportation Council (NYMTC), 2013; Sriraj, Fruin, & McNeil, 2003), I determined census tracts to be the most appropriate unit of analysis for my study. Larger than census blocks or census block groups, but smaller than zip codes or community districts, census tracts are spatially disaggregated enough to capture differences in socioeconomic characteristics

of areas of New York City. Census tracts in New York City have a mean population of 3,774 (standard deviation: 2,176), while the mean population of NSZs was 19,189 residents living within the borders of the zones (standard deviation: 11,916).

To determine which census tracts were environmental justice or community of concern tracts, I used thresholds for minority and low-income populations, and New York City as the reference area to determine these thresholds. Regarding the threshold for minority census tracts, 66.7% of New Yorkers were minorities in 2010 (decennial census), including Black, Latino, Asian, Native Americans, and Pacific Islanders. The threshold for low-income tracts used the citywide mean of households living in poverty, which was 18.8% in 2010 (Mayor's Office of Operations, 2016). Using New York City (as opposed to the US, New York State, or the New York City region) as a reference area for thresholds ensures that the analysis is relevant to the area of study.

Following the definitions of these MPOs and Federal guidelines, this paper considers tracts that are above *either* threshold "environmental justice" tracts. Tracts that are above *both* minority and poverty thresholds are considered "communities of concern" (Klancher & Ritacco, 2016; New York Metropolitan Transportation Council (NYMTC), 2013). Although threshold method to determine communities of concern has drawbacks as compared to a participatory, self-identification method, it can nonetheless be useful to reach a spatial understanding of the needs and vulnerabilities of a community and to examine a large area (D. Rowangould, Karner, & London, 2016).

Descriptive statistics for the variables used in this study are included in Table 1. The unit of analysis for this dataset is census tracts in New York City (N=2,166). The variable "NSZ," a binary variable, indicates that about 7% (std. dev. .25%) of the City's tract's borders intersect or are contained by an NSZ. The variable "Minority" shows the mean percentage of minority residents in the tract (66.7%,

std. dev. 30.1%), and “Low-Income” shows the mean percentage of people living below the poverty line, also by census tract (15%, std. dev. 13.3%). The “Community of Concern” was a binary variable that indicated that about 26 % (std. dev. .44%) tracts were above *both* minority and low-income city-wide means. Finally, “Environmental Justice” was a binary variable and showed that about 60% (std. dev. .49%) of the city’s tracts were above *either* minority and low-income city-wide means.

Table 1 Descriptive Statistics

Variable	Mean	Standard Deviation
NSZ	.067	.250
Minority	66.7%	30.92%
Low-income	15.04%	13.34%
Community of Concern	.264	.441
Environmental Justice	.600	.491

4.2 Statistical Analyses

This paper includes two statistical analyses. The first analysis compares the proportion of environmental justice populations in the NSZ tracts to the same levels for the entire city, and uses chi-squared to test for significance. The second analysis is a multiple logistic regression that examined the likelihood of NSZ tracts having environmental justice populations, of risk exposure to traffic injury, and of traffic casualties occurring in the NSZ tracts relative to non-NSZ tracts. I was interested in risk exposure and traffic injuries in the NSZ tracts in order to assess if the zones were implemented in areas that needed them in terms of traffic safety; if these

areas were already safe, implementing zones in them would have little consequence for reducing traffic injuries. Both analyses use alpha levels of .05 to determine statistical significance.

This study used population density as a proxy for exposure to risk of traffic injuries and fatalities. Ideally, measures of risk exposure would include volumes of all types of traffic users, including motorized traffic, pedestrians, and cyclists. In practice, researchers often use only motorized traffic volumes, as municipalities rarely, if ever, collect comprehensive data on pedestrian or cyclist volumes (Gemzøe, 2001). Since data on motorized traffic is not uniformly available for streets in New York City, the regression used population density as a proxy for exposure to the risk of road traffic injury, as density is positively correlated with pedestrian injuries (LaScala, Gerber, & Gruenewald, 2000; Loukaitou-Sideris, Liggett, & Sung, 2007; Morency, Gauvin, Plante, Fournier, & Morency, 2012; Wier, Weintraub, Humphreys, Seto, & Bhatia, 2009), which disproportionately affect minority and low-income populations.

The multiple logistic regression used the following formula:

$$\ln \frac{\Pr(NSZ)}{(1 - \Pr(NSZ))} = a + b_{Minority} + b_{Low-income} + b_{CoC} + b_{Density} + b_{Vulnerable\ User} + b_{MVO}$$

Where:

The dependent variable is the natural logarithm of the odds of the dependent variable being a case, i.e., the probability (Pr) of a tract being an NSZ tract or not. *NSZ* is a binary dependent variable (0,1), where 1 signifies that a census tract was one of the 145 tracts contained within, or intersecting the borders of the 28 NSZs, and 0 was a non-NSZ tract,

a is the intercept,

b are the estimated regression coefficients,

Minority indicates the percentage of minority residents in the tract,

Low-income indicates the percentage families living below the poverty line in the tract,

CoC is a binary variable (0,1) that indicates whether a tract is a “community of concern,” i.e., above thresholds in New York City for minority (66.7%) and low-income (18.8% of families living in poverty),

Density is population density per square mile, a proxy for exposure to pedestrian traffic injury, as discussed above,

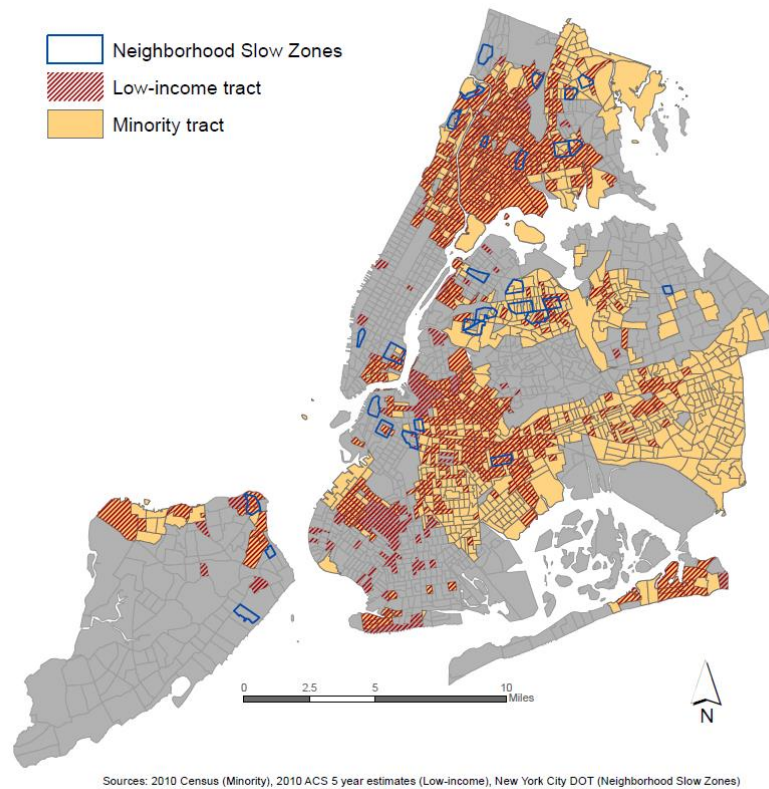
Vulnerable User indicates the total number of pedestrian and cyclist casualties for each census tract for the years 2005-2010, and

MVO indicates the total number of Motor Vehicle Occupant casualties for each census tract for the years 2005-2010.

5 Results

As previously stated, the study used New York City as the reference area to determine which census tracts of the city were minority and low-income areas. Figure shows zones that were at or above the threshold for minority residents (66.7%), families living below the poverty line (18.8%), and the NSZs.

Figure 1 Map of Environmental Justice Census Tracts and Neighborhood Slow Zones



New York City contains 2,166 census tracts. A total of 145 tracts are contained within or intersect the borders of the 28 NSZs. City-wide, 66.7% of the population is minority, and 18.8% is low-income (**Error! Reference source not found.**). Of all tracts in New York City, 26.5% were communities of concern (minority *and* low income) and 59.6 % were environmental justice (minority *or* low-income). The corresponding proportions in NSZ tracts were 71.8%, 16.7%, 34.5%, and 64.1%, respectively. While the proportions of minority, communities of concern, and environmental justice populations were slightly higher in NSZ tracts, the low-income population was slightly lower in NSZ tracts than for all of New York City. Chi-squared tests revealed that these differences were statistically significant at the 95% confidence level only for communities

of concern. Overall, this analysis shows that environmental justice tracts are represented at similar proportions in the NSZ areas as compared to all of New York City.

Table 2 Environmental Justice Tracts in New York City and Neighborhood Slow Zones

	New York City Tracts (n=2166)		NSZ Tracts (n=145)		Difference	Chi-Squared	p-value
	Total	Percentage	Total	Percentage			
Minority	1187	66.7%	90	71.8%	5.1%	1.60	0.20
Low-income	681	18.8%	47	16.7%	-2.1%	0.39	0.53
Community of Concern	573	26.5%	50	34.5%	8%	4.41	0.04*
Environmental Justice	1290	59.6%	93	64.1%	4.5%	1.15	0.28

*Significant at the 95 % confidence level

The results of the logistic regression, which explores the relationship between NSZ tracts, environmental justice populations, exposure to risk of traffic injury, and counts of traffic casualties, are displayed in **Error! Reference source not found.** (below). The table includes the odds ratio (derived from the estimated regression coefficients), the 95% confidence interval, and the *p*-values of the independent variables.

Table 3 Multiple Logistic Regression of NSZ and Non-NSZ Tracts

Independent Variable	Odds Ratio	95 % CI	p-value
Percent Minority	1	.99, 1.01	.47
Percent Low-income	1	.98, 1.02	.75
Community of Concern	1.64	.90, 3	.10
Density	.99	.98, .99	.00*
Vulnerable User Casualty	.99	.98, 1	.01*
Motor Vehicle Occupant (MVO) Casualty	1	1, 1	.13

n = 2,166

*Significant at the 95% confidence interval

The results showed two variables to be statistically significant at the 95 % confidence level: Density, and Vulnerable User Casualty. However, the odds ratios for these variables were very close to 1 (.99), suggesting that risk exposure and cyclist and pedestrian injuries in NSZ tracts are similar to those of the rest of New York City.

The variable with the largest odds ratio (1.64) is Community of Concern. However, the result for Community of Concern in this model cannot be differentiated from what might occur by chance at the 95 % confidence interval.

Minority, Low-income, and MVO Casualty had neither particularly large or small odds ratios, nor significant *p*-values. These results imply that the likelihood that NSZ tracts are above the minority and low-income thresholds for NYC are the same as for non-NSZ tracts. The same is true for motor vehicle occupant casualties.

5.1 NSZ program: planning and implementation

What follows are the results of the qualitative research on the NSZ program. The results of the qualitative data are divided into the following categories: 1) applications and review, 2) presentation to the community, and 3) implementation and results.

5.1.1 Application and Review

The DOT created a webpage to enable individuals and organizations to request a zone by submitting an application form. Guidelines on the DOT website instructed applicants to choose an area roughly a quarter-mile in area, or five square blocks, that was primarily residential, avoided wider, heavier volume streets or industrial and major commercial sites, and had strong

boundaries, including major streets, parks, and elevated rail lines (New York City Department of Transportation, n.d.-a). Applicants were instructed to include an inventory of institutions located inside the boundaries of the zones, such as schools or senior centers. The DOT also requested that applicants demonstrate support for the zones by providing letters of support from community organizations such as local civic groups, churches, and Community Boards (a form of local government in New York City), as well as from elected representatives and local police precincts. Successful applications were typically submitted by and included letters of support from a combination of these actors. After the initial pilot NSZ was implemented in 2011, the DOT accepted applications for NSZs for two periods. There were over 100 applications for the first round of zones (13 zones, selected 2011-2012). The DOT received 74 applications for the second round, (14 zones selected 2014-2015) (New York City Department of Transportation, n.d.-a). For the second round of zones, the DOT reached out to community groups, such as the Brownsville Partnership in Brooklyn (from the predominantly African-American neighborhood of Brownsville), to make them aware that the DOT was accepting applications for the zones (personal communication, DOT officials, 03 October 2016).

The DOT reviewed the applications, ranking the proposed zones in terms of need and feasibility for implementation. The two most important factors in ranking the proposed traffic-calmed areas were support for the zones and the numbers of collisions in the zones. While support for the zones was prioritized for the first round of NSZs with traffic casualty counts weighted second, for the second round of zones, this was reversed, with casualty counts taking first priority and support given second priority. The DOT also considered the presence of facilities such as daycare, schools, senior centers, parks, and proximity to subway stations. After selecting the potential zones for implementation, the DOT adjusted the borders of the zones

proposed by the community groups as needed in order to create an area with strong boundaries that could effectively slow traffic.

5.1.2 Presentation to the Community

DOT personnel then presented these proposed zones at Community Board meetings, which are open to the public. These presentations outlined the safety benefits of traffic calming and 20 mph/30 kmph zones, citing the resulting reductions in traffic injuries. They also emphasized the potential gains in neighborhood quality of life of the 20 mph zones, including reductions in traffic noise and through traffic and “more social streets.” The presentations gave data on traffic injuries in the zones and evidence of local support for the zones (e.g., applications from community groups and Community Boards, elected representatives, letters of support, and petitions). They then showed the boundaries of the proposed zones and concluded with additional arguments for the implementation of the zones. These arguments emphasized the presence of schools or senior centers and speeding motorists inside the boundaries of the zones.

5.1.3 Implementation and results

The selected zones that did not encounter considerable opposition at Community Board meetings were implemented. Of 30 selected zones, two were not implemented because of community opposition: Midland Beach, Staten Island and Crown Heights, Brooklyn. A third zone, Clinton Hill, Brooklyn, was originally planned to encompass the neighboring neighborhood of Bedford-Stuyvesant, but was made smaller because of opposition in the latter area.

DOT officials stated that the feedback regarding the zones from communities has been generally very positive, that “people like the zones.” In general, there was “less pushback” from

the public toward NSZs than other types of facilities the agency typically implements. The DOT officials also mentioned that several elected representatives, including members of the New York State Assembly and City Council, sought zones for their district and generated positive press from the implementation of the zones. A staff member of an advocacy group for sustainable transportation modes, Transportation Alternatives, praised the program, saying it was at the “intersection of citizen participation and evidence-based policy” (personal communication, Julia Kite, 20 September 2016). She said that her organization was also concerned with the equity and worked to ensure that such safety improvements were distributed fairly throughout the city, not just in those communities that “shout the loudest.” Her organization saw NSZs as a cost-effective and “citizen-driven” way to quickly create safer streets.

6 Discussion

The results of the above analyses of the NSZs are encouraging with regard to environmental justice, both in terms of location and community participation. The first analysis shows that Neighborhood Slow Zones are distributed in environmental justice areas in similar proportions as compared to all of New York City. While the proportion of environmental justice populations was at least the same in NSZ areas as for the entire city, the chi-squared analysis showed that proportions of communities of concern are significantly higher for NSZ tracts than city-wide. The results of the multiple logistic regression were consistent with this result, with communities of concern having the odds ratio with the greatest magnitude, although this result was not statistically significant at the 95 % confidence interval. Overall, it is fair to say that the DOT was successful in distributing the zones equitably in minority and low-income areas of the city.

The regression also found that the zones are adequately implemented in New York City when considering risk exposure and counts of traffic casualties. Risk exposure to traffic injury and counts of vulnerable user casualties were almost the same (only very slightly lower) in NSZ tracts and non-NSZ tracts. For Motor Vehicle Occupant casualties, the probability was the same for NSZ tracts. This shows that the DOT located the NSZs in areas of the city that had similar traffic safety needs as compared to the city as a whole.

In addition to the location of the zones, I was also interested in exploring whether the program furthered environmental justice in terms of incorporating minority and low-income communities in participatory planning processes. The qualitative data gathered for the paper showed that the 28 NSZs were created in a participatory, community-driven, “bottom-up” manner. Further, beyond the participatory nature of the program, the DOT structured the program in ways that made it more likely to reach environmental justice populations. When soliciting NSZ proposals, the DOT reached out to community groups, particularly in low-income and minority areas, such as the predominantly African-American neighborhood of Brownsville in Brooklyn. Next, the DOT gave priority to areas with high counts of traffic casualties, which are more likely to be minority, low-income areas. This was particularly true in the second round of NSZs, which prioritized traffic casualties over levels of support when selecting potential zones for implementation. This finding shows that the NSZ program furthered the environmental justice goal of incorporating minority and low-income communities into the planning process. The equitable siting of the zones reflects the redistributive nature of the planning process the DOT employed.

The location of the zones in environmental justice areas suggests that traffic calming is well received in many environmental justice communities. This is interesting, considering that

reportedly, minority, and particularly African-American, community groups have opposed initiatives that support cycling infrastructure, such as bike lanes and bike share systems, in cities including Portland, Austin, Washington D.C., and New York City (Alcorn, 2016; Goodyear, 2011; P. Stein, 2015; S. Stein, 2011; Walljasper, 2013). This opposition is said to be related to tensions surrounding gentrification, and research has shown an association between bike lanes and gentrification in San Francisco, Chicago, and Portland (Flanagan, Lachapelle, & El-Geneidy, 2016; Stehlin, 2015). Thus, compared to bike lanes, area-wide traffic calming may be better received in environmental justice communities.

7 Policy Implications and Conclusion

The outcomes of this study suggest that the NSZ program has been successful in furthering environmental justice, both in terms of the location of the zones and in the participatory process that led to their siting. The healthy representation of minority and low-income areas in the NSZs suggests that traffic calming is well-received in such neighborhoods. Further, the large number of applications for zones, which outnumbered the implemented zones by about 6 to 1 (174 applications to 28 implemented zones), suggests that the demand for safer streets and sustainable transportation outstrips supply in New York City.

As such, the NSZ program appears to have important potential to further environmental justice by introducing traffic calming in additional low-income, minority areas of the city. The DOT could build on the program's success by using similar outreach methods and selection criteria to bring the zones to additional environmental justice areas of the city.

However, the participatory approach used by the program may have limits in terms of reaching the most dangerous places for traffic injuries. Of course, the NSZ program is not the

only traffic safety program of the DOT. Particularly since adopting a “Vision Zero” policy (the goal of no deaths or serious injuries from road traffic) in 2014, the DOT has increasingly focused on “hot spots” - places where high amounts of injuries occur. As such, the NSZ program’s citizen-driven approach may be a good complement to ongoing data-driven traffic safety initiatives adopted under Vision Zero.

The NSZ program has excellent potential to address directly all three objectives of the USDOT’s environmental justice directives, that is to: 1) ensure full and fair public participation of minority and low-income populations in transportation decision-making processes, 2) mitigate disproportionate adverse health and human effects on these populations, and 3) deliver the benefits of transportation systems equitably to minority and low-income populations. As such the USDOT could provide support for the implementation of similar programs in municipalities throughout the country.

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Chapter Three

Not slow enough? Traffic Casualty Reductions in New York City's 20-mph zones

Abstract: This paper examines whether New York City's Neighborhood Slow Zones (NSZs) are associated with reductions in traffic casualty rates. It uses data on traffic casualties from 2006 to 2016 and employs a quasi-experimental, before/after research design with a comparison group. With two years of data in the post-implementation period, this allows for analysis of 18 of the 28 zones implemented through 2016. This analysis examines three types of traffic casualties: pedestrians and cyclists, motor vehicle occupants, and total casualties. The paper first conducts a "simple" analysis (without controls), and then two controlled analyses that employ a difference-in-differences approach. The first uses t-tests to derive an "adjusted treatment effect" and the second uses multivariate regression with an interaction coefficient. While the simple analysis finds statistically significant reductions, the two analyses that include control zones show reduced effects, none of which are significant. The controlled studies do not find the NSZs to be associated with significant reductions in traffic casualty rates. Although none of the decreases in the controlled analysis were significant, pedestrians and cyclists experienced the smallest reductions in casualty rates, suggesting that the zones may be particularly ineffective for vulnerable users.

1 Introduction

Each year over 1.25 million people die in road traffic around the world, and tens of millions are injured or disabled (World Health Organization, 2015). In the US, there were over 35,000 road traffic deaths and 2.4 million injuries in 2015 (National Highway Traffic Safety Administration, 2017), and in New York City, the corresponding figures for 2014 were 239 and 38,428 (New York State Department of Motor Vehicles, 2015). Motor vehicle collisions are the leading cause of injury-related death in New York State, with annual hospitalization and emergency room charges of about \$1.1 billion (New York State Department of Health, 2017). Beyond seeking to reduce traffic casualties (deaths and injuries) for public health and economic reasons, governments have taken an active interest in slowing traffic to increase the safety of, and thereby increase the use of, the environmentally sustainable, “zero-emissions” travel modes of walking and cycling (Banister, 2011; Banister, Pucher, Lee-Gosselin, & Lee, 2007).

Traffic calming seeks to create safer and more livable street environments by slowing motorized traffic through the placement of physical barriers in the roadway (Lockwood, 1997). When traffic calming is introduced to an entire area, as opposed to an individual street, street segment or intersection, it is called “area-wide traffic calming.” Area-wide traffic calming has been found effective at reducing traffic casualties and creating more comfortable conditions for pedestrians and cyclists, particularly in Europe and the UK (Elvik, Vaa, Erke, & Sorensen, 2009). New York City’s Neighborhood Slow Zones (NSZ) program is one of the few area-wide traffic calming initiatives in the US and the first systematic area-wide traffic calming program in a major US city. The 28 NSZs were implemented between 2011 and 2016, and approximately 540,000 people (about 7% of the city’s population) live within the borders of the zones.

In this paper, I analyze the NSZs in terms of their associations with traffic casualties (deaths and injuries). Although two previous analyses have examined the traffic safety impact of the NSZs (Jiao, Kim, Hagen, & Muennig, 2017; New York City Department of Transportation, 2015), my study is an improvement of these studies. In contrast to these analyses, my examination of the zones accounts for changes in a well-matched control group and identifies the effects of the zones on different kinds of street users (vulnerable users, motor vehicle occupants, and total casualties). I am particularly interested in the zones' effects on vulnerable street users, given traffic calming's potential to improve their safety and comfort. My research question is: *Are the Neighborhood Slow Zones associated with reductions in vulnerable user, motorized vehicle occupant, and total traffic casualty rates?*

After reviewing literature on the effects of area-wide traffic calming, I provide background on the NSZ program. I then present the research methods and data. The paper uses a quasi-experimental research design that examines injuries before and after implementation both in the zones and in comparison zones. After presenting the results of the analysis, I provide a brief discussion and conclusion, with future research needs for NSZs.

2 Literature Review

This review briefly summarizes theoretical and empirical literature on travel speed and traffic safety, motivations for improving sustainable transport modes, the effects of area-wide traffic calming, and the two previous analyses that examine the effectiveness of the NSZs at reducing traffic injuries (Jiao et al., 2017; New York City Department of Transportation, 2015).

Since the emergence of the automobile-based transportation system in the US since the 1920s, increased travel speeds have created unprecedented levels of mobility. However, fast travel also has negative consequences, including the millions of traffic casualties mentioned above. Nonetheless, mainstream roadway design in the United States generally prioritizes the speed and volume of automobile traffic flows over traffic safety, and pedestrian safety and comfort (Ben-Joseph, 1995; Black, 1990; Dumbaugh & Li, 2010; Noland, 2013).

Beyond improving public health, promoting safety for people on foot and bicycle can also help cities reach environmental goals (Banister, 2008). Walking and cycling are environmentally sustainable modes, and increasing their use versus motorized transport leads to fewer emissions of local air pollutants and greenhouse gases (Ribeiro et al., 2007). Improved conditions for walking and cycling, in turn, can strengthen the use of another environmentally sustainable mode, public transportation, as people often combine these modes, for example, by cycling to a bus stop (Kager, Bertolini, & Te Brömmelstroet, 2016). There is also evidence that better conditions for pedestrians in general (Freeman et al., 2013; Neckerman et al., 2009), and traffic calming in particular (Morrison, 2004) lead to increased tripmaking by walking and cycling. For these reasons, this analysis seeks to understand the effect on the NSZs on safety of the vulnerable users as well as on people inside motorized vehicles.

Auto speed is a primary determinant of traffic injury severity and frequency (Global Road Safety Partnership, World Health Organization, FIA Foundation for the Automobile and Society, & World Bank, 2008; Haddon Jr, 1970, 1980). Empirical studies describe the relationship between a car's speed at the moment it collides with a pedestrian and the severity of the pedestrian's injury (Anderson et al., 1997; Rosén & Sander, 2009). These studies generally show

an exponential increase in injury severity as auto speeds increase. For example, Anderson et al. show an 8 % likelihood of fatal injury for a pedestrian struck by an automobile travelling at 30 km/h (19 mph), a 58 % chance of fatality at 45 km/h (28 mph) and an 85% chance of fatality at 50 km/h (31 mph). The authors also showed that braking distance increases proportionally with the square of speed; this makes it easier to avoid collisions (and thereby injuries) at lower speeds.

Traffic calming slows traffic by introducing physical devices in the roadway, forcing vehicles to move at slower speeds. These devices include speed humps, curb extensions, median islands, chicanes, and traffic circles. While other safety measures separate motorized traffic from vulnerable street users, e.g., sidewalks for pedestrians, and bikeways for cyclists, traffic calming aims to slow motorized vehicles to speeds that ensure the safety of pedestrians and cyclists in the roadway. Area-wide traffic calming introduces these devices in entire areas, and has proven effective at reducing casualties (Bunn et al., 2009; Cairns, Warren, Garthwaite, Greig, & Bambra, 2015; Elvik, 2001). This measure can also reduce emissions of local pollutants and greenhouse gases (Baldasano et al., 2010; Hedström, 1999; Madireddy et al., 2011) and improve social inclusion (Sauter & Huettenmoser, 2008).

Researchers have found varying effects of area-wide traffic calming on traffic casualties. A meta-analysis found an average reduction of injury accidents after introduction of the schemes of about 25% on residential streets, and about 10% on main roads (Elvik, 2001). A review with more stringent inclusion criteria found more heterogeneous results, and concluded that area-wide traffic calming “appears to be promising” (Bunn et al., 2009, p. 11) for reducing traffic injuries and deaths. An umbrella review (an analysis of systematic reviews) found traffic calming to be “an effective means of improving public health via reduced accidents and injuries” (Cairns et al.,

2015). In the brief review of individual studies that I carried out for this study, the upper range of reductions I encountered was a 61% decrease in road casualties for London's Slow (20-mph) Zones (Webster & Layfield, 2003), followed by a 41% reduction for the same zones (Grundy et al., 2009). Researchers found a 25% reduction in injuries for traffic-calmed areas in Holland (Vis, Dijkstra, & Slop, 1992). Finally, although this measure did not examine area-wide traffic calming but rather speed humps on individual street segments, researchers did not detect any traffic safety improvements for speed humps in New York City (Ewing, Chen, & Chen, 2013).

There are currently two studies that examine the NSZ's effects on traffic safety. The first came from the New York City Department of Transportation (DOT), which clearly stated that the analysis was preliminary (New York City Department of Transportation, 2015). Using data from four zones with one-year of data in the post-implementation period, this preliminary analysis found a 14% reduction in injury crashes and a 31% decrease in vehicle injuries. However, this was a "simple" analysis; it did not contain a control group or account for background trends in traffic injuries in other ways, nor did it provide tests for statistical significance.

The second study analyzed the cost-effectiveness of NSZs (Jiao et al., 2017). This study found statistically significant injury reductions of 8.74% in the zones, as compared to an increase in injuries in control zones of 0.31%. That study included these results in a model that found the NSZs to be a cost-effective intervention. However, this study can be improved in several key ways. First, the authors do not specify the characteristics of the streets that they used for controls. This is fundamental, as the NSZs are mostly found on narrower, lower-volume streets. The number of injuries on such streets is generally lower than on wider, arterial streets with higher

traffic volumes. This is true in New York City, where the majority of pedestrian fatalities occur on arterial roads (Tri-State Transportation Campaign, 2015). Further, we do not know if the control zones in this study are well-matched in terms of pre-implementation injuries, which is another important criterion for an adequate control group (Elvik, 2002) - the 'methods' section below discusses this in greater detail. Next, there is no indication that Jiao et al.'s statistical test of the effect of NSZs on traffic safety explicitly included the comparison group. Finally, the study did not specify the effects of the zones on different kinds of road users. If, for example, the NSZs were very effective at reducing casualties for people inside motor vehicles, but not those walking or cycling, this would be a major concern.

3 Background of NSZ program

Since 2007, New York City's Department of Transportation (DOT) has intensified its efforts to improve traffic safety. These efforts have focused largely vulnerable street users and have sought to increase use of these environmentally sustainable modes. These efforts have included the pedestrianization of perhaps the most iconic public space in the city (Times Square), and safety improvements for people walking under the Safe Routes to School and Safe Routes for Seniors programs. The DOT has redoubled efforts to improve traffic safety since the adoption of Vision Zero, a policy that seeks to eliminate traffic deaths, in 2014. Under this policy, the DOT has pursued improvements for pedestrians at key corridors with high numbers of injuries, such as Queens Boulevard in Queens, Fulton Street in Brooklyn, and Grand Concourse in the Bronx, to name just a few priority projects (New York City Department of Transportation, 2017). Further, the DOT has continued to promote cycling by building out a network of cycle lanes and, since 2013, implementing and expanding the operational area of a bikesharing system (Citibike).

The NSZs were first proposed in the *New York City Pedestrian Safety Study & Action Plan* (Viola, Roe, & Shin, 2010). They were inspired by London's aforementioned 20-mph zones (Health Resources in Action, 2013), which showed healthy reductions in traffic casualties. A first pilot slow zone was implemented in Claremont, in the Bronx, in 2011, followed by the planning and implementation of the other 27 zones through 2016.

The DOT combined participatory planning methods with the traffic safety needs of communities to select the potential traffic calming zones for implementation. The DOT identified potential zones for implementation by soliciting them from the public. People could apply for the zones by filling out a form that was available on the DOT website. In these applications, neighborhood-based organizations proposed boundaries of zones and provided letters of support for the zones from other community groups, including churches and schools, as well as from police precincts and elected officials. The DOT used the number of casualties in the proposed zones to determine the areas that would benefit most; higher casualty counts meant that an area would stand to benefit the most from a zone and was therefore given preference for implementation. The DOT used these two factors (levels of support and numbers of casualties) to determine which zones to implement (personal communication, DOT officials, 03 October 2016).

The NSZs cover areas of about five square blocks. The measures they use to slow traffic are "gateways," vertical signs that advise motorists that they are entering zones with a speed limit of 20 mph, regularly-spaced pavement markings that indicate the speed limit, and regularly spaced speed humps. The zones are distributed across the city's five boroughs, with eight in the Bronx, five in Brooklyn, four in Manhattan, eight in Queens, and three on Staten Island.

The NSZ program proved quite popular, as evidenced by the high number of applications: the DOT received a total of 174 proposals for 20-mph zones. Further, DOT officials and a representative of a local transportation advocacy organization reported that the zones were well-received in the neighborhoods they were implemented in (personal communication, DOT officials, 03 October 2016, and Julia Kite, Transportation Alternatives, 20 September 2016).

4 Methods and Data

This section outlines the quasi-experimental approach used in this study and provides a description of the data. Quasi-experimental research in social sciences can help determine the effectiveness of interventions in the real world by inferring what might have happened in the absence of the intervention, the “so-called “counterfactual inference” (Shadish, Cook, & Campbell, 2002, p. xvii). Similar to laboratory experiments, quasi-experimental research can use a treatment-and-control approach. This analysis uses streets within implemented NSZs as the treatment group, and streets segments in areas with similar characteristics, but not in the slow zones, as the control group, or, as Hauer defines them, “comparison group (nonequivalent control group)” (1991, p. 609).

For the treatment group, I downloaded a shapefile with the borders of the NSZs from a DOT website (New York City Department of Transportation, n.d.). I wanted to ensure that my analysis only included injuries in the NSZs, and not on streets that border the zones. For this reason, I used Google Streetview to adjust these borders so they accurately reflected the file of New York City’s street network (Lionfile 16c), which I downloaded from the City’s open data website (New York City Department of City Planning, n.d.). I then used ArcGIS to further modify the file to included only injuries in the NSZs.

For the quasi-experimental research design used here, the study needed a well-matched comparison group; choosing this group comprised a major task of this research. As mentioned previously, the NSZs did not contain wider, heavier-volume arterial streets, and were bordered by such streets or parks. The challenge, therefore, was to choose comparison zones that had similar characteristics. I sought areas that were similar in size to the NSZs with a similar amount of street segments, had similar width streets (narrower, non-arterial), with similar types of boundaries (arterial streets or parks).

For each NSZ, I set out to choose one comparison zone from the same police precinct and community district. Using the same precinct should ensure that law enforcement practices (e.g., ticketing for speeding) are similarly applied in treatment and comparison areas. Further, DOT officials alerted me to the possibility of systematic errors in casualty data from specific police precincts (personal communication, DOT officials, 17 March 2017). Specifically, data for 2015 may considerably underreport pedestrian and cyclist injuries from some precincts. Using the same precinct for NSZ and comparison zones decreased the possibility that any such errors would impact the results of this analysis. For additional information on this possible data anomaly, please see Appendix A to this paper.

Community districts were originally created to represent coherent geographic, demographic and political entities (Freeman & Braconi, 2004). As such, using the same community district helps ensure that the NSZs and comparison zones are from similar types of areas according to these criteria, reducing the possibility that endogenous factors would influence the models' outcomes.

Another key criterion for the comparison group was a similar amount of injuries in the pre-implementation period. Having similar pre-implementation injuries is an implicit way of

controlling for “regression-to-the-mean” (Elvik, 2001; Ewing et al., 2013). Traffic safety researchers seek to control for the regression-to-the-mean effect because traffic safety features are often implemented in places that experienced a large number of crashes before implementation. However, because measures to reduce collisions and casualties are more likely to be associated with a significant reduction in traffic casualties when they are implemented in places that had previously experienced relatively high casualties, researchers often suspect that regression-to-the-mean may play a role in these reductions (Elvik, 2002; Ezra Hauer, 1997). This suggests that the reduction may have more to do with the randomness of the location of traffic crashes than the efficacy of the measure. In addition to similar pre-implementation casualty rates in the NSZs and comparison zones, the healthy length of the pre-implementation period (5 years) in the study provides additional control for regression-to-the-mean.

I acquired data on injuries from the New York State Department of Transportation via a Freedom of Information Law (FOIL) request. This dataset is derived from police reports, and includes all motor vehicle collisions, whether they resulted in an injury or not. The collisions are geocoded to street addresses and include information on the number of people injured in the collision (if any), as well as the type of street user injured (pedestrian, cyclist, or motor vehicle occupant). The latest data available from this dataset at the time I requested (May 2017) it was 2016.

The DOT provided the implementation dates of all 28 NSZs. This included the day that implementation began and was concluded. I used these dates to determine the financial years before and after implementation, excluding the entire implementation period. For example, if an NSZ’s implementation period began on 09 April 2014 and ended on 23 June 2014, I included all injuries from 08 April 2014 to 09 April 2009 (5 financial years) in the “before” period, and all

injuries from 24 June 2014 to 23 June 2016 (2 financial years) in the “after” period. Because I wanted at least two years of data in the “after” period for each NSZ in this analysis, I was able to include 18 zones implemented by the end of 2014.

4.1 Statistical analyses

My analyses compare mean annual casualty rates of segments in the post and pre-implementation periods for the NSZs and the comparison zones. The first two analyses are illustrative in nature. The first is a “simple” analysis that only examines casualty rates in the NSZs before and after implementation, without controls. Next, I graph casualties in the NSZs and comparison zones. The final two analyses examine the difference between the changes in both types of zones (NSZ and comparison zones).

The final two analyses use a difference-in-differences approach. The natural experiment created by the implementation of the NSZs in some areas of the city, but not in other similar areas, afforded the opportunity to use this identification strategy. Often used for policy analysis, this approach uses the differences between the two groups before and after a policy goes into effect to estimate the causal effect of that policy. Difference-in-differences analyses can detect plausible effects of a treatment, while effectively ruling out most alternative explanations for the estimates obtained (Meyer, 1995).

The difference-in-differences approach has been used to examine the effects of minimum wage increases on employment (Card & Krueger, 1993), anti-discrimination laws on housing voucher utilization (Freeman, 2012), traffic calming on traffic injuries (Ewing et al., 2013), and bikesharing on bus ridership (Campbell & Brakewood, 2017). A major potential threat to validity of difference-in-differences approach is a poorly matched control group (Lee, 2016). My analysis

attempts to overcome this threat to validity by selecting a carefully matched comparison group, as described above.

4.2 Adjusted Treatment Effect

The first difference-in-difference analysis used t-tests to see if the differences in the mean casualty rates were statistically significant. T-tests are appropriate to determine the differences of means of populations when the sample populations are normally distributed or when the sample sizes are “sufficiently large” (Kanji, 2006, p. 33). Although the data did not meet the first condition (it was not normally distributed), the sample size was large enough (N=1,214 for NSZs, N=1,261 for comparison zones) to justify the use of t-tests.

In order to include the comparison zones in a measure of the safety impact of the NSZs, I adapted the methodology used by Ewing et al. to derive the “adjusted treatment effect” (Ewing, Chen, & Chen, 2013, p. 34) of the NSZs for the three categories of casualties: vulnerable users, motor vehicle occupants, and total (vulnerable users + motor vehicle occupants). This method subtracted the change in annual casualty rates in the comparison zones from the corresponding rates in the NSZs:

$$\text{adjusted treatment effect} = (\text{casualties}_{aNSZ} - \text{casualties}_{bNSZ}) - (\text{casualties}_{aCNSZ} - \text{casualties}_{bCNSZ})$$

Where:

casualties = mean annual casualty rates for segments,

a = the “after” implementation period,

b = the “before” implementation period,

NSZ = street segments within the NSZs, and

CNSZ = street segments in the comparison zones.

After getting the adjusted treatment effect, I conducted a power analysis (Cohen, 1988) to determine the statistical power of the difference-in-differences test described above.

4.3 Regression with Interaction Coefficient

The difference-in-differences regression was based on the method used by Freeman (2012). That article uses ordinary least squares regression to examine the impact of a policy (anti-discrimination laws) on rates (housing voucher utilization) in treatment and comparison areas. The present analysis uses the same approach to estimate the effect of NSZs on annual casualty rates.

Selecting a carefully matched comparison group limits the possibility of confounding factors that could emerge if the comparison group had vastly different street characteristics and pre-implementation casualty rates. The well-matched comparison group helps obtain variation in the casualty rates that are plausibly exogenous, i.e., that can be attributed to the implementation of the 20-mph zone. The analysis uses street segments in the NSZs and comparison zones as observations. The dependent variable in the analysis was the mean annual casualty rates for the treatment and control segments in the period before and after the intervention (five and two years, respectively).

The regression used the following structure to estimate the effects of the NSZs on casualties:

$$\text{CASUALTY RATE}_i = a_0 + b_1\text{NSZ}_i + b_2\text{PERIOD}_i + b_3(\text{NSZ}_i * \text{PERIOD}_i)$$

where

CASUALTY RATE_i = annual casualty rates for each street segment in the before and after period, for each casualty category: vulnerable users, motor vehicle occupants and total

a_0 = an intercept

NSZ_i = a dummy variable indicating whether the segment is in an NSZ or comparison zone

PERIOD_i = a dummy variable indicating if the period is before or after implementation for the NSZ or for the corresponding period in the comparison zone

and

b_1 NSZ_i * b_2 PERIOD_i= an interaction term between the two above variables

The “NSZ” variable will show the difference in casualties between the treatment and comparison group, both before and after the implementation period. “Period” will show differences in rates of casualties before and after implementation for both treatment and comparison segments.

The interaction term captures the difference in the differences between treatment and comparison segments, before and after the treatment period. A statistically significant and substantively meaningful interaction term would provide evidence that the NSZs are contributing to improving traffic safety in the places they are implemented. If this controlled analysis shows that casualty rates decrease significantly in the zones, this reduction would provide compelling evidence that the area-wide traffic calming program is working in terms of traffic safety.

Descriptive statistics for the variables used in the regression are included in Table . The unit of analysis for this dataset is street segments in NSZs and comparison zones, and it includes two

observations for each segment, with one in the “before” period, and one in the “after” period (N=4,950).

The variables “Vulnerable User Casualties,” “Motor Vehicle Occupant Casualties,” and “Total Casualties” are annual casualty rates for each street segment. The means are .12 (standard deviation .36), .21 (standard deviation .58), and .33 (standard deviation .45), respectively.

“NSZ” is a binary variable and indicates that about half the segments are in the NSZs (.49, standard deviation .5). Exactly half of the “Period” binary variable are in the “before” or “after” phase (standard deviation .5). Finally, for the “Interaction” binary variable indicated that about 25% (standard deviation .43) of observations were both in the NSZs and in the “after” period.

Table 1 Descriptive Statistics

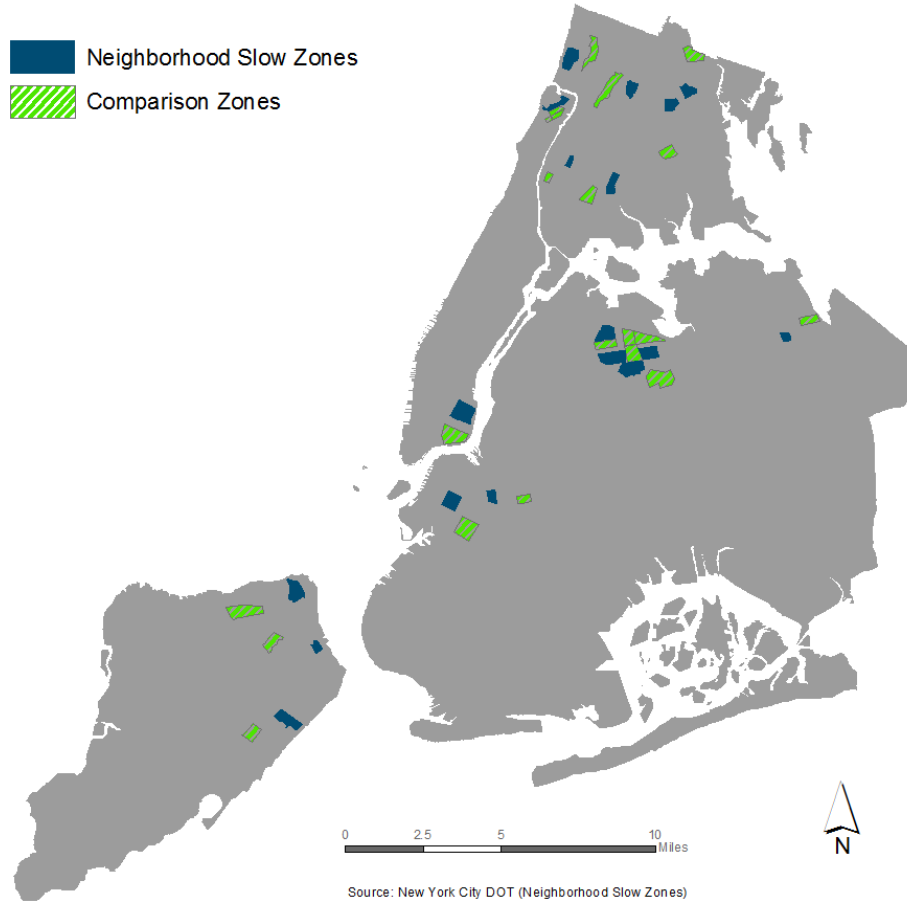
Variable	Mean	Standard Deviation
Vulnerable User Casualties	.120	.356
Motor Vehicle Occupant Casualties	.210	.582
Total Casualties	.328	.450
NSZ	.491	.500
Period	.5	.5
Interaction	.245	.430

5 Results

5.1 NSZs & Comparison Zones

Below is a map of the NSZs and comparison zones. The map shows that both types of zones are similar in size and in relative proximity. This is because I sought to choose comparison zones of similar size and within the same police precinct and community district as the NSZs.

Figure 1 Neighborhood Slow Zones and Comparison Zones



The table below compares key characteristics of the treatment and comparison zones. The numbers of street segments in both types of zones is similar, with just 4% more segments in the comparison zones. The mean street width (curb-to-curb measurement, including parking lanes) of all segments was slightly (3%) higher in the comparison group, and this difference was statistically significant at the 95% confidence interval. Traffic lanes and parking lanes (the number of these types of lanes per street segment) was also slightly (2%) higher in the comparison group, but these differences were not statistically significant.

Table 2 NSZs and Comparison Zones

	<i>NSZ</i>	<i>CNSZ</i>	<i>Difference</i>		
Street Segments	1,214	1,261	-47 (-4%)		
<i>Per-segment Mean</i>					
				<i>t</i>	<i>p</i>
Street Width	32.3	33.2	-.810 (-3%)	-2.23	.001*
Traffic Lanes	1.30	1.32	-.027 (-2%)	-1.29	.099
Parking Lanes	1.75	1.79	-.035 (-2%)	-1.54	.061
<i>Per-segment Mean Pre-Implementation Casualties</i>					
				<i>t</i>	<i>p</i>
Vulnerable User	.127	.102	.025(25%)	2.10	.025*
MVO	.209	.243	-.034(-14%)	1.56	.118
Total	.336	.345	-.009(-3%)	.310	.757

*p<.05

Regarding traffic casualties before implementation, there was a statistically significant difference between the NSZs and comparison zones for vulnerable users, with a 25% higher rate in the NSZs. For motor vehicle occupants, this rate was 14% lower in the NSZs, and for total injuries, the per-segment, pre-implementation mean was just 3% lower in the NSZs. Neither of the latter differences were statistically significant.

5.2 Simple analysis

Below are the results of injuries in the 18 NSZs before and after implementation. This analysis shows the difference in per-segment average annual casualties. The test shows that vulnerable user injury rates actually increased by about 6% after NSZ implementation, although this result was not statistically significant. Motor vehicle occupant injuries decreased by around 20% in the zones. This decrease drove an overall reduction of about 10% in the zones. The two latter results were statistically significant at the 95 % confidence level.

Table 3 Average Annual Casualty Rates in NSZs Before and After Implementation

Casualty type	Before	After	Difference	Percent Change	<i>t</i>	<i>p</i>
Vulnerable user	.127	.135	.008	6.3 %	-.90	.184
Motor vehicle occupant	.209	.167	-.041	-19.6%	2.54	.006*
Total	.336	.301	-.034	-10.1%	1.82	.035*

N=1,214

*Significant at the 95% confidence level

While this result appears encouraging, this is a simple one-group analysis, and does not include controls. The true effect of the NSZs on traffic safety will only be revealed by including the comparison group. The traffic casualty reductions in the “simple” analysis will only be verified if the results of the controlled analysis are also statistically significant.

5.3 Graphs of casualties

To get an idea of the trends in the data for both groups, I created the graphs below, which simply display the numbers of vulnerable users, motor vehicle occupant and total casualties. The graphs

display counts of casualties in the years before (5 to 1 year before) and after (1 and 2 years after) implementation.

Figure 2 Vulnerable User, Motor Vehicle Occupant, And Total Casualties in NSZs And Comparison Zones 5 Years Before And 2 Years After Implementation

Figure 2.a. Vulnerable user casualties

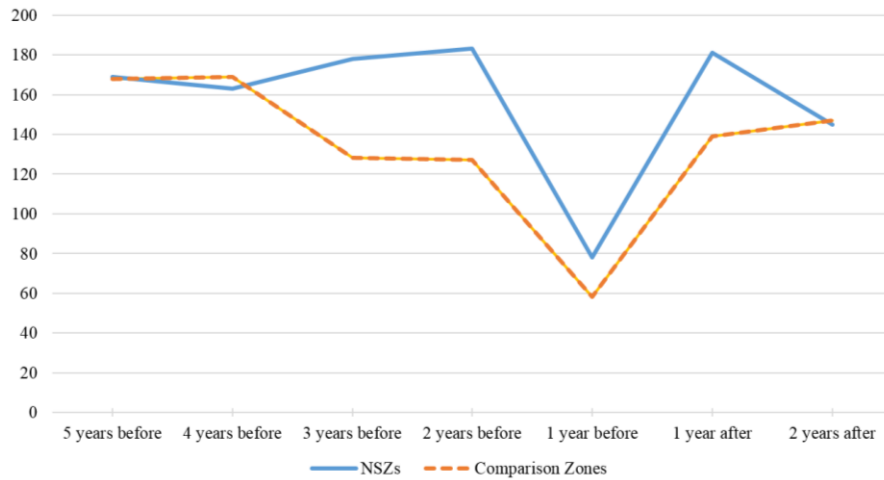


Figure 2.b. Motor vehicle occupant casualties

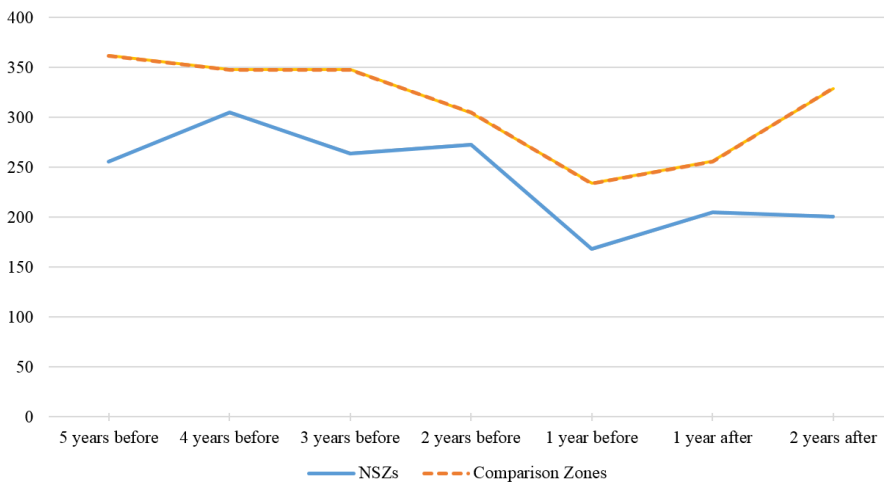
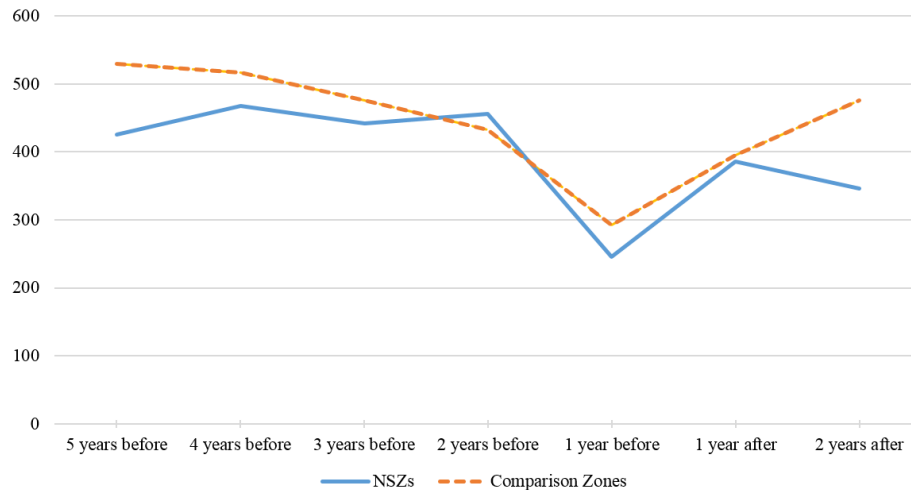


Figure 2.c. Total casualties



While these graphs do not include tests for statistical significance of differences between the treatment and comparison groups, they give an idea of the trend of traffic casualties in both types of zones. For vulnerable street users, we can see that although the pre-implementation casualties are somewhat higher, there is not a dramatic difference in the number of casualties in the two-year “after” period. For motor vehicle occupant injuries, this is reversed, with visibly higher numbers of “before” period casualties in the comparison areas, but the outcome in the “after” period is similar, with both groups experiencing slight reductions. For total casualties, the pre-implementation numbers appear to be rather close. The number of total casualties in the “after” period appears to be higher for the comparison group, but again, the difference is not dramatic. Overall, these graphs appear to tell us that traffic casualty counts in the “after” period reduced by a greater magnitude in the NSZs than in comparison zones. However, the reductions in both types of zones do not appear to be dramatically different. The next analysis includes tests to see if these differences are statistically significant.

5.4 Difference-in-differences Analyses

5.4.1 Adjusted Treatment Effect

This analysis combines the traffic casualties in the before and after periods of the NSZs and comparison zones. The observations are segments in the NSZs and comparison zones. I used t-tests to determine if the differences between the changes in injuries in both types of zones was statistically significant. The table below contains the results, with the change in traffic casualties expressed as the Adjusted Treatment Effect.

Table 4 Difference-in-Differences: Change in Mean Annual Casualty Rates After Implementation

	Adjusted Treatment Effect	<i>SE</i>	<i>t</i>	<i>p</i>	95 % <i>C.I.</i>
Vulnerable users	-.005	.013	.360	.719	-.021, .031
Motor Vehicle Occupant	-.016	.025	.649	.516	-.033, .067
Total	-.020	.029	.700	.484	-.037, .077

N for NSZ = 1,214

N for CNSZ = 1,261

I used the mean differences of casualty rates of the before and after period, standard deviations and sample sizes of NSZs and comparison zones to conduct a power analysis. The power analysis determined the statistical power of the difference in means test from which the adjusted treatment effect was derived. The resulting measure of effect size, also known as Cohen's D, is considered "small" at 0.2, "medium" at 0.5, and "large" at 0.8 (Cohen, 1988, p. 24). The present analysis resulted in a Cohen's D of 0.07 for vulnerable users, and 0.1 for motor vehicle

occupants and total traffic casualties. These results suggest that the difference between the before and after period of the NSZs and comparison zones was not sufficiently large nor consistent to be important.

5.4.2 Regression analysis

The regression results for all three dependent variables (annual casualty rates for vulnerable users, motor vehicle occupants, and total) are shown in **Error! Reference source not found.** The three independent variables are “NSZ,” which indicated whether the observation (street segment) was located in a treatment zone (NSZ) or comparison zone. “Period” indicates if the rate is in the before or after timeframe. The variable “Interaction” captures the difference in the differences for the treatment and the comparison group, before and after the intervention timeframe.

Table 5 Difference-in-Differences Regression of Effect of Neighborhood Slow Zones on Annual Traffic Casualty Rates

Casualty type	Variable	Coefficient	SE	p	95 % Conf. Interval
Vulnerable Users	NSZ	.025	.014	.08	-.003 / .053
	Period	.013	.014	.37	-.015 / .041
	Interaction	-.005	.020	.81	-.044 / .035
R ² = .0012					
Motor Vehicle Occupants	NSZ	-.035	.023	.14	-.080 / .011
	Period	-.025	.023	.28	-.070 / .020
	Interaction	-.016	.033	.62	-.081 / .045
R ² = .002					
Total	NSZ	-.001	.030	.76	-.069 / .050
	Period	-.014	.030	.65	-.073 / .046
	Interaction	-.020	.043	.64	-.110 / .064
R ² = .0005					
N = 2,475					

For vulnerable users, the treatment variable (NSZ) is positive (.025), but not significant at the 95 % confidence level ($p = .08$). This is consistent with the graphs of casualty counts, where the numbers of vulnerable user casualties appeared to be higher in the NSZs than in the comparison zones. The variable that indicated the period (before and after treatment) was also positive, but not significant. The interaction coefficient, which captures the difference in the differences, was of small magnitude (-.005) and not significant. Versus the pre-implementation casualty rates of vulnerable users in the NSZs, the interaction coefficient represents a reduction (percent change) of about 4%.

With rates of motor vehicle occupant casualties as a dependent variable, the treatment variable is negative (-.35), but not significant at the 95 % confidence level ($p = .14$). This is consistent with the graphs of casualty counts, where the numbers of motor vehicle occupant casualties were higher in the comparison zones than in the NSZs. The period variable was negative (-.025), but not significant. The interaction coefficient was of reasonable magnitude (-.016) but not significant. This represents a reduction of about 8% vis-a-vis pre-implementation casualties for motor vehicle occupant casualties.

The results for total user casualty rates were as follows: for the variable NSZ (treatment and comparison zones), the coefficient was of small magnitude (-.001) and not significant. This shows that the groups were quite well matched in terms of total injuries. The variable for before and after the treatment time (Period) was negative and of reasonable magnitude (-.014), but not statistically significant. Finally, the interaction coefficient for total users was negative and also of reasonable magnitude (-.02), but not significant. Using this result, pre-implementation rates of total casualties in the NSZs decreased by about 6%.

None of the r-squared results were robust, suggesting that the variation in casualty rates are not well explained by the variation in the variables in the model. This suggests that there may be omitted variables, or on the other hand, any changes in casualty rates in the before and after periods could be the result of random fluctuation.

Regression diagnostics did not detect issues related to heteroscedasticity nor multicollinearity. A Breusch-Pagan / Cook-Weisberg test resulted in a relatively small chi-square (0.64), suggesting heteroskedasticity was probably not an issue (Meuleman, Loosveldt, & Emonds, 2014). The results of a test of variance inflation factors for the independent variables were well under 10, a common rule of thumb to check for multicollinearity (mean VIF 2.31).

6 Discussion and Conclusion

This section discusses the suitability of the comparison group, the outcomes of the first two (illustrative) analyses, and the controlled analyses. Finally, it presents areas for future research.

Although they are far from perfect, the comparison zones were suitable for this analysis. The most glaring shortcoming was the elevated number of vulnerable user casualties in the pre-implementation period. However, the other differences – number of segments, street width, number of traffic lanes and parking lanes, and pre-implementation motor vehicle occupant and total casualties – were of smaller magnitude. Of these variables, only difference in street width was statistically significant.

Of course, the NSZs represent much more coherent zones for area-wide traffic calming than the comparison zones. The NSZs were the product of many months of planning by the

DOT, involving careful inventories of destinations in the zones, site visits, and negotiations with local community stakeholders. The comparison group was my best effort as an individual researcher with time and resource constraints to select areas similar to the NSZs. As such, the comparison zones should not be considered a perfect control group, but rather, a real-world approximation of the treatment group.¹

The “simple” test showed a small and insignificant increase in vulnerable user casualties, and a statistically significant decrease in motor vehicle occupant and total casualties. However, this uncontrolled pretest-posttest design was, as Hauer says, “naïve” (1997, p. 73). Because it lacked a comparison group, this test did not control for possible confounding factors and likely overstated the effects of the intervention. Such simple analyses “should never be trusted” (Elvik, 2002, p. 635); the real effect of the NSZs on traffic casualties is more likely to be found by the analyses that included controls.

The graphs of user casualties provided initial evidence that the simple analysis might be overstating the effects of the NSZs on traffic safety. They showed that despite some differences, the casualties in the comparison zones followed those in the NSZs, at least to some degree. This established that statistical tests that included the comparison group were necessary to see if the casualty reductions seen in the simple analysis would hold or not.

The difference-in-differences analyses showed that none of the traffic safety gains in the zones were statistically significant. While the simple analysis showed an increase in vulnerable user casualties, these also went up in the comparison zones, leaving a small reduction overall for people walking and cycling. Similarly, despite the relatively large and statistically significant

¹ I attempted, but was unable to, identify neighborhoods that had applied for NSZs but did not receive them, in order to use them as comparison zones. Further, I am unaware if these areas were included in my own comparison zones.

decrease in casualty rates for people inside motor vehicles, this effect disappeared after the introduction of the comparison group. The same was true for total casualties; the gains shown by the simple analysis were wiped out by the introduction of controls.

The tables that showed the trend for casualties in the NSZs and comparison zones (Tables 2.a., 2.b. and 2.c.) showed a curiously sharp dip in injuries one year before implementation. For example, while the NSZs had 456 total casualties two years before implementation, the NSZs had only 246 casualties one year before implementation. Injuries for other road user types experienced similar declines in the “one year before” period, and the comparison zones mirrored this trend. The decline is so dramatic as to suggest that a data anomaly in the “one year before” period.² As such, I eliminated this period and reproduced the trend graphs and the “difference-in-differences” analyses. The new graphs and results are presented in Appendix B. While the new graphs appeared much more credible than the original ones, the results of these analyses, were strikingly similar to the original ones. All coefficients were of very similar magnitude, and the p-values were essentially unchanged. This leads me to conclude that despite possible data anomalies for the “one year before” period, the findings of the original analyses are valid.

The results from the difference-in-differences analyses using t-tests and the regression were the same for the adjusted treatment effect and interaction variables, respectively. The similarity in outcomes between these analyses suggest both are appropriate for evaluating traffic safety treatments with a comparison group. The regression revealed more information, i.e., it showed the differences in casualty rates in the treatment (NSZ) and comparison area, as well as

² This possible data anomaly is likely different than the issue with 2015, as the latter issue would only have affected one NSZ, and I determined that it did not significantly impact my analysis (see Appendix A).

between the before and after periods, in addition to the difference-in-differences. Put together, both tests were valuable in that they provided a check for the robustness of the difference-in-differences results. Future analyses with more years of data could use different analyses, such as negative binomials, which are useful for count data (i.e., numbers of injuries) that are overdispersed.

Although the difference in pre-implementation vulnerable user casualties was relatively large (25%), this could also be interpreted to strengthen the finding of no effect of NSZs on this category of street user. Because annual vulnerable user casualties were higher in the NSZs, theoretically, it could be easier to achieve a reduction in the NSZs as opposed to in the comparison group. Higher casualties in the treatment group could also lead to “regression to the mean” which could also lead to overstated reductions of the treatment’s effect. However, despite higher pre-implementation casualties for vulnerable users in the NSZs, this analysis found no measurable reduction for this group. This was true in both the simple analysis, and the analysis that included the comparison group.

The “simple” analysis (without the comparison group) and the difference-in-differences analyses suggested the NSZ improved the safety of people inside motor vehicles more than those walking or on bicycles; although safety improvements for motor vehicle occupants were not statistically significant after the introductions of controls, this group experienced larger reductions in traffic casualty rates than vulnerable users (8% versus 4%, respectively). As mentioned above, the higher numbers of pre-implementation period vulnerable user casualties in the treatment group could be interpreted to strengthen this effect. Despite a lack of statistical significance for reductions for either type of user in the controlled analysis, this could point to a trend whereby motorists benefit more from the intervention than vulnerable users. If this proved

to be the case, it would be of concern to policymakers, as the NSZs were created with the goal of improving pedestrian safety.

My analysis reached different conclusions than the previously published study on the traffic safety effects of the NSZs (Jiao et al., 2017). That paper used different crash data, time periods, and methods, but showed a similar effect of the NSZs on traffic casualties in the zones; that paper showed an 8.7% reduction in total casualties in the zones (without controls), versus a corresponding reduction in my simple analysis of 10.1%. However, I differentiated between types of traffic casualties; this allowed me to identify potential variation of the safety effects of the zones between people inside motorized vehicles and those on foot or bicycles. Next, my comparison zones may be a better match in terms of street segment characteristics and pre-implementation injuries. Finally, and most importantly, I included the comparison group in my statistical analysis of the NSZs, and this showed that the casualty reductions were not statistically significant.

The results of my study are consistent with those found on traffic calming on individual street segments (Ewing et al., 2013). This is not surprising, considering that the main intervention in the NSZs, speed humps, was the same intervention used to increase street safety in that study. However, my results stand out compared to research on the effects of area-wide traffic calming mentioned in the literature review. Additional research is needed to understand why area-wide traffic calming in New York did not lead to significant reductions in traffic casualties, as did the many other schemes examined in individual studies and meta-analyses.

Future analyses of the safety effects of the NSZs will benefit from additional years in the “after” period, which will allow the inclusion of all 28 zones (ten of these zones were excluded in this analysis because there were not sufficient years of data available). However, the results of

my analysis, albeit preliminary, are disappointing. Particularly worrisome is that my study found very small reductions (around 4%, and not statistically significant) for people walking and cycling. This is unusual given the potential of area-wide traffic calming to improve conditions for vulnerable users. For example, for 20-mph zones in London, a 2009 study of found showed statistically significant pedestrian casualty reductions of 32%, with a 42% reduction overall (Grundy et al., 2009), and a more recent study found reductions of 24% and 21%, respectively (Li & Graham, 2016).

Further, while my investigation used pre-implementation casualties and street geometry as the main criteria for the comparison group, subsequent evaluations could also consider other variables when searching for comparison zones. These include other built-environment and travel mode characteristics, such as land use and building types, public transportation stops, and traffic volumes. My study supposes that the “difference in differences” analysis can account for this type of difference in the treatment and control group, but subsequent analyses could include these types of variables explicitly, for example, in a multivariate regression.

Additional research is needed discover why New York’s 20-mph zones are not witnessing similar benefits as those seen in other places, and in particular, why they are not benefitting vulnerable street users. The increases in vulnerable user casualties in the NSZs and control areas suggest that tripmaking by foot or cycle may be increasing. It is also possible that people injured using these modes in recent years may more frequently report their injuries.

Future studies could investigate possible reasons for area-wide traffic calming’s success in reducing traffic casualties in some cities (e.g., London) versus the lack of reductions in New York City’s NSZ’s. One aspect to be considered is street design: future research could compare the type and density of traffic calming devices implemented in 20-mph zones in a city where the

zones led casualty reductions and compare this to street design used in the NSZs. This may shed light on the disappointing effects of area-wide traffic calming on traffic safety in New York City.

6.1 Study limitations

The largest limitation of this study is the small number of years in the post-implementation period. While two years of post-implementation data is sufficient, a period of five years would be ideal. Next, the inclusion of denser zones with more pedestrian traffic, e.g., West Village and Hamilton Heights (there was not enough “after” data available at the time of this draft), could show greater improvements for vulnerable users. On the other hand, additional years of data may not show greater decreases in casualties, as casualty reductions in 20-mph may diminish over time (Grundy et al., 2009; Li & Graham, 2016). Additionally, this study found reductions of casualties in the NSZs (10.1%) is similar to those (8.7%) found by the previously published study (Jiao et al., 2017), which used more recent data and included 27 of the 28 NSZs.³ Further, the study on traffic calming on individual street segments (Ewing et al., 2013) included five years of post-implementation data, and still found no effect on traffic safety. Taken together, these facts suggest the effect of the NSZs may remain stable, or even diminish, in studies with additional years of data.

Another important caveat is related to the comparison zones. As mentioned above, these were far from a perfect match for the NSZs. However, consider the hundreds of hours that went into determining the NSZs, by both the community groups that proposed them, and the highly competent DOT officials that revised them. Considering that the zones were likely placed in

³ Because that paper used data whose earliest year is 2009 and is not geocoded to street addresses, I used a different dataset for my analysis.

possibly the best-suited areas in terms of a range of variables including need (in terms of traffic casualties), local support, trip destinations, and boundaries, it would be extremely difficult to find perfectly matched zones.

The outcomes of this study may also be influenced by selection bias, under which systematic differences in the control group could cause an observed effect (Shadish et al., 2002). Self-selection could play a large role in the configuration of the NSZs, as local communities largely determined their placement. For this study, selection bias means there could be something about the NSZs that would make them different from the comparison zones, which could lead to different outcomes in terms of traffic casualties. While the carefully matched comparison group attempted to minimize selection bias, this threat to internal validity is particularly difficult to eradicate, given the genesis of the zones.

This study did not examine the effects of zones on traffic injuries in nearby areas. In theory, if motorists avoided the NSZs and chose nearby streets for travel, casualties might increase in these areas. However, some empirical studies on area-wide traffic calming have found that this was not the case. For example, researchers in London found no evidence of casualty migration in streets adjacent to London's 20-mph zones (Grundy et al., 2009), and the previously published study on NSZs (Jiao et al., 2017) found no difference in casualties in neighborhoods adjacent to NSZs and control zones.

An additional limitation of this study is the potential of the confounding effect of anomalies in the dataset. While I feel confident that I have effectively diagnosed potential issues with data, future analyses will benefit from additional data that will (hopefully) not have the same data issues I encountered.

Finally, there are exogenous circumstances that could have impacted the traffic safety effects of the NSZs. Chief among these is the DOT's adoption of Vision Zero, the goal of zero deaths from the road transportation system, which was adopted in 2014. However, interventions under this policy are focused on "priority" corridors and intersections. These are high-fatality locations located on higher-volume, arterials streets, such as Queens Boulevard or Grand Concourse (City of New York, 2018a). Neither the NSZs nor the comparison zones were located on such streets. Other important aspects of Vision Zero are outreach and enforcement. These are either concentrated in priority locations, or implemented in a way that would have city-wide impacts, e.g., a media campaign or truck driver education (City of New York, 2018b). Another exogenous change was the City's 2014 city-wide speed limit change from 30 to 20 mph. However, this change should have an even impact on all streets in the city. In conclusion, it seems plausible that these exogenous factors would have minimal, if any, impact on this study, as 1) it did not include the type of streets most impacted under Vision Zero, and 2) other Vision Zero initiatives and the speed limit change should have city-wide impacts.

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Appendix A Note on Possible 2015 Data Anomaly

When requesting crash data via FOIL, the New York City DOT made me aware of a data issue: possible underreporting of vulnerable user injuries for ten select police precincts for 2015 (personal communication, DOT officials, 17 March 2017). The DOT officials advised me to conduct my own investigation to see how this issue could impact my analysis. They suggested I identify the precincts with the largest drops in vulnerable user injuries.

Following this advice, I compared vulnerable user injuries for 2014 and 2015 to see which precincts were impacted. First, I found an overall decline in vulnerable user injuries of 9.7% from 2014 to 2015. Then I examined the ten police precincts that experienced the largest drops in magnitude and percentage change. After identifying these police precincts, I mapped them to see if the borders of these precincts overlapped with the borders of the 18 NSZs in my analysis.

Of the 18 NSZs in my analysis, none were impacted by the 2015 data issue when looking at differences in vulnerable user injuries by *magnitude*. When looking at differences by *percentage change*, about ¼ of the Boerum Hill NSZ may have been impacted, as about ¼ of the area of this NSZ was located in a precinct that experienced large drops in vulnerable user injuries when measured by percentage change. Specifically, about 6 months in the “after” period of Boerum Hill was located in one of the possibly impacted police precincts.

I looked closely at the time period that may have had data impacted by the data issue. Specifically, in the year after implementation for the Boerum Hill NSZ (19 June 2013 – 18 June 2014), there were 15 vulnerable user injuries. In the second year after implementation, which included about 6 months of 2015 (19 June 2014 – 18 June 2015), there were 14 vulnerable user injuries. This small difference in vulnerable user injuries suggests that the 2015 data issue did not significantly impact the overall analysis.

Further, the control NSZ for Boerum Hill was in the same impacted police precinct as the impacted portion of Boerum Hill, which should reduce the likelihood of an impact from missing data. Finally, any impact from missing 2015 vulnerable user data would have favored showing an overall reduction in vulnerable user injuries. Since my analysis did not detect any such reduction, it is unlikely that this data issue significantly impacted my analysis.

Appendix B Casualty Trends and Analyses Without “One Year Before”

Trend graphs for all user types showed dramatic reductions in traffic casualties in the “one year before” period, both for NSZs and comparison zones. This suggests that a data anomaly may be at play. To diagnose how this could have impacted the other analyses, I removed the “one year before” period and reproduced the graphs and models. In their study of London’s 20-mph Zones, Grundy et al. (2009) also removed individual years of data to check for model robustness.

Below are the graphs of trend of casualties without the data from the “one year before” period. The dramatic decrease and subsequent increase in casualties is replaced by a smoother trend line. This is a more intuitively logical trend and suggests there may be an issue with the original data.

Figure 1 Vulnerable User, Motor Vehicle Occupant, And Total Casualties in NSZs And Comparison Zones 5 Years Before And 2 Years After Implementation

Figure 1.a. Vulnerable user casualties

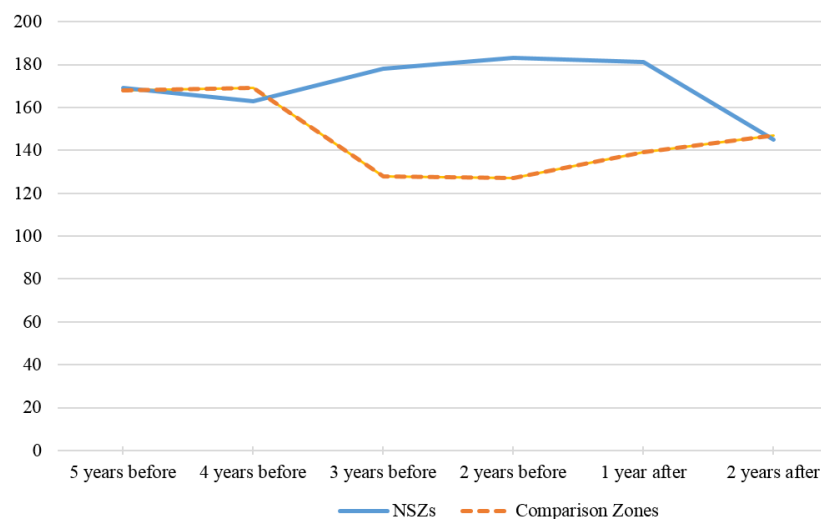


Figure 1.b. Motor vehicle occupant casualties

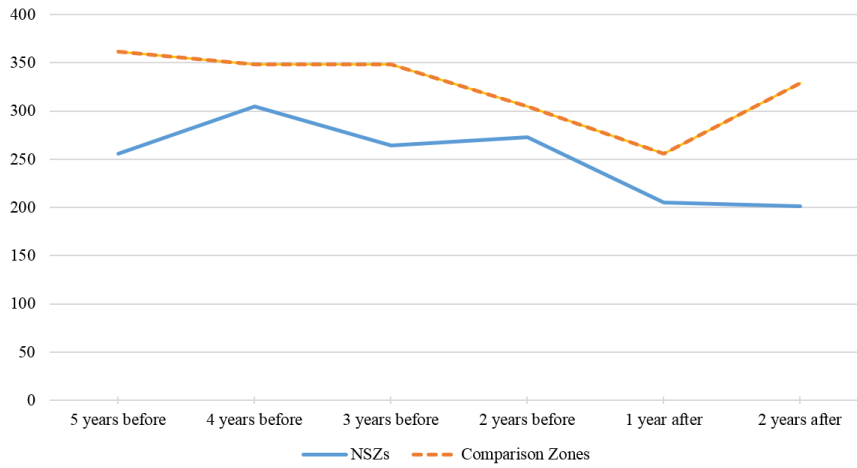
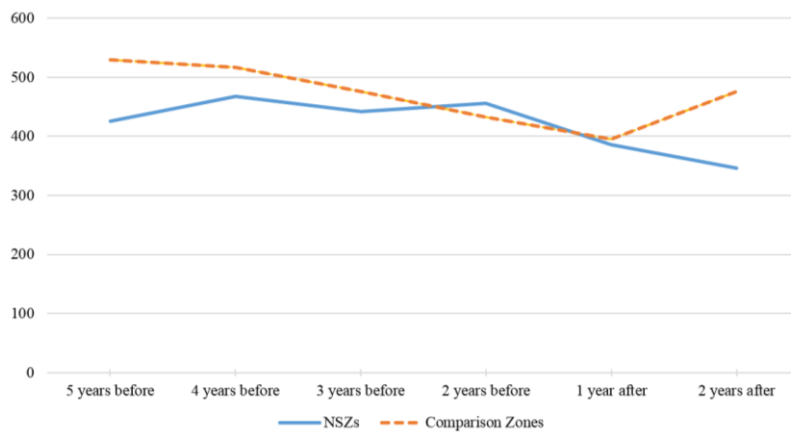


Figure 1.c. Total casualties



Despite the differences in the trend graphs, the “difference-in-difference” analyses without the “one year before” data show very similar results to the original ones. Both the “adjusted treatment effect” and coefficients of the regressions are of very similar magnitude compared with the originals, and the p-values remain essentially unchanged, with no statistically significant results. The similarity in results of the analyses makes sense when considering that both the NSZs and comparison zones showed the dramatic reduction in casualties in the “one

year before” period. These results show that any data anomaly is unlikely to have impacted the original analyses and findings.

Table 1 Difference-in-Differences: Change in Mean Annual Casualty Rates After Implementation

	Adjusted Treatment Effect	SE	t	p	95 % C.I.
Vulnerable users	-.006	.014	-.455	.649	-.033, .021
Motor Vehicle Occupant	-.018	.027	-.672	.502	-.07, .035
Total	-.024	.031	-.755	.450	-.085, .037

N for NSZ = 1,214
 N for CNSZ = 1,261

Table 2 Difference-in-Differences Regression of Effect of Neighborhood Slow Zones on Annual Traffic Casualty Rates

Casualty type	Variable	Coefficient	SE	p	95 % Conf. Interval
Vulnerable Users	NSZ	.026	.015	.08	-.003 / .056
	Period	-.0013	.015	.93	-.030 / .028
	Interaction	-.006	.022	.77	-.048 / .036
R ² = .001					
Motor Vehicle Occupants	NSZ	-.033	.025	.18	-.081 / .016
	Period	-.040	.024	.09	-.089 / .007
	Interaction	-.018	.035	.61	-.087 / .050
R ² = .002					
Total	NSZ	-.006	.033	.85	-.070 / .058
	Period	-.044	.032	.17	-.0107 / .020
	Interaction	-.024	.046	.61	-.114 / .067

R² = .001

N = 2,475

References

Grundy, C., Steinbach, R., Edwards, P., Wilkinson, P., & Green, J. (2009). *20 mph zones and Road Safety in London* (Report to the London Road Safety Unit). London School of Hygiene and Tropical Medicine. Retrieved from <http://www.tourdefrancelondon.com/cdn/static/cms/documents/20-mph-zones-and-road-safety-in-london.pdf>

Chapter Four

Humps, Circles and Chicanes: Policy Transfer of 20-mph Zones from London to New York City

Abstract: New York City's Neighborhood Slow Zones program, the first systematic area-wide traffic calming program in a major US city, was inspired by London's Slow Zones. However, while London's zones achieved significant reductions in traffic casualties, the zones in New York did not. In this paper, I use a policy transfer framework to determine if street design contributed to the disappointing traffic safety impacts of area-wide traffic calming in New York. I use both quantitative and qualitative data on the traffic calming devices implemented in 20-mph zones in both cities. While speed humps were the only device used to slow traffic in New York City, London's 20-mph zones used a much broader range of traffic calming devices. Further, the quantity of traffic calming devices was much higher in London. The large difference in the street designs used in 20-mph zones in each city shows that the transfer was far from a copy of the original model and suggests that New York's more skeletal version of area-wide traffic calming contributed to the disappointing results in that city. Barriers to a more complete transfer of street designs for 20-mph zones include the cost of, and public opposition to, more robust traffic calming measures, in addition to the emergence of other traffic safety priorities in New York. This finding helps address the theories that explain the diffusion of traffic calming. Despite relatively non-robust streets designs and negligible impact on traffic safety of 20-mph zones in New York, I argue that the NSZ program is not a failure.

1 Introduction

Road traffic injury is a major health problem. Annual traffic deaths exceed 1.24 million people worldwide (World Health Organization & World Health Organization, 2013), and over 32,000 in the U.S. (National Highway Traffic Safety Administration, 2014). Excessive traffic speed is a major cause of traffic injury and death, as vehicle speed is a primary determinant of traffic injury severity (Anderson, McLean, Farmer, Lee, & Brooks, 1997; Global Road Safety Partnership, World Health Organization, FIA Foundation for the Automobile and Society, & World Bank, 2008).

Until the emergence of the automobile in the first decades of the twentieth century, most street users proceeded at relatively low speeds (under 15 mph). Slow-moving traffic allowed streetcars, horse-drawn carriages, and pedestrians to share the roads with peddlers and children at play (Norton, 2011). Since the mid-1920s, higher speed auto traffic has dominated city streets. Conventional traffic engineering seeks to establish the highest possible speed limits in order to reduce travel times and increase traffic volumes (Dumbaugh & Li, 2010; Noland, 2013).

Traffic calming seeks to slow autos by introducing physical measures in the roadway, forcing motorists to drive at lower speeds. The benefits of traffic calming include safer streets with fewer traffic casualties, quieter neighborhoods, greater comfort for pedestrians and cyclists (Elvik, Vaa, Erke, & Sorensen, 2009), better air quality (Hedström, 1999), and greater potential for personal development and social inclusion (Elvik, Vaa, Erke, & Sorensen, 2009; Hedström, 1999; Sauter & Huettnermoser, 2008).

London has introduced traffic calming on many of its streets. The city's "Slow Zones" are areas that have a speed limit of 20-mph and traffic calming devices implemented throughout. Several robust studies have shown significant increases in traffic safety in these zones (Grundy et

al., 2009; Li & Graham, 2016; Webster & Layfield, 2003). Inspired by London's 20-mph zones, New York City began a similar initiative, "Neighborhood Slow Zones" (NSZs), in 2011 (Health Resources in Action, 2013).

However, as I demonstrated in Chapter Three, the NSZs have not had a significant impact on traffic safety in NYC. The potential benefits of 20-mph zones depend on how effectively these zones slow traffic. This, in turn, is largely dependent on the characteristics (e.g., type and quantity) of the traffic calming devices implemented in the zones.

Policy transfer studies the flow of policies from one place to another. This approach examines how transfers occur, what is transferred, and how successful the policy was in the place that it was transferred (Dolowitz & Marsh, 1996; Dolowitz & Marsh, 2000; Marsden & Stead, 2011). The genesis of the NSZ program (in London) and the effectiveness of 20-mph zones in improving traffic safety in that city and lack thereof in New York raises the question of what exactly was transferred from London to New York, and how this transfer may have affected the lack of effectiveness seen in the latter city. In this paper, I examine the transfer of street designs used in the zones.

To complete this analysis, I gathered data on the type and quantity of traffic calming devices implemented in 20-mph zones in London and compared these to similar data for New York City. This comparison uses precise data on all traffic calming devices implemented in the NSZs in New York and in a sample of "Slow Zones" in London. I also gathered quantitative data on the NSZ program and street designs in those zones. To the best of my knowledge, such a precise comparison of approaches to street design used in different traffic calming schemes has not previously been completed.

This paper proceeds as follows: after a review of literature on traffic calming and policy transfer, I present background information on 20-mph zones in both cities. I then present the methods and data for the analysis, followed by the results. After a discussion of the results, I conclude with future research needs on 20-mph zones in London and New York City.

2 Literature Review

This review provides a definition of traffic calming as well as “area-wide” schemes. It then gives theoretical background and a brief history of traffic calming in Europe, the UK and the US, followed by a summary of the policy transfer literature. Previous scholarship has documented the history of traffic calming, identifying different measures used in Europe since the 1960s (Kjemtrup & Herrstedt, 1992). Other research has presented self-reported data on the types of traffic calming measures commonly used in US cities (Ben-Joseph, 1995b; Ewing, 2008). However, no previous studies of traffic calming have used a policy transfer perspective, provided precise information on street design in different traffic calming schemes, nor sought explanations for the policy’s lack of effectiveness in some locales.

2.1 Traffic Calming: Definition and Area-wide Schemes

The Institute of Traffic Engineers defines traffic calming as “the combination of mainly physical barriers that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users” (Lockwood, 1997, p. 22). Traffic calming uses physical devices placed in the roadway that force traffic to proceed at slower speeds. These devices include speed tables, curb extensions, median islands, chicanes, and traffic circles. While other safety measures separate motorized traffic from vulnerable street users, e.g., sidewalks for

pedestrians and bikeways for cyclists, traffic calming aims to slow motorized vehicles to speeds that ensure the safety of pedestrians and cyclists in the roadway. Traffic calmed areas often have speed limits of 20 mph (31 kmph) or 30 kmph (19 mph), although lower speeds (e.g., 20 kmph/12 mph, or walking speed, about 5 kmph/3 mph) are common in cities in Europe and the UK.

Traffic calming devices can be implemented in an isolated fashion on individual streets, segments or intersections. Area-wide traffic calming introduces these devices in an entire area systematically, with the aim of slowing traffic throughout that area. Ewing & Kooshian (1997) reported that in the US, area-wide traffic calming had been implemented systematically in smaller cities (e.g., Boulder and Sarasota), and sporadically by one major cities (Seattle). To the best of my knowledge, the NSZs is the first systematic area-wide traffic calming program in a major US city.

2.2 Theory, Genesis and Diffusion of Traffic Calming

Increasing travel speed has been the primary goal of transportation advancements that have brought humanity from human and animal-powered travel to a world of planes, trains and automobiles (Lyons, 2012). Since the 1920s, transportation planning has prioritized the speed and volume of automobile traffic flows, often referred to as “mobility,” over other concerns, including traffic safety, and particularly pedestrian safety (Ben-Joseph, 1995a; Black, 1990; Dumbaugh & Li, 2010; Henderson, 2011; Noland, 2013; Norton, 2011; M. Southworth & Ben-Joseph, 1995). Many scholars challenge this orientation, proposing transportation systems that subordinate concerns of “mobility” to goals of “access.” The latter concept centers on peoples’ ability to reach destinations that are of value to them, which is in fact the main goal of transport (Handy, 1993;

Metz, 2008; Sclar & Schaeffer, 1980). If planners place greater focus on access versus mobility, public transportation, walking and cycling can flourish, according to these scholars.

Other scholars propose moving from an auto-dominated scenario to one with a greater amount of trips made by public transportation, walking and cycling in order to achieve environmental and safety goals (Banister, 2008, 2011; Newman & Kenworthy, 1999). Some theorists refer to the auto-dominated landscape as “automobility” and suggest that a successful transition to a more sustainable transportation system requires the development of travel regimes where the car is less dominant (Kemp, Avelino, & Bressers, 2011; Urry, 2004; Zijlstra & Avelino, Flor, 2011).

For all these scholars, one of the key strategies to achieve safer, more environmentally-friendly transportation systems is slowing car traffic and generally restricting auto use. Having fewer cars making fewer trips and travelling more slowly can simultaneously make travel for vulnerable users (pedestrians and cyclists) safer and more comfortable and generally improve quality of life by creating “livable” (Appleyard, Gerson, & Lintell, 1981) streets and neighborhoods. Traffic calming is one of the tools that can be used to slow autos and create safer streets, while promoting walking and cycling and improving neighborhood quality of life. For these theorists, the desire to move from an auto-dominated transportation system to one with increased tripmaking by sustainable modes and improved livability in cities is the motivation behind the diffusion of traffic calming.

Historical evidence from Europe bears this out. Increasing opportunities for children’s play was the reason for the appearance of the first traffic-calmed streets in Holland (woonerfs) in the late 1960’s (Kjemtrup & Herrstedt, 1992). The subsequent diffusion of traffic calming to Denmark, Germany, Sweden and France was motivated by the desire for increased traffic safety and less air

and noise pollution, as well as enhanced commercial activity and priority for pedestrians in village centers. Although traffic calming arrived later in the UK, local, and then national, authorities began adopting the policy in the 1980s for similar reasons (Pharoah & Russell, 1991, p. 81).

The earliest traffic calming programs in the US appeared in the 1970s, however, these were anomalies (Ewing & Brown, 2009). Traffic calming continued to be “virtually unknown” (2009, p. 1) in the US around 1992, but by 1997 dozens of programs were in place, and the topic featured prominently in professional meetings and literature. A 1995 survey of 75 US municipalities showed that speed humps or bumps were the most commonly implemented measure, used in 25 (35%) of the cities under study (Ben-Joseph, 1995b). A smaller number of cities used other measures, such as traffic diverters, traffic circles, and pinch points. Early reference material in the US for the application of traffic calming devices included *Traffic Calming: The State of the Practice* (Ewing, 1999), followed by the *U.S. Traffic Calming Manual* (Ewing & Brown, 2009). Additionally, a number of State Department of Transportations (DOTs) and local jurisdictions, including Delaware, Pennsylvania and San Jose (City of San Jose Department of Transportation, n.d.; Delaware Department of Transportation, 2012; Pennsylvania Department of Transportation, 2012), created their own guidelines for the application of traffic calming devices.

In the US, the diffusion of traffic calming was motivated by safety and livability concerns (Ben-Joseph, 1995b; Ewing, 2008). Ewing found that different from Europe, in the US the explicit desire to increase levels of walking and cycling through traffic calming was missing. He suggested using traffic calming devices that would lead to increased walking and cycling, including raised intersections, curb extensions at intersections, and gateways with priority lanes for cycles. He also suggested that municipalities adopt the “area-wide” approach to traffic calming, and include high-

volume, arterial streets in the schemes. The area-wide approach and traffic-calmed arterial streets would be particularly effective at encouraging walking and cycling, according to Ewing.

2.3 Traffic Calming Devices and their Effects

Different traffic calming devices reduce traffic speed and volumes, crashes, and casualties to varying degrees. Measures of the effectiveness of traffic calming devices include reductions in auto speed and volume, crashes in general, pedestrian-vehicle crashes, and injury crashes. For example, for speed humps, Ewing (Ewing, 1999) found a 20% reduction in traffic volume and a 23% reduction in speed, and Elvik reports a 41 % reduction in “injury accidents” (Elvik et al., 2009, p. 455). “Narrowings,” (Ewing, 1999, p. 39) an umbrella term for measures that decrease road width, reduced volume by 10%, and speed by 4 %.

The quantity of traffic calming devices used is also important. The greater the number of devices implemented per mile or per street segment, the greater the overall effect on speed, volume and safety. To achieve midpoint speeds of 20 mph, the distance between “slow points,” (Ewing, 1999, p. 63) where traffic calming devices are located, should be no greater than 200 to 250 feet. For 25 mph, this distance increases to 400 feet, and for 30 mph, 400 feet or greater.

Slower speeds, of course, lead to some mobility losses for motorists, as their travel time increases. However, vulnerable users stand to gain mobility, safety and comfort. Two cost-benefit analyses determined the benefit of area-wide traffic calming to be greater than the cost (Elvik et al., 2009; Steinbach, Cairns, Grundy, & Edwards, 2013). Further, a spatial equilibrium assessment (Nitzsche & Tsharaktschiew, 2013) determined that speeds of 30 km (19 mph) on local roads are economically beneficial from a societal standpoint. In all three studies, the bulk of the benefits of slower traffic came from reduced traffic casualties.

2.4 Policy Transfer

Dolowitz and Marsh defined policy transfer as “a process in which knowledge about policies, administrative arrangements, institutions etc. in one time and/or place is used in the development of policies, administrative arrangements, institutions in another time and/or place” (1996, p. 344). Policy transfer can be treated as an independent or dependent variable; researchers can seek to explain the policy transfer process or use the policy transfer framework to explain policy outcomes.

Policy transfer research has its roots in comparative policy analysis, and has grown considerably since the late 1990s (Benson & Jordan, 2011). A prominent example of policy transfer is the use of welfare-to-work policy from the United States in Britain since the early 1980s (Dolowitz & Marsh, 2000). This framework has also been used in research on urban policy, where it is sometimes called “urban policy mobility” (McCann, 2011). Researchers have used the policy transfer approach to study city-to-city diffusion of urban transportation practices (Timms, 2011). Municipal governments have adopted policies from other cities reduce congestion and improve safety and accessibility (Attard & Enoch, 2011; G. Marsden, Frick, May, & Deakin, 2011).

Dolowitz & Marsh (2000) defined seven possible questions for policy transfer research:

- 1) Why engage in policy transfer?
- 2) Who is involved?
- 3) What is transferred?
- 4) Where are lessons drawn from?
- 5) What are the degrees of transfer?
- 6) What restricts or facilitates the policy transfer process?
- 7) Is the policy that was transferred successful?

Depending on the aim of the research, policy transfer studies can emphasize different questions. For example, if the object of study is the process of the transfer itself, researchers can emphasize questions 1 (Why engage in policy transfer), 2 (Who is involved?), 3 (What is transferred?), and 4 (Where are the lessons

drawn from?). If the goal is to use policy transfer to help explain the outcomes of policy, researchers can focus on questions 5 (What are the degrees of transfer?), 6 (What restricts or facilitates the policy transfer process?) and 7 (Is the policy that was transferred successful?).

Regarding the fifth question (what are the degrees of transfer?), the authors outlined four types of transfers that could occur. The first type, “copying” (2000, p. 13) is the most complete type of transfer, when a policy is directly and completely transferred, making it an exact replication of the original. Next, “emulation” is the transfer of ideas behind a policy or program. This is followed by “combinations,” which are mixtures of several different policies. Finally, under “inspiration,” a policy in another place inspires a change in another but does not draw on the original policy.

This study uses policy transfer as an explanatory variable, seeking to understand how the transfer of 20-mph zones from London to New York impacted the policy’s success in the latter city. As such, this study will focus on questions 5, 6 and 7, as these are the most relevant to discovering reasons for the disappointing impacts of area-wide traffic calming in New York City. The study examines the street design elements that were transferred and reasons for the street designs used in New York City’s 20-mph zones. In answering the fifth policy transfer question, this paper identifies the type of transfer that took place. Exploring the sixth question helps identify possible barriers to the policy transfer process. In answering the last question of policy transfer research, the paper presents an overall evaluation of the program’s success.

3 Background: 20-mph zones in London & NYC

London's first traffic-calmed 20-mph zone was introduced in 1991. In 1999, new legislation in the UK allowed local authorities to implement traffic calmed streets without approval by the central government, leading to more widespread adoption of the practice (Chris Grundy, Steinbach, Edwards, Wilkinson, & Green, 2009). In 2008, there were 399 zones throughout Greater London. These zones are associated with significant reductions in traffic casualties (C. Grundy et al., 2009; Webster & Layfield, 2003), and greater equality through the mitigation socioeconomic differentials in road injury (Steinbach, Grundy, Edwards, Wilkinson, & Green, 2011).

London's appetite for slower auto speeds has remained steady since the first 20-mph zones were introduced in 1991. By 2016, nine of the city's 33 boroughs (Islington, Camden, City of London, Southwark, Lambeth, Lewisham, Tower Hamlets, Hackney and Haringey) had adopted borough-wide 20-mph speed limits, with 20-mph limits on all, or almost all, of their streets. According to an estimate by the NGO Twenty's Plenty, about 3,310,000 Londoners, or 38% of the city's total population of Greater London, lived on roads that have speed limits of 20-mph zones in 2016 (Leach, 2016).

Prior to the NSZ program, The New York City Department of Transportation (hereafter, DOT) had previously implemented traffic calming under programs such as Safe Routes to School, Safe Routes for Seniors, and the speed hump program. Under the last program, which has existed since 1996, an individual or organization can request a speed hump to improve safety on an individual street segment (New York City Department of Transportation, 2017).

Inspired by the success of London's aforementioned 20-mph zones (Health Resources in Action, 2013), the DOT first proposed NSZs in the *New York City Pedestrian Safety Study &*

Action Plan as a way to improve traffic safety for vulnerable street users (Viola, Roe, & Shin, 2010). The DOT implemented a pilot 20-mph zone in Claremont, the Bronx, in 2011. Area-wide traffic calming had previously been implemented in only a handful of US cities.⁴

Following the successful implementation of the pilot zone, the DOT created the NSZ program, under which neighborhood groups could apply for the zones. The DOT received 174 applications, and implemented 28 NSZs by 2016. These zones are distributed throughout the city's five boroughs, with eight in both the Bronx and Queens, five in Brooklyn, four in Manhattan, and three in Staten Island.

Using 2010 census data, I calculated that about 316,000 New Yorkers, about 4% of the city's population, lived on the streets in the 28 NSZs implemented through 2016. In a preliminary analysis, the DOT has reported a 10-15% decrease in speeds, 14 % reduction in crashes, and 31 % reduction in injuries of motor vehicle occupants (New York City Department of Transportation, 2015) in the zones. A more recent study (Jiao, Kim, Hagen, & Muennig, 2017) found an 8 % reduction in injuries in the zones but did not include a statistical test that adequately controlled for background reductions in injuries. My analysis in Chapter Three shows that the zones have not had a significant effect on traffic safety.

In addition to London being the inspiration of NYC's NSZ program and therefore an obvious selection for a study of policy transfer, similarities between these cities' transportation systems also make this analysis compelling. The percentage of trips to work made by auto are similar in London (35%) and New York (29%) (data from 2009, Southworth, Reuscher, & Hwang, 2012; Transport for London, 2012). Further, the stated goals of the 20-mph zones in both cities were the same: to create "self-enforcing" zones that improve traffic safety (New York

⁴ Curiously, I found no indication that the US cities that had previously adopted area-wide traffic calming (e.g., Seattle, Sarasota) influenced the adoption of the measure in New York.

City Department of Transportation, n.d.-a; Webster & Layfield, 2003). While the comparison of the traffic calming devices implemented in 20-mph zones in both cities certainly has limitations (some of these are discussed in the ‘Discussion’ section), the similarities in the percentages of trips made by auto and the goals of the area-wide traffic calming zones strengthen the validity of this comparison.

4 Methods, Data & Procedure

This study uses mixed (both quantitative and qualitative) methods (Creswell, 2009; Jupp, 2006) to determine how the transfer of 20-mph zones from London to New York may have influenced the disparate results in the two cities. The main focus of the study is a comparison of the approaches to street design used in 20-mph zones in each city.

The qualitative data focussed on the street designs used in New York’s NSZs. I had been following the program closely since 2013. That year was during the first half of the program’s implementation period, which began in 2011 and finished in 2016. I gathered qualitative data from site visits, interviews and documents. The data include two interviews with DOT officials and one with a community activist involved in the application for an NSZ. The three interviews were semi-structured and between about 20 and 40 minutes in length. The documents were web articles from a neighbourhood news website (*DNAinfo*) and a blog that advocates for sustainable transportation (*Streetsblog*). The qualitative data shed light on the process of policy transfer and provided important context and explanations for the findings of the quantitative research. Taken together, the qualitative and quantitative components “triangulate” the data (Mathison, 1988), thereby validating the overall findings of the research.

The quantitative data consisted of information on the street designs used in area-wide traffic calming in both cities. Prior to collecting this data, I conducted site visits to zones in both cities and observed that traffic calming devices were more robustly implemented in London's 20-mph zones than in New York City's. However, I needed to collect data in a systematic way to confirm that this was the case.

I gathered most of the data on the traffic calming devices used in New York City's 20-mph zones from presentations on the DOT website. These presentations included maps of proposed NSZs, which included the locations of traffic calming devices to be implemented. I used Google Streetview to count the traffic calming devices in the two zones for which these presentations were not available online (Claremont and Auburndale). I then confirmed with DOT officials that these data were accurate, and received more precise information from these officials for four of the 28 zones (personal communication, DOT officials, 10 July 2016 and 13 October 2016).

I used the Lionfile 16C for data on the street network in New York City, which I downloaded from the City's open data website (New York City Department of City Planning, n.d.). The borders of the NSZs came from the a shapefile on the DOT's website titled "Vision Zero View" (New York City Department of Transportation, n.d.-b), which I modified to include only the segments that were inside the borders of the zones.

Gathering the data on the traffic calming devices in London's 20-mph zones was much more complex and time consuming. First, I consulted publicly available sources for this information (reports and websites), but did not find comprehensive data. I then confirmed that data on the number of traffic calming devices used in London's 20-mph zones was not available in a central location, first with a leading researcher on the topic (personal communication, Chris Grundy, 17

January 2017), and then with an official of London's transportation authority, Transport for London (personal communication, Naomi Baster, 07 February 2017).

After establishing that this data was not available, I gathered it myself. I collected information on the types and quantities of devices in London's 20-mph zones by using a shapefile with the location of the slow zones and Google Streetview. A researcher at the London School of Hygiene and Tropical Medicine provided a shapefile containing the locations of the 399 slow zones implemented in London between 1993 and 2008. I also used shapefiles of London's street network and boroughs in this process. The shapefiles of London's street network came from OpenStreetMap via the online open datastore of the City of London (Greater London Authority, n.d.). The boroughs came from the same open datastore.

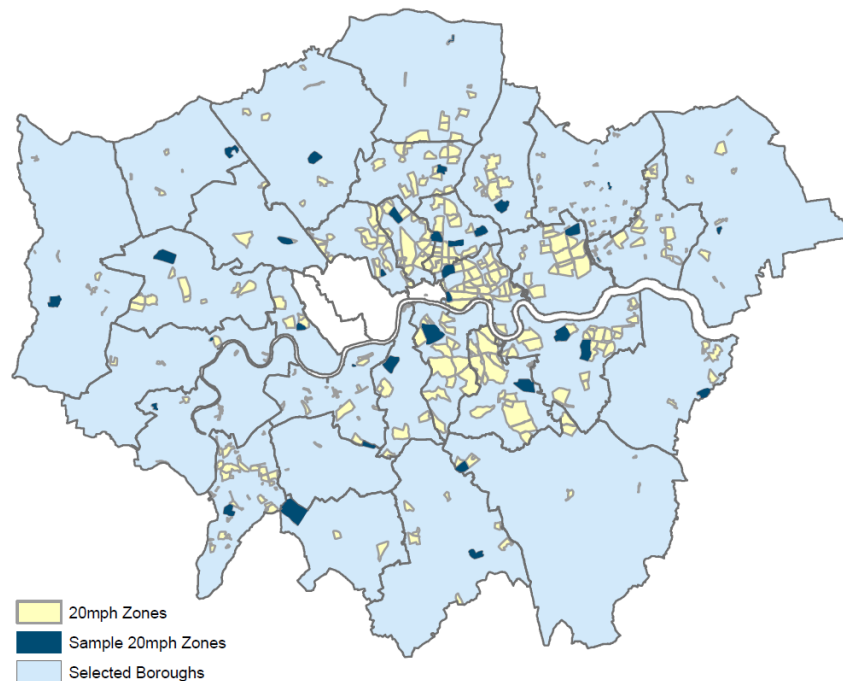
At the beginning of this research, I determined that I lacked sufficient resources and time to gather information on the traffic calming devices used in all 399 zones in the file, or even a statistically representative sample.⁵ As such, I decided to gather a stratified sample of the zones. Stratified sampling creates a sample that is representative to some degree by including key variables of a population (Harding, 2006). In this case, I selected 34 zones based on their geographical location, the year implemented, the size of the zone, and the purpose of the zone.

The zones in the sample were in most (30 of 33) of London's boroughs. I excluded the three boroughs that did not have more than one zone from the sample. The sample contains at least one zone for each of the years the zones in the file were implemented: 1993-2008, excluding 1994, when no zones were implemented. After dividing the zones into quintiles according to size, I evenly distributed the sample zones across these quintiles. Finally, I used a

⁵ I found that I would have to collect information for 196 zones, about half of all 399 zones, to reach a statistically representative sample. Collecting data on traffic calming devices on the first zone in the sample took about 25 hours. As such, I determined that collecting a statistically representative sample was beyond the scope of this research.

spreadsheet that included the land use in the zone's area and the reason(s) for installation of the zones. The former included residential, mixed-use and commercial, and the latter included improving traffic safety around schools, to reduce 'rat-running' (high-speed through traffic), and to improve social inclusion. I sought to ensure diverse and evenly distributed land uses, and at least one zone for each of the stated reasons for the zone in the sample. As such, although the sample is non-representative, it does reflect key characteristics of the 399 zones implemented until 2008. Twenty's Plenty London Campaign Manager confirmed that the sample was at least reasonably representative of the diversity of the zones according to implementation date, geographical distribution, and size (personal communication, Jeremy Leach, 13 April 2017). The 34 sample zones, as well as all 399 zones in the file, are displayed in Figure (below).

Figure 1 London's 20-mph Zones and Sample Zones



Using the shapefile and information in Appendix F of a 2009 report on London's 20-mph zones (Chris Grundy et al., 2009), which included the name and borough of the zones, I located the 34 sample zones on Google Streetview. Streetview allowed me to visualize the entirety of the segments inside and bordering the zones. I then registered the types, quantity, and approximate location of traffic calming devices in the zones in ArcGIS. I used the earliest images available on Google Streetview, which were from 2008. This ensured that the measures recorded were the closest possible to the ones that existed at the date of the creation of the shapefile (2008).

5 Results

This section includes the results of the information gathered on street designs in 20-mph zones in 20-mph zones in London and New York City as well as the qualitative data on the NSZ program.

The data gathered on traffic calming devices are presented in Table (below). The measures in the table include only the devices that force motorized vehicles to move at slower speeds by imposing physical obstacles. This means that signage (e.g., posted signs with the speed limit or pavement markings with the speed limit) is not included. I decided to include only measures that physically force motorists to drive at slower speeds, as these are much more effective at reducing traffic speeds and injuries than simply visually indicating a lower speed limit (Elvik et al., 2009).

The table divides these measures into two categories: horizontal and vertical (Ewing & Brown, 2009). Vertical refers to measures that cause vehicles to change elevation as they traverse the device, e.g., over a speed hump or a raised crosswalk. Horizontal refers to measures that cause vehicles to shift laterally, e.g., around a chicane or a mini-roundabout.




Table 1 Traffic Calming Devices in 20-Mph Zones in London and New York City

Category	Device	London	New York
Vertical	Speed hump	767	452
	Speed cushion	653	
	Raised crosswalk	199	
	Raised intersection	90	
	Midblock raised crosswalk	38	
Horizontal	Curb extension	197	
	Pedestrian refuge	126	
	Semi-diverter	116	
	Gateway	68	
	Raised median	55	
	Mini-roundabout	13	
	Chicane	8	
Total		2330	452
Miles of street		147.9	149.3
Segments		3021	2057
Devices/mile		15.8	3.2
Devices/segment		.77	.23

Figure 2 Images of Traffic Calming Devices (All images from London and Google Streetview unless otherwise noted)

Speed hump	 <p data-bbox="824 495 1295 527">New York City, Photo: Jonas Hagen</p>
<p data-bbox="297 533 690 604">Borough: Manhattan Inwood NSZ, Dyckman Street</p> <p data-bbox="297 606 1419 709">https://www.google.com/maps/@40.868039,-73.9302549,3a,75y,325.35h,78.73t/data=!3m6!1e1!3m4!1sYqjc18JhTx7m8pvp0IZayw!2e0!7i13312!8i6656</p>	
Speed cushion	
<p data-bbox="297 1079 760 1150">Borough: Enfield Forty Hills Slow Zone, Bull's Cross</p> <p data-bbox="297 1152 1406 1255">https://www.google.com/maps/@51.6743502,-0.0598233,3a,75y,8.3h,73.46t/data=!3m7!1e1!3m5!1sjOvciXQfN6SUA10UHvrHOw!2e0!5s20080701T000000!7i13312!8i6656</p>	
Raised crosswalk	
<p data-bbox="297 1583 1101 1654">Borough: Southwark, East Walworth Slow Zone, Walworth Road and Larcom Street</p> <p data-bbox="297 1656 1419 1759">https://www.google.com/maps/@51.4903651,-0.096977,3a,75y,79.16h,76.26t/data=!3m6!1e1!3m4!1sDPPXTeBlg7kUczPw4OfOw!2e0!7i13312!8i6656</p>	

<p>Raised intersection</p>	
<p>Borough: Redbridge, Oaks Lane Slow Zone, Oakes Lance & Whites Avenue https://www.google.com/maps/@51.5764586,0.09398,3a,75y,1.69h,76.66t/data=!3m6!1e1!3m4!1sE1HEzjB1_YK3TB25CuBIJw!2e0!7i13312!8i6656</p>	
<p>Midblock raised crosswalk</p>	
<p>Borough: Southwark, East Walworth Albany road https://www.google.com/maps/@51.4871527,-0.0777524,3a,75y,228.34h,95.1t/data=!3m7!1e1!3m5!1sb_7Fv8DGSYG_RQq-sWdVhA!2e0!5s20161001T000000!7i13312!8i6656</p>	
<p>Curb extension</p>	
<p>Borough: Sutton, Worcester Park Slow Zone, Green Lane https://www.google.com/maps/@51.3810411,-0.2427672,3a,75y,5.77h,67.72t/data=!3m7!1e1!3m5!1sMmKQVRqsLAuaeUMch4y6A!2e0!5s20120901T000000!7i13312!8i6656</p>	
<p>Pedestrian refuge</p>	

<p>Borough: Greenwich, Herbert Road Area Slow Zone, Shooters Hill/A207 https://www.google.com/maps/@51.4696554,0.063841,3a,75y,106.56h,99.6t/data=!3m6!1e1!3m4!1s11JFVbm7d-MIhorjJ6asMg!2e0!7i13312!8i6656</p>	
Semi-diverter	
<p>Borough: Southwark, East Walworth Slow Zone, Balfour St. & Munton Road https://www.google.com/maps/@51.4936483,-0.0916487,3a,75y,189.08h,92.68t/data=!3m7!1e1!3m5!1sdyPnE8oK0VFzILH6xgrv9A!2e0!5s20161001T000000!7i13312!8i6656</p>	
Gateway	
<p>Borough: Hillingdon, Whitehorn Estate Slow Zone, Colham Ave. https://www.google.com/maps/@51.5120989,-0.4694932,3a,75y,181.27h,82.88t/data=!3m6!1e1!3m4!1sZ9GXwx37JHf8TYKbB3m8OQ!2e0!7i13312!8i6656</p>	
Raised median	
<p>Borough: Southwark, East Walworth Slow Zone, Rodney Road</p>	

https://www.google.com/maps/@51.4927787,-0.0939161,3a,75y,82.32h,71.15t/data=!3m7!1e1!3m5!1sJrqB-SiHo42MpW-K5Lpew!2e0!5s20080701T000000!7i13312!8i6656	
Mini-roundabout	
Borough: Sutton, Worcester Park Slow Zone, Browning Ave. & Brinkley Road https://www.google.com/maps/@51.3818413,-0.2357605,3a,75y,148.45h,90.41t/data=!3m6!1e1!3m4!1sD9YiF_JkPFy1NTMd5GeaA!2e0!7i13312!8i6656	
Chicane	
Borough: Bexley Heath Road Area Slow Zone, Galloway Drive https://www.google.com/maps/@51.4436884,0.1798374,3a,75y,260.03h,79.6t/data=!3m7!1e1!3m5!1sPqu_ROIy3xy84yt58iEcFg!2e0!5s20120501T000000!7i13312!8i6656	

The horizontal and vertical measures used in the two cities differ in both variety and quantity. While I identified twelve distinct types of traffic calming devices in London, only speed humps were transferred to the zones in New York. And despite having similar miles of street (148 and 149 in London and New York, respectively), the sample zones from London included more than five times as many measures as New York's (2,330 and 452, respectively).

This difference was also reflected in the density of measures per street segment and per mile. A segment here is the street length between two intersections, sometimes referred to as a “block.” Despite having over 1,000 additional street segments in the sample zones from London versus in New York’s 28 zones, the per-segment density of devices was more than three times higher in London (.77 versus .23 in New York). Per mile, there were roughly five times more devices in the sample of 20-mph zones in London (15.8) versus New York’s (3.2). T-tests for differences in means showed these differences to be highly significant ($p < .0001$).

In addition to these vertical and horizontal measures, I noted other interesting features of the zones in London that were not transferred to the zones in New York City. For example, many streets in the zones had pavement markings in “zig-zag” formation, particularly leading up to intersections. Further, the zones also typically included many bollards, implemented on the sidewalks. I counted a total of 3,795 bollards in London’s 20-mph zones.

The traffic calming devices implemented varied considerably from zone to zone in London. For example, the zones in denser, more urban areas included raised crosswalks at the intersections on borders of the zones, while many of the less dense, more suburban places did not use raised crosswalks. In comparison to London’s zones, the NSZs were much more uniform in the traffic calming devices used (speed humps).

Finally, several of the sample zones in London included higher-volume streets, which might be considered arterial streets in the US context. Some of these streets contained bus routes and had vertical traffic calming devices, such as midblock raised crosswalks. None of the zones in New York City included high-volume, arterial streets.

5.1 Qualitative Data

Data from site visits, interviews and documents provided context on the policy transfer of 20-mph zones in London to New York City and the street designs in the NSZs. The qualitative data revealed the origin of the NSZ program and its status within the DOT. The data also showed that street designs used in the NSZs changed over time.

Preliminary research on the NSZs revealed that the idea of using area-wide traffic calming in New York City began when DOT officials were conducting research for the agency's *Pedestrian Safety Plan* (Viola et al., 2010). These researchers found studies showing that many European cities had successfully reduced traffic casualties by lowering speed limits, and sought to “do a New York version” of London’s 20 mph zones (personal communication, DOT officials, 05 April 2013). This led to the implementation of the pilot NSZ in Claremont, Bronx in 2011.

Initially, the main features of the NSZs were speed bumps, signs, and gateways with “daylighting.” The gateways were placed at intersections where cars and trucks entered the zones, and the DOT removed parking at the intersections, thereby providing visibility for crossing pedestrians and turning motorists. The “daylit” gateways were demarcated by paint on the pavement, and included signs with 20 mph speed limits, anchored by steel drums covered with plastic casings.

These daylit intersections were intended to clearly identify the entrance of the zones to motorists. Theoretically, this intervention could facilitate crossing for people on foot by shortening the crossing distance, much like a standard curb extension made of concrete. Also in theory, daylighting could slow cars’ speeds by narrowing street space for cars and creating a tighter turning radius; tighter turning radii slow turning vehicles (McCann, 2008).

On a site visit conducted in April 2013, residents of a slow zone in Inwood, Manhattan, mentioned problems associated with the gateways. For example, several residents said they did not like that parking spaces had been removed. Another said that the signs made it more difficult for street cleaning, and that she had seen a dead rat at the base of one of the signs.

A community activist who supported Inwood's application for the NSZ said that some people thought that "daylighting" reduced a naturally-occurring traffic-calming effect that was created when parked cars reached the corners of intersections (personal communication, David Thom, 08 April 2013). These people thought that with improved visibility at intersections from daylighting, motorists drove around corners at higher speeds, thereby placing pedestrians at greater risk of injury.



The DOT shared the dissatisfaction with the "daylit" gateways expressed by residents of Inwood, and removed the daylighting in 2015. The agency devolved the street space to its previous purpose, parking, and moved the horizontal signs that indicated the entrance to the slow zones from streets to sidewalks. In addition to restoring parking spaces at NSZs implemented before 2015, the DOT did not include daylighting in zones implemented during or after that year.

In an interview, DOT officials informed that the decision to change the configuration of gateways was chiefly one of resource allocation (personal communication, DOT officials, 03 October 2016). The same group of DOT engineers worked on drawings, signs, and speed humps for all traffic safety projects in the city. The officials also mentioned that the "daylit" gateways also required much attention for maintenance. The plastic bases of the signs were frequently damaged, and fixing these required the engineers' attention.

As such, the DOT decided that the engineers' time was better spent on working on high-crash areas. The officials also said that public pushback against the zones decreased after the

agency moved the gateway signs from the street to the curb (and thereby restoring parking spaces).

Figure 4 Gateways With and Without Daylighting

	
<p>Gateway with Daylighting, Inwood Slow Zone, Manhattan, West 218th St. & Park Terrace Image: Jonas Hagen</p>	<p>Same intersection, no daylighting Image: Google Streetview</p>

Web articles by the advocacy site streetsblog.org and the neighborhood news site provided additional information on street designs used in the NSZs. An article on an NSZ to be implemented in 2015 in the Hamilton Heights neighborhood of Manhattan reported that residents welcomed the NSZ because parents were concerned that speeding cars endangered their children (Armstrong, 2015). The same article reported that some residents were concerned that the NSZ would “cost them a large number of parking spaces,” but that these residents’ fears were allied because the new configuration of the gateways did not entail the loss of parking spaces.

In reaction to the removal of the daylighting at the gateways, an article from the advocacy website *Streetsblog* (Aaron, 2015) said that the DOT had “watered down some Slow Zone features, apparently in a response to motorist complaints about curbside parking.” That article went on to recognize that maintenance of the signs was also likely to be an issue, and argued for “concrete bulb-outs” at the intersections where cars entered the zones. A DOT statement added

to that article said that the gateway signs were “hit and damaged at an unsustainable rate and could put pedestrians at risk so we now place them on the sidewalk.”

At least some residents desired more robust street designs in the zones. In an article on a proposed NSZ in Prospect Heights (Smith, 2015), a Community Board member said of the DOTs plan that “the elements proposed, while good, do not go far enough.” The same person said that members of his community felt that more traffic control elements, including curb extensions, were needed to slow speeding traffic.

Regarding the future of the program, the DOT officials said that the agency was reevaluating the program in the context of Vision Zero (personal communication, DOT officials, 03 October 2016). This policy has the goal of zero deaths and serious injuries from road traffic and was adopted by the agency in 2014. The number of requests for speed humps had increased since Vision Zero began, and the DOT had dedicated much of its attention and resources to the backlog of speed hump requests, the officials informed.

6 Discussion and Conclusion

Although London’s 20-mph zones inspired New York’s, the transfer of street designs from London to New York was sparse, resulting in a large difference in the robustness of the policy in both cities. London used a large variety of devices to slow traffic and implemented these devices relatively frequently in its Slow Zones. While New York’s NSZs originally included prominent gateways with daylighting, the street design in the zones was ultimately limited to a relatively small number of speed humps. The large difference in street design in the zones in both cities plausibly contributed to the ineffectiveness of the NSZ program.

This discussion uses a policy transfer analysis, which helps expose potential barriers to more robust street designs for area-wide traffic calming in New York. The discussion also explores theories that explain the diffusion of traffic calming, which helps understand the role the NSZ program plays in improving safety and sustainability of the city’s transportation system.

The quantitative data exposed a large difference in the street designs used in the 20-mph zones in London and New York. The qualitative data showed that cost and public resistance to more robust implementation of traffic calming were important factors that led to the nature of the transfer of street designs that occurred between London to New York. Taken together, these data paint a comprehensive picture of the dynamics that led to the skeletal implementation of area-wide traffic calming in New York.

Cost was an important consideration for the implementation of the street designs used for the NSZs. First, the curb extensions implemented for the original gateways (with daylighting) used paint, rather than concrete. Demarcating road space with paint costs much less than using concrete (National Association of City Transportation Officials, 2013), not only because of the cost of the material and installation, but also because using concrete can also necessitate moving drainage and utility poles, which is relatively expensive. Further, speed humps are relatively inexpensive compared to other traffic calming devices, as the table below demonstrates.

Table 2 Average Cost of Traffic Calming Devices

Traffic Calming Device	Average Cost (US Dollars)
Speed Hump	\$2,640
Raised Crosswalk	\$8,170
Chicane	\$9,960
Curb Extension	\$13,000
Pedestrian Refuge	\$13,520
Semi-diverter	\$15,000
Raised Intersection	\$50,540
Roundabout/Traffic Circle	\$85,370

Data Source: Bushell, Poole, Zegeer, & Rodriguez, 2013

The qualitative data also showed that the “daylighting” originally used in the NSZ gateways was problematic for cost and possibly safety reasons. The daylighting proved expensive to maintain, due to frequent problems with the plastic bases of the signs placed in the roadway. Next, increased visibility may actually have put pedestrians at greater danger, as reflected by the comments of a community activist and the DOT. The DOT ultimately decided that the possible benefits of daylighting were not worth the cost, and did away with the measure at the entrances to the NSZs.

With a limited pool of engineers to work on road safety projects, the DOT decided to prioritize speed hump requests and high-crash corridors. Under Vision Zero, the DOT has focused its efforts on reducing deaths and serious injuries. In New York City, about 60 % of pedestrian fatalities occurred on arterial roads (Viola et al., 2010). The NSZs are located only on non-arterial streets. Since the NSZs are located on relatively safe streets, it is logical that the agency would choose to use its resources on areas where safety initiatives could have a larger impact.

The qualitative data also revealed tension surrounding the street designs used in the NSZs between those who wished to preserve parking, and who desired to use street space to increase safety. The DOT has decided, at least for now, to return street space at the gateways to the NSZs to parked cars. Considering the agency’s finite resources and within the context of Vision Zero, this decision is understandable.

6.1 Policy Transfer of 20-mph Zones

Regarding the questions of policy transfer research, the data shows us that (1) planners from the DOT engaged in policy transfer because they were dissatisfied with the status quo of street safety in New York City and wished to import policies that had proven successful in other places, (2) the main actors involved in the policy transfer were planners at the DOT, (3) the policy that was transferred was area-wide traffic calming, and (4) the main inspiration for the NSZ program was London's Slow Zones, as documented in research on the effects of the zones (e.g., Grundy et al., 2009; Webster & Layfield, 2003). These four findings help explain this policy transfer process. However, this study is more concerned with how this process impacted the policy's outcomes in New York. Question 5, 6, and 7 of policy transfer research are better suited to answer this question.

The fifth question of policy transfer research asks about the degree of transfer that occurred, ranging from an exact copy of the original to "inspiration," (2000, p. 13) where a policy in another place inspires a change in another but does not draw on the original policy. In this case, the transfer of area-wide traffic calming was a "combination": the DOT combined the street hump program with the area-wide approach, and, at least initially, gateways with daylighting, although these were then removed.

Under the speed hump program, the DOT responds to requests to implement humps on individual street segments. The DOT used the same procedure and measure but expanded it to entire areas rather than limiting it to individual segments. However, although the NSZ program is essentially an adaptation of the speed hump program, the latter program is implemented more robustly than the former. Under the speed hump program, the DOT implements at least one

hump per segment. In the NSZ program, about a quarter of segments in the zones received a hump.

The sixth question of policy transfer research explores factors that restrict or facilitate the transfer process. The qualitative data showed that there are two main factors that may have restricted a more complete transfer of street designs of 20-mph zones from London to New York: cost and public resistance. In this case, cost means both the cost of implementing traffic calming devices and the cost of allocating finite human resources to planning and maintaining these devices.

Regarding the cost of the devices themselves, as speed humps are the least costly traffic calming device, it stands to reason that keeping costs low was an important consideration for the implementation of the zones. This possibility is reinforced by the daylighting at the gateways, which were essentially painted curb extensions, as opposed to more expensive concrete ones.

The cost of human resources also restricted the transfer of street design, as we learned that the same group of engineers work on all traffic safety projects throughout the city. This made it difficult to maintain the signs that were placed in the street at the gateways. Further, with the adoption of Vision Zero and the subsequent emphasis on high-fatality corridors, using the finite pool of engineers to work on relatively safe streets became less of a priority for the DOT.

The desire to preserve on-street parking was also a significant barrier to a more complete transfer of street design for 20-mph zones. While many of the measures used in London could entail the loss of on-street parking (e.g., chicanes, curb extensions, semi-diverters), the only physical traffic calming device in New York's zones, speed humps, do not use street space that could be used for parked cars. The qualitative data showed that while the NSZs were relatively well-received, many residents were reticent to sacrifice parking space in the zones. Pushback

from the public against the zones in New York reduced when the DOT removed daylighting and restored parking at the gateways.

The final question of policy transfer asks if the policy that was transferred was successful. With a minimal transfer of street design for traffic calming from London, the zones in New York did not achieve the reductions in traffic casualties seen in the former city. While the program has not achieved the main goal of improving traffic safety, I argue that it cannot be considered an “implementation failure, in which actual policy outcomes fall short of expected outcomes” (Pressman & Wildavsky, 1984, p. 211) for several reasons.

First, the program was very well received by the public, as evidenced by the large number of applications for zones (applications outnumbered the number of implemented zones by 6 to 1). Further, DOT officials and a representative from a local advocacy group, Transportation Alternatives, report that the measure has been popular in the places it was implemented (Chapter Two). The program rapidly introduced a new measure – area-wide traffic calming – to a relatively large number of neighborhoods (28) across the city in a relatively short time (five years – from 2011 to 2016). Further, as Chapter Two showed, the NSZ program advanced environmental justice in the city: the planning process was inclusive of poor and minority populations, and the zones were distributed equitably in terms of these populations. The DOT established a mechanism for creating future zones and doing so in a participatory and equitable way. As such, the NSZ program was at least partially successful in putting New York on a path to safer, more equitable and sustainable streets and transportation systems.

6.2 Theory and Diffusion of Traffic Calming

The data on street designs in New York and London provide the opportunity to revisit the previously outlined theories that explain the diffusion of traffic calming. While designs of in the NSZ has not radically altered the dynamics of New York City's streets, the program could prove to be part of a the gradual process of policymaking, as outlined by Lindblom (1959). In this scenario, the program would be an incremental step forward toward a safer, more sustainable and equitable city.

The mid-block speed humps used in the NSZs may slow traffic somewhat, the increase to pedestrian and cyclist comfort is likely marginal. Neither the speed humps on individual street segments (Ewing, Chen, & Chen, 2013) nor the NSZs (Chapter Three) have significantly improved traffic safety. As such, the NSZs likely restrict auto movement slightly by forcing motorists to proceed at slower speeds, but do not create areas where pedestrians, cyclists, and children playing have priority over car traffic.

The diffusion of area-wide traffic calming to New York City appears to have been motivated primarily by safety, and perhaps livability, concerns. Traffic calming devices that directly improve pedestrian safety and comfort, such as raised crosswalks (which slow autos at intersections and give priority to crossing pedestrians) and curb extensions (which shorten crossing distances for people walking) are not included in the NSZs. Curb extensions reduce road space for travelling or parked autos, as do other measures that are absent in the NSZs, such as pedestrian refuges or mini-roundabouts. The NSZs' street designs aim to improve safety, but do not imply a significant restriction of auto movement and use, nor do they explicitly seek to increase walking and cycling.

These findings are consistent with Ewing's (2008) conclusion that traffic calming in the US aims to promote safety and livability, but not increase walking and cycling. This could be interpreted as further evidence that the US trails behind Europe, both in adopting robust street design for traffic calming (Ben-Joseph, 1995a; Ewing, 2008; Garrick, 2005) and in transitioning to a more sustainable transportation system (Buehler, 2011; Sheller, 2011). Nonetheless, borrowing a term from diffusion literature, New York is an "early adopter" (Rogers, 2010) of area-wide traffic calming in the US. As such, the NSZ program could be interpreted as a crack in the dominant regime of automobility, and a small step forward in a transition to a safer, more sustainable transportation system.

6.3 Future Research and Conclusion

Future research can illuminate aspects of London's experience with 20-mph zones that could help planners in New York improve the robustness of street design for traffic calming and thereby the impact of the NSZ program. One of the barriers to implementing traffic calming robustly is the desire to preserve on-street parking for autos. In contrast, it appears that planners in London regularly sacrificed parking to make streets safer; many of the horizontal measures (e.g., curb extensions and chicanes) introduced in London's zones likely entailed the loss of parking spaces. Ishaque and Noland (2006) provide evidence of a fierce debate between those who wished to provide free and unobstructed spaces for auto travel and those who advocated using street space for pedestrian safety in London and the UK. Future research should explore how London's planners were able to dedicate street space to pedestrian safety in the 20-mph zones.

The inclusion of wider, higher volume roads (“A” roads in the UK, “arterial” roads in the US) in London’s 20-mph zones, and lack of such roads in New York, may also have contributed to the disparity in the effects of the zones in each city. Including such roads in slow zones could have a large impact on traffic safety, considering that the majority of traffic casualties occur on arterial roads. Because lower speeds on arterial roads in New York City could lead to considerable gains in traffic safety, it would be worthwhile to examine how planners in London’s were able to implement 20-mph speed limits and traffic calming devices on high-volume streets. This investigation could examine road design manuals from the UK, which provide guidelines for traffic calming on such roadways (e.g., Highways Agency, 2004)

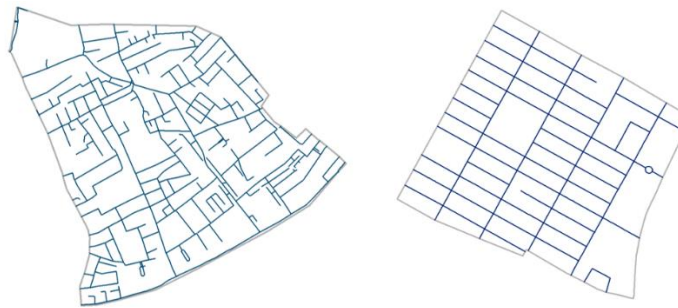
Moving forward, the DOT has the opportunity to build upon the strengths of the program. Options to do this include expanding the number of zones in the city, making existing zones more robust by implementing more traffic calming devices, and modifying the scope of the zones to include arterial streets. More robust traffic calming in the existing and future NSZs could help the measure realize its potential to improve traffic safety, encourage walking and cycling, and improve social inclusion.

7 Study limitations

This study suffers from a number of limitations. An important limitation is that street networks in the two cities are very different; this could affect the variety and quantity of traffic calming devices planners used to slow traffic in each city. First, London has shorter segments than New York. The sample slow zones from London had a mean segment length of .046 miles, versus .073 miles in New York’s NSZs. London also has greater intersection density, with about 33 intersections per mile in the sample 20-mph zones, and about 23 per mile in the New York.

Additionally, London's street network follows a less rectilinear street pattern than New York's. This difference is shown in two similar-sized zones from both cities, depicted below.

Figure 1 Street Networks in East Walworth (London, Left) and Alphabet City (New York, Right) 20-Mph Zones (in Same Scale)



It is not clear how these differences in street networks would affect the type and quantity of traffic calming devices needed to improve traffic safety in each city. It is possible that this difference leads to different travel patterns and movements for motorized vehicles, cyclists and pedestrians, and therefore necessitates the greater variety of measures found in London. However, it is also possible that the shorter segments and increased intersection density in London create safer streets even before any traffic calming intervention. Marshall and Garrick (2011) found that intersection density was negatively associated with total, severe and fatal crashes (denser street networks had fewer crashes), and speculated that this is due to lower speeds on street networks with higher intersection density. A review of literature on the effects of the built environment on traffic safety is consistent with this finding; overall, the research shows that "... the shorter the uninterrupted length of roadway, the slower traffic will travel and the less severe crashes will be" (R. Ewing & Dumbaugh, 2009, p. 354).

Next, it is possible that residential streets in London tend to serve as “through” streets more frequently, therefore necessitating a greater range and density of devices to effectively calm traffic. Indeed, “rat-running,” (Chris Grundy et al., 2009, p. 74) fast-moving motorized traffic cutting through residential areas to avoid congested, high-volume streets, was an important motivation for London’s boroughs to implement many of the 20-mph zones. If such through traffic is a relatively more serious problem in London than in New York, it could help explain the higher density of traffic calming devices in 20-mph zones in the former city.

Additional limitations in the comparison of street designs used in 20-mph in both cities include legal and cultural differences that may lead to different motorist, pedestrian and cyclist behavior, as well as different practices regarding enforcement of speed limits or dangerous driving or walking. The availability of transit could also impact the degrees to which authorities were able to implement street designs that restricted auto movements and parking in either city. Additional research, including qualitative data from interviews with planners in both cities, as well observational studies in the 20-mph zones, could help answer these questions.

However, the difference in devices transferred from London to New York is so great (about 5 times as many devices implemented per mile in London), that these differences in street network characteristics would only likely partially explain the differences in the traffic calming devices used in each city. As such, this large difference in the street designs of the 20-mph zones in the two cities likely contributed to the disappointing safety impact of the NSZs.

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Chapter Five

Conclusion

1 Neighborhood Slow Zones: Incrementally Improving New York’s Streets

This dissertation has examined the NSZ program in terms of environmental justice, its impact on traffic safety, and the policy transfer of street design. This conclusion includes a general discussion of the findings of the three empirical chapters, evaluates the methods employed, and outlines areas for future research. Despite the program’s shortcomings, this dissertation finds that the NSZs represent an incremental, not radical, step toward improving road traffic safety, environmental sustainability, and social equity in New York City.

The first empirical chapter showed that the NSZ program advanced environmental justice in New York City. Not only did the DOT distribute the zones equitably in minority and low-income parts of the city, but the agency also placed the NSZs in areas that could benefit from them considering of exposure to traffic injury. Further, the planning process that led to the siting of the zones was participatory and inclusive of environmental justice populations.

This is encouraging news and speaks to the DOT’s ability to reach diverse areas of the city and different populations. However, any enthusiasm for the NSZs generated by this finding must be tempered by the disappointing results of the second empirical chapter, which showed that the zones had not had a significant impact on traffic safety. This chapter’s quasi-experimental research design used treatment zones (NSZs) and a carefully selected comparison group to determine the impact of the intervention. The chapter used two types of “difference-in-differences” tests. Both analyses reached the same conclusion of no detectable impact on safety from the zones, reinforcing the validity of this finding.

The final empirical chapter used a policy transfer framework to determine if street designs used in the zones could have been a contributing factor to the lack of effectiveness of the NSZs. This chapter examined the policy transfer of area-wide traffic calming from London to New York, as the former city's 20-mph zones were the inspiration for the latter's, and had been found effective at reducing traffic casualties (Grundy et al., 2009; Li & Graham, 2016; Webster & Layfield, 2003). This analysis focused on differences in street designs used for area-wide traffic calming in both cities and found that the zones in New York used far fewer traffic calming devices, both in variety and quantity. Qualitative data and the policy transfer analysis revealed that cost (both capital and human resources), as well as public opposition to the removal of parking spaces, were barriers to the implementation of more robust street designs for traffic calming.

The last empirical chapter found that the type of transfer of street designs of 20-mph zones from London to New York (a "combination," as defined in policy transfer literature) contributed to the disappointing results of the NSZ program. Nonetheless, I argue that the program cannot be considered an implementation failure. Its successes include equitably distributing the zones in minority and low-income neighborhoods, including these populations in a participatory planning process, and implementing 28 slow-speed zones in a relatively short period of five years. Moreover, area-wide traffic calming had rarely been used in the US, making New York an "early adopter" (Rogers, 2010) of the policy, providing a starting point for refinement of this important traffic safety tool in this country.

2 Contributions to Knowledge

This research makes several original contributions to existing knowledge on traffic safety. First, despite the potential importance of the NSZ program to improving traffic safety in the US, there is only one published peer-reviewed study on the program to date (Jiao, Kim, Hagen, & Muennig, 2017). Although that study examined the effects of the zones on traffic safety, this dissertation's study of the same topic represents a significant improvement, because it uses a carefully matched comparison group and combines the results of both the treatment and comparison groups. While the first study found significant impacts of the zones, my study did not.

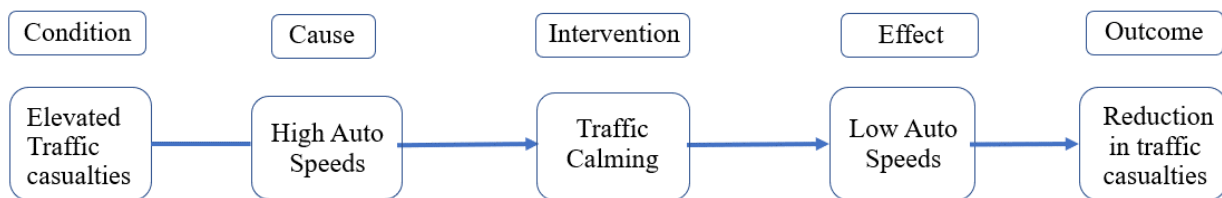
Next, the first empirical chapter analyzes a traffic safety program from a social equity perspective. While researchers have carried out similar analyses in the UK (Rodgers, Jones, Macey, & Lyons, 2010; Steinbach, Grundy, Edwards, Wilkinson, & Green, 2011), no similar peer-reviewed research exists in the United States. This gap is particularly pressing considering that minority and low-income populations are at greater risk of traffic injury (Cottrill & Thakuriah, 2010; Cubbin, LeClere, & Smith, 2000; Deka, 2004).

The final empirical chapter includes a detailed analysis of street designs used in 20-mph zones in two cities. While previous analyses (Ben-Joseph, 1995; Ewing, 2008) have identified different types of traffic calming devices used in different cities, this is the first analysis to also identify the quantity of devices used. This precise data allows for a more complete comparison of street designs for traffic calming, and taken together with the second empirical chapter, shows how street design contributes to traffic calming's impact on safety.

2.1 A New Model of Traffic Calming’s Safety Impacts

The evaluative literature of traffic calming I encountered, including meta-analyses (Bunn et al., 2009; Cairns, Warren, Garthwaite, Greig, & Bambra, 2015; Elvik, 2001) and studies of individual schemes (Grundy et al., 2009; Jiao et al., 2017; Vis, Dijkstra, & Slop, 1992) followed the assumption that high auto speeds led to elevated levels of traffic casualties and injury severity, and that traffic calming slowed speeds and thereby improved traffic safety. This theory has its roots in Haddon Jr.’s (Haddon Jr, 1970, 1980) theory of traffic injury, where speed plays a central role in the sustaining of traffic injuries. For Haddon, the human body’s capability to withstand mechanical violence is the basis of strategies to reduce traffic injury, and chief among these strategies is reducing the kinetic energy in the transport system. The implicit theoretical model of the research on the effects of safety outcomes of area-wide traffic calming is that the measure reduces traffic speed, thereby improving traffic safety. A diagram of the theory of the safety outcome of traffic calming implicit in the evaluative research is displayed in Figure 1 Theoretical Model of Safety Outcome of Traffic Calming.

Figure 1 Theoretical Model of Safety Outcome of Traffic Calming

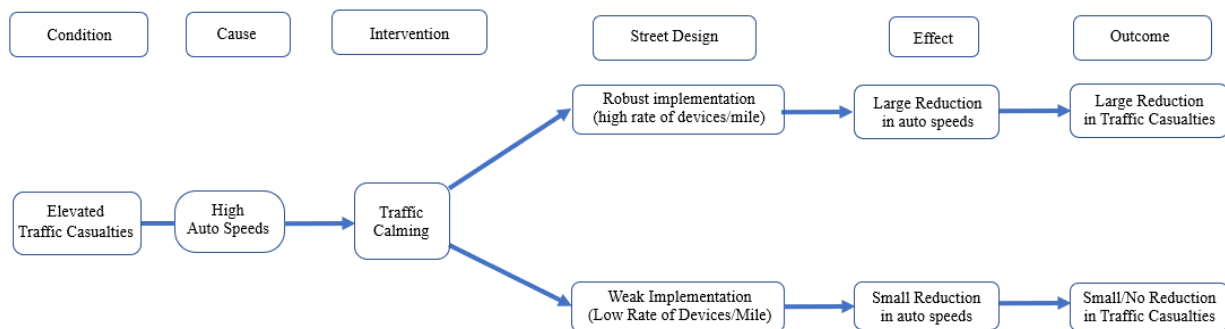


Although one meta-analysis emphasized that traffic calming had heterogeneous results (Bunn et al., 2009), and at least one study found no effects of traffic calming (Ewing, Chen, & Chen, 2013), previous research has not sought possible explanations for the lack of effectiveness

of the measure. Such explanations could reveal factors that lead to the measure’s effectiveness or lack thereof, allowing for a more nuanced theoretical model of the safety impacts of traffic calming.

London’s 20-mph zones included a robust implementation of street designs to calm traffic and improve traffic safety, whereas the NSZs were neither robustly implemented nor significantly reduced traffic casualty rates; it is plausible that the skeletal implementation of traffic calming devices contributed to the disappointing results in New York. This understanding of the effectiveness of area-wide traffic calming as related to the street design informs the theoretical model of the measure illustrated above. The new model of the effects of traffic calming considers the robustness of the street designs implemented, as outlined below. In this model, street design is an intervening variable, where robust implementation of traffic calming devices (high rates of devices/mile) leads to large reductions in auto speed and traffic casualties, while weak implementation leads to small reductions in speeds, and small or no effects on traffic casualties.

Figure 2 New Theoretical Model of Safety Outcome of Traffic Calming



This new theory of the safety outcomes of traffic calming helps explain the heterogeneity of the findings on the effectiveness of traffic calming encountered by previous researchers as well as for the difference between the results of the policy in New York and London. The model

can also help orient practitioners as to the expected results of the implementation of the policy. Naturally, it is probable other variables influence the traffic safety outcome of traffic calming, including the relative danger of the intervention site (e.g., number of pre-implementation traffic casualties). Future research can help provide evidence to support this theory, in addition to discovering other variables that can help explain the variation of the traffic safety outcomes of the policy.

3 Public Health Perspective in Planning

One of the overall aims of this dissertation was to contribute to the movement to reconnect urban planning with public health. This dissertation has done this in several ways.

The first empirical chapter of this dissertation used environmental justice perspective, which seeks to address the disproportionate burden of an environmental health risk on minority and low-income populations, to analyze the program. The following chapter employed methods commonly used in epidemiology to research the effects of the NSZs on traffic casualties. The final empirical chapter revealed that Vision Zero, a program that uses the theory of traffic injury developed by a prominent figure in public health, William Haddon Jr. (Haddon Jr, 1970; Johansson, 2009), to achieve greater road safety, was a potential barrier to a more complete transfer of traffic calming from London to New York. Under this program, DOT concentrated its resources to high-fatality locations, thereby diverting potential resources from the NSZ program.

Curiously, a program that puts public health concerns at the center of transportation planning (Vision Zero) became a barrier to the effectiveness of another transportation program that sought to improve public health (NSZs). In a context of limited resources, the agency made a

rational choice to prioritize high-fatality locations. Knowing that limited resources were an issue in the DOT's decision to de-emphasize the NSZ program could inspire stakeholders to seek additional resources for street safety and area-wide traffic calming.

Undoubtedly, reducing deaths and serious injuries from road traffic is the highest priority of traffic safety. However, these occurrences are relatively rare; only 0.4 % of overall casualties and 1.4% of pedestrian casualties were fatalities in 2015 (author's calculations (New York State Department of Transportation, 2017)). Therefore, only considering the most severe injuries could lead to an inadequate definition of the scope of the problem of dangerous streets. This notion is supported by an in-depth study of traffic injuries conducted at a Level I trauma center in Manhattan (Bellevue Hospital), where the authors concluded that the low mortality rate of traffic victims means that focusing on fatalities "fails to capture the true magnitude of the problem" (Dultz et al., 2013, p. 1143). Morency and Clautier (2006) argue that the area-wide approach should be used to improve pedestrian safety in Montreal, as pedestrian "black spots," places with high numbers of injuries, represented only 4% of pedestrian injuries; the same might be true in New York. In any case, it seems that area-wide traffic calming has an important role to play in New York as the city continues to strive for improved safety, environmental sustainability, social equity, and neighborhood quality of life.

The final empirical chapter also showed that a struggle for street space between those who wish to preserve automobility and those who seek to improve road safety is an important dynamic in the reconfiguration of streets as places that prioritize vulnerable user safety and comfort over motorists' ability to drive at high speeds and park their vehicles on the street. This conflict is part of the ongoing struggle to define the purpose of street space. This shows the relevance of the social constructivist lens, where the dominant definition of an artefact (streets) is

forged by ongoing social interactions. The question of what street space should be used for has become a contentious one in New York City in recent decades and has played out in very visible examples. These include the implementation of a pedestrian plaza in one of the city's most iconic places, Times Square, in 2009 (Mayor's Fund to Advance New York City, 2010), and a bike lane along the West side of Prospect Park, which outraged wealthy residents to the point that they brought a lawsuit against the DOT in 2011 (Robbins, 2011). While the NSZ program has certainly not resolved the conversation on the purpose of streets (thoroughfares for cars? places for child's play?), it has brought this discussion to neighborhoods throughout New York City.

4 Reflections on Methods

Each empirical chapter used the methods best suited to address their respective research questions. The mixed-methods used in Chapters 2 and 4 provided data that gave a much more complete perspective on the papers' respective topics (environmental justice of the NSZ program and policy transfer of 20-mph zones, respectively) than either purely quantitative or qualitative methods would have. Qualitative data provided information about the planning process of the NSZ program and the policy transfer and evolution of street designs in the NSZs; without this information, the quantitative data would have had insufficient context, and important dynamics related to the NSZs would have been unexplained. In the absence of the qualitative data, the reader would not be informed of important issues surrounding the program, such as the program's inclusion of poor and low-income communities in the planning process that led to the siting of the zones, or some residents' opposition to dedicating street space used for on-street parking to traffic calming. On the other hand, without the quantitative data in these studies, such as on the distribution of the NSZs in environmental justice areas of the city, or the quantity of

traffic calming devices used in London and New York, the qualitative data leave crucial questions unanswered (e.g., Were the NSZs equitably distributed in poor and low-income areas? Did the NSZs include robust street designs?). Taken together, the qualitative and quantitative data helped triangulate the information, adding context and validity to the findings.

Although the qualitative data adequately addressed the research questions of this dissertation, the number of interviews was quite low (four). These interviews did provide a wealth of relevant information, but additional interviews may have given further depth and breadth to the studies, or provided data for additional, complementary studies. Although I spoke briefly to community members from NSZs and conducted one interview, a stronger qualitative component would likely provide richer detail on the perceptions and impacts of the zones in the communities where the DOT implemented them. These interviews could be strengthened by observational data in the zones, particularly regarding interactions between motorists and vulnerable users. Site observation could provide data on auto speed, stopping, and near-misses in the NSZs, as well as in London's 20-mph slow zones. Such a comparison may or may not strengthen the case for more robust street designs in New York's zones.

The purely quantitative approach of Chapter 3 was equally well suited to research on the effects of the NSZs on traffic safety. The quasi-experimental approach effectively determined the impact of the program. This was evidenced by the difference between the "simple" (one-group) analysis, which found statistically significant impacts, and the disappearance of this impact after the introduction of the comparison group. The carefully matched comparison group strengthened the validity of the analysis and provided an implicit control for "regression to the mean," which might have led to overstating the NSZs' impact on traffic safety. The two "difference-in-differences" analyses, one that relied on t-tests and the other on OLS regression, had the same

results, further strengthening the robustness of the conclusion that the zones did not have a statistically significant impact on traffic safety. With a relatively large number of observations (over 2,000), this is likely due to ineffectiveness of the intervention, rather than a lack of statistical power, a threat to statistical conclusion validity that could lead to the conclusion that the relationship between the treatment and outcome is not significant (Shadish, Cook, & Campbell, 2002).

5 Research Agenda

Future research on area-wide traffic calming in New York and beyond should explore several areas. First, as additional years of traffic injury data become available, new studies should examine the effects of the NSZs on traffic injuries. When crash data for 2018 is available, the analysis can include two years of post-implementation data for all 28 zones. As additional years of data become available, analyses that use count data instead of rates, such as negative binomial regressions, should be conducted to determine if the NSZs are associated with traffic casualty reductions.

Future research on the traffic safety impact of the NSZs could also investigate the possibility that the NSZs had different effects on pedestrians and cyclists. According the DOT, cyclist risk of injury decreased considerably between 2000 and 2016 (New York City Department of Transportation, n.d.) ; it would be interesting to see how this may have played out in the NSZs.

Next, while this study has examined the effect of the zones on traffic safety, future research could explore other possible impacts, such as reductions in speeds and volumes of motorized traffic, improvements in air quality, and increases in walking or cycling. Other possible areas to research are improvements to quality of life, perception of safety and comfort

for vulnerable street users, increased opportunities for child's play; qualitative methods would be well suited to investigate these topics. The interviews with the DOT and the advocacy group Transportation Alternatives revealed that community members of NSZ areas generally felt that the NSZs had a positive impact; this contrasts with the finding that the zones were not associated with lower casualty rates. Interviews with members of communities living in NSZs would help illuminate these issues.

Chapter 4's study of the policy transfer of street designs from London to New York revealed unanswered questions of relevance to practitioners who wish to implement traffic calming more robustly. Chief among these is how planners in London were able to implement the street designs in the Slow Zones from a cost perspective, as these were likely much more expensive than those used in the NSZs. This research should also explore London's planners' ability to sacrifice on-street automobile parking for traffic calming devices – did these planners face opposition from the public regarding the loss of parking, and if so, how did they manage this opposition? Finally, the implementation of the measure on wider, higher-volume streets in London, the equivalent of “arterial” roads in the US, is of great relevance to traffic calming's potential safety impact in New York and beyond. Additional qualitative data from interviews with planners in both cities would help answer these questions. This qualitative data could also help address study limitations outlined in Chapter 4 related to the possible confounding influence of differences in cultural and enforcement practices, and transit availability.

As pointed out in the previous section, observational studies from 20-mph zones in both cities would assist in clarifying possible variations in the impacts of street designs used. Do the more robust street designs used in London's Slow Zones translate into safer and more comfortable conditions for vulnerable street users? Data gathered from observations of

interactions between motorist and vulnerable user interactions in 20-mph zones in both cities would help answer this question.

The qualitative data in Chapter 4 also raised questions about the appropriateness of low-cost, pilot implementations of street interventions. Since 2008, the New York City Department of Transportation pioneered the use of low-cost, temporary measures to test changes to road geometry and create additional pedestrian space, e.g., in Times Square, Madison Square, and along sections of Broadway. This approach has been celebrated by various actors concerned with improving public space, who have referred to it as “lighter, quicker, cheaper” (Project for Public Spaces, 2011) and “tactical urbanism” (Lydon & Garcia, 2015). It has been used in cities throughout the US, including Boston, San Diego, and Dallas.

However, in the case of the gateways with “daylighting,” the low-cost approach may have had drawbacks. For example, some residents perceived that autos increased their speed as they drove around the painted curb extensions. Had these curb extensions been implemented with higher-cost concrete or landscaping, this may not have been the case. Such low-cost interventions may not always be the most appropriate option; the tradeoffs between inexpensive pilot projects versus higher-cost modifications to streets deserve further investigation.

Traffic calming’s role in the coming decades is uncertain, as the transportation scenario, at least in wealthy countries, appears to be heading toward a future of autonomous vehicles and “smart cities” (Fagnant & Kockelman, 2015; Glasmeier & Christopherson, 2015). Automated vehicles include safety features to prevent collisions with vulnerable street users. As such, planners may decide they do not need to pursue traffic calming to improve safety for people walking and biking. However, planners may want to consider the following reflection by researchers writing about traffic calming over a quarter century ago:

But all this about physical speed reducing measures-is it not a thing of the past’?- and is not the future in fitting each vehicle with a speed regulating device picking up signals from a transmitter at kerbside? No, automatic speed regulation by using modern electronics is quite a long way into the future, in our opinion. Even if it is technically feasible today, as experimental set-ups have already demonstrated, its general practical use is still a long way off. The entire car manufacturing industry would have to approve it and to agree on international standards. (Kjemtrup & Herrstedt, 1992, p. 64)

The authors above point out the political obstacles to technologically enforced speed regulations, and the need for planners to pursue traffic calming in the face of the uncertain outcome of this debate. This debate that has existed at least since 1923, when safety advocates in Cincinnati unsuccessfully attempted to pass legislation requiring autos to use “speed governors” (Norton, 2011, p. 96), which would shut autos down if motorists exceeded 25 miles per hour. Considering the uncertain promise of increased safety from automated vehicles, researchers should continue to contribute knowledge of how to implement traffic calming, a measure that has proven potential to increase safety.

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