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Exploring the Impact of Select Speed-Reducing Countermeasures on Pedestrian and Bicyclist Safety

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16. Abstract

This project explored efforts to reduce speed and evaluated them based on their effectiveness in improving safety for pedestrians and bicyclists. This project included two phases. Phase 1 was a program scan that identified countermeasures in use throughout the United States. Based on findings from the program scan, the project team evaluated speed safety camera enforcement and road conversions in five municipalities to explore their impact on motor vehicle-related pedestrian and bicyclist crashes. Speed safety camera enforcement evaluations showed some potential for reductions in pedestrian and bicyclist crashes with results limited to one type of deployment in one location. Evaluations of road conversions showed potential reductions in pedestrian and bicyclist injury crashes and mixed results for total injury-related crashes.

Phase 2 of the project evaluated safety benefits of a select group of temporary road conversions implemented in response to the COVID-19 pandemic. A scan for localities identified locations with temporary installations to create space for pedestrians and bicyclists. This phase included an evaluation that found some crash reduction benefit in the short term and identified quick-build installations and promising measures to test conversion designs before permanent installations.

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Executive Summary

Vehicle speed contributes to both the likelihood and severity of crashes involving pedestrians and bicyclists. Efforts to manage vehicles' speeds involve many different approaches – some reduce posted or default speeds, some use different enforcement methods, and others use infrastructure to slow vehicles. This project aimed to evaluate these efforts to lower speeds through their impact on pedestrian and bicyclist safety.

The project consisted of two main phases. In Phase 1, the project team began with a program scan of efforts across the United States to reduce vehicle speeds. The team identified a selection of speed-reducing countermeasures and, through different channels, found localities that had previous or ongoing programs. In the first step of the program scan, the team listed localities that had implemented speed safety cameras (SSC), high-visibility enforcement, speed limit reductions, road conversions (RCs), and traffic-calming. After discussions with several localities, the team selected two countermeasures and five localities to proceed with an evaluation: SSC in Boulder, Colorado, Seattle, Washington, and Washington, DC; and RCs in Minneapolis, Minnesota, San Francisco, California, and Seattle, Washington.

The team developed a data collection manual and working with agencies at each locality, collected roadway characteristics, volumes, and crash data. For SSC, data were selected for roadway segments with cameras (treatment segments), sites adjacent to segments (near-treatment segments), and reference segments (similar segments not near treatment segments used as a control comparison to evaluate changes). For RCs, the team collected data for treatment segments and reference segments. In the evaluation, the team first developed safety performance factors (SPFs) to estimate expected safety outcomes on each segment. The SPFs were then used to generate crash modification factors (CMFs), estimates of the impact of a treatment on crash outcomes based on a comparison between actual crash numbers and what would be expected given past trends.

Road conversions were divided into two groups, four-lane to two-lane conversions (San Francisco and Seattle) and three-lane to two-lane conversions (Minneapolis and San Francisco). For four-lane to two-lane RCs, the analysis found a CMF for total injury-related crashes of 0.95 and for pedestrian and bicyclist injury crashes of 0.90. These CMFs indicate a 5% reduction in total injury crashes and a 10% reduction in pedestrian and bicyclist injury crashes. For the three-lane to two-lane RCs, the analysis found a CMF of 1.26 for total injury crashes and 0.81 for pedestrian and bicyclist injury crashes. These values indicate a crash increase for total injury crashes of 26% and a reduction in pedestrian and bicyclist injury crashes of 19%.

The analysis of SSC was performed on each locality separately because each program had different deployment sites and regulations, meaning they were not the same treatment across localities. Boulder had a mobile SSC program with cameras on vans that moved from site to site. No segment continuously had a camera in place, therefore, it was not possible to form definite before treatment periods for analysis. The team attempted to develop an SPF to identify if having a camera at any point in the study period affected safety outcomes. However, in the models for developing an SPF, SSC did not emerge as a contributor to safety.

Seattle had an SSC program based completely in school zones with cameras operational when school zones were active. For the treatment segments (segments with a camera), the analysis found a CMF of 1.32 for total injury crashes and 0.82 for pedestrian and bicyclist injury crashes. This indicates a 32% increase in total injury crashes and an 18% reduction in pedestrian and

bicyclist crashes. For near-treatment segments (segments near the section with a camera), the analysis found a CMF of 1.04 for total injury crashes and 0.95 for pedestrian and bicyclist crashes, indicating a 4% increase in total injury crashes and a 5% decrease in pedestrian and bicyclist crashes.

Washington, DC, had fixed camera sites deployed throughout the city. For these segments, the team only had complete total injury crash data throughout the before and after treatment periods. The analysis found CMFs of 1.37 and 1.14 for treatment and near-treatment segments. These both indicate total injury crash increases of 37% and 14%, respectively.

Overall, both RCs and SSCs showed mixed results for crash reduction of pedestrian and bicyclist injury-related crashes with CMFs in some cases showing crash reductions and others showing no effect or even crash increases. More data would inform the reasons for these changes. Volume data that is more complete for vehicles, bicyclists, and pedestrians, may add insight to fluctuations in use on the roads being evaluated. Although implemented with the intent to reduce speeds, in many cases speed data are not available to analyze pre/post countermeasure speed changes so there is no way to determine if speeds decreased. Among some segments with available speed data, analyses showed increased speeds and decreased vehicle volumes after countermeasure installation. With speed data, the evaluation could link these treatments with observed speed reductions and potential improvements in safety.

Phase 2 of the project presented case studies of quick-build transportation projects in response to the COVID-19 pandemic. The project aimed to evaluate projects that served as temporary versions of the RCs in Phase 1. The team began the project with a scan for localities with projects that reallocated lanes to create more space for pedestrians and bicyclists. The scan resulted in a short list of cities with example projects: Atlanta, Georgia; Chapel Hill, North Carolina; and Los Angeles, California. Following the scan, agencies submitted available data about the projects and provided narrative about the projects' purpose.

Atlanta implemented a temporary multiuse lane for about half a mile in one-direction to reduce a section of roadway from three lanes to two lanes. In Chapel Hill, the town and State Departments of Transportation installed a multiuse lane in two directions, reducing a street from four lanes to two lanes. Finally, in Los Angeles, the city implemented a permanent RC on a six-mile length of roadway to reduce lanes from four to two with a center turn lane (three lanes total) and add bike lanes in both directions. Based on the available data, these projects combined show the potential short-term benefits in terms of crash reduction from quick-build projects. In addition, quick-build projects offer the chance to test designs that could lead to longer-term changes.

Introduction

In 2021, the United States experienced an estimated 42,915 motor vehicle fatalities (National Center for Statistics and Analysis, 2022a). Pedestrians have made up an increasing share of fatal crashes since 2012. In 2012, pedestrians made up 14% of those killed in crashes. By 2020, that share had increased to 17% (NCSA, 2022b). Speed contributes to nearly 30% of fatal crashes overall and around 9% of crashes involving pedestrians and bicyclists (NCSA, 2022c, 2022d). Speed also contributes to both a greater chance of serious injury and greater chance of fatality for a pedestrian struck by a vehicle. The chance of serious injury rises from 25% at 23 mph to 50% with an increase of only 8 mph to 31 mph (Tefft, 2011). Similarly, the chance of a pedestrian fatality when struck by a vehicle, grows from 25% at 32 mph to 50% with an increase to 42 mph. Chances of serious injury or fatality reach 90% with speeds of 46 mph and 58 mph, respectively. As with pedestrians, bicyclists also see increased likelihood of death at higher speeds.

States and municipalities have employed many different countermeasures aimed at reducing speed on the roadway. These can involve behavioral campaigns, different enforcement methods, changes to signing, or changes to the physical roadway. Some efforts aim to have a direct impact on speed, while others have several effects, such as allocating space for other road users, that include speed reduction. This project explores efforts to reduce speed and their impact on the safety of bicyclists and pedestrians.

The project was divided into two phases with the results from Phase 1 guiding the efforts in Phase 2. Phase 1 included a scan of localities implementing speed-reducing treatments and an evaluation of the speed reduction countermeasures for pedestrian and bicyclist safety benefits. Phase 2 involved a scan for localities with temporary RCs in response to the COVID-19 pandemic followed by several case studies of two selected countermeasures (SSCs and RCs) with evaluation of available crash data.

Phase 1: Overview

Phase 1 proceeded along the following steps.

- Identification of countermeasures and agencies
- Development of the data collection guidelines for each countermeasure
- Coordination with local agencies for data collection
- Preparation of data for analysis
- Evaluation of data by locality and countermeasure

Identification of Countermeasures and Agencies

Program scan

To identify countermeasures used to reduce speed, and localities where these countermeasures have been deployed, the project team completed a program scan of potential localities across the United States. The program scan was completed through several routes, discussed below, to identify potential sources of data for the project. To guide identification of these sources, the team developed a list of example speed reduction strategies.

- Lowering speed limits, either on specific corridors or locality-wide
- Operating speed enforcement cameras
- Redesigning roads to lower speeds
    - Road diets, changes in number and/or width of vehicle lanes to lower speed and add capacity of non-motorized modes
    - Roundabouts
- Conducting long term traditional speed enforcement efforts (i.e., not a short-term, high-intensity campaign).

(Educational efforts or strategies were not asked about specifically but were addressed and mentioned if an agency brought up educational strategies or program components.) These speed reduction strategies were included in an open call for information that was distributed to the National Highway Traffic Safety Administration regional offices and Federal Highway Administration (FHWA) staff. In addition, the team used its institutional knowledge and experience to identify localities that may have employed these countermeasures. An Insurance Institute for Highway Safety database of speed camera enforcement programs provided information on States and cities where SSC was in use. The team also worked with staff members at the National Association of City Transportation Officials (NACTO) to seek information on cities in its network. Finally, through online searches, the team looked for any materials that would identify localities where any countermeasures to reduce speeds have been widely used.

During the program scan, the team maintained a database of potential localities with details on the type of countermeasure, the length of time they have been deployed, contact information for agencies, and any information on data availability. The program scan began with a list of 63 candidate localities. Team members were responsible for initial outreach to agencies at their assigned localities. When contacts responded to the outreach, a group of team members met on the phone to discuss the project, hear an overview of what speed-related countermeasures were in that locality, and discuss data availability and the willingness of the agency to share those data.

Initial scan results

The following list provides details on the localities with which the team was able to engage and obtain more details on its speed-reduction efforts.

Speed safety cameras

Boulder, CO

Description: The police operate the speed enforcement cameras through mobile deployment in vans. A sign is deployed warning drivers when the van is present. The Colorado-legislated penalty is relatively low, consisting of a $40 civil fine and no effect on driving points. The fine doubles if the violation occurs in a school zone. In comparison, a citation in Seattle from SSC will cost $139 and if speeding occurs in a school zone the fine increases to $237.

Scale of Implementation: Boulder has operated its speed camera program since 1998. Around 40 distinct locations are treated, including some school zones. Since 2007, vans have deployed around 4,000 hours per year.

Site Selection Criteria: Locations for deployment were selected by the police and were influenced by a knowledge of sites where more violations were expected to occur.

Data Availability: Boulder has data available from the deployment of cameras that detail speeds, traffic volume, and citations for each location and time the cameras are in use. The city has crash data only back to 2009 and is currently working its crash data into a new system that will better link the data to corridors. Officials indicated that it would be easy to identify which crashes involved a pedestrian or bicyclist.

Previous Evaluations: Boulder conducted a minimal non-rigorous study to evaluate whether speed camera vans cause motorists to drive slower. Results indicated that consistent deployment of the speed camera vans did influence speed. Their evaluation did not involve control locations.

Other Information: Boulder representatives indicated that they would be able to identify control sites (e.g., corridors/locations where the mobile speed cameras were rarely/never deployed).

Seattle, WA

Description: Seattle installed SSCs in school zones, in an effort they call *School Zone Safety Cameras*. They posted gateway signs on highways entering the city about photo enforcement of traffic laws.

Scale of Implementation: SSC was implemented in 2015 at nine school zones. When contacted, SSC was used in 15 school zones.

Site Selection Criteria: Sites were selected by examining the number and percentage of drivers exceeding the school zone speed limit.

Data Availability: Seattle tracked speed, citation, and crash data before and after camera installation. Citywide data on pedestrian and bicyclist crashes are available. They have modeled traffic volume estimates and pedestrian/bicyclist volume estimates for the entire network, including neighborhood streets.

Previous Evaluations: Seattle conducted a simple before-after analysis of the effect of the school zone cameras and published the results in its Vision Zero 2017 Progress Report (City of Seattle & Seattle Department of Transportation, 2017).

Washington, DC

Description: SSC was initially operated through cameras mounted on vehicles but transitioned to fixed location cameras over the years. The SSC program is part of a larger photo enforcement program that also includes red light running enforcement, stop sign running enforcement, and oversize vehicle enforcement (consisting of citing vehicles operating in lanes in which they are not allowed). Other measures that accompany these cameras are large yellow signs indicating "photo enforcement area." These signs are present constantly, even if no active camera is operating. SSCs are typically installed on two-lane roads with 35 mph speed limits. A few cameras are present on higher speed limit roads, but none are installed on roads with speed limits over 50 mph.

Scale of Implementation: Washington, DC, has been operating SSC since 1999. When contacted, the city was operating approximately 80 to 90 SSCs.

Site Selection Criteria: The SSC sites were selected according to crash data, citizen requests, and other internal priorities. The selection was informed by a study conducted by a contractor.

Data Availability: The Washington, DC, website shows the locations of the SSC equipment. Citation data are available for the treatment locations for at least the last 5 years and crash data for these areas are available and are geo-coded and crash typed. Roadway inventory data available from the city are limited. The spatial roadway inventory consists of segments by classification, but they did not have an inventory for all the roadways at the time of inquiry, nor geometric elements such as number of lanes and lane width. Traffic volume data were stored separately from roadway inventory and were not yet directly linkable. However, before and after traffic volume data are available for the SSC sites, since it was collected as part of the warrant evaluation process. Warrants in general are specific circumstances that must be present for a countermeasure to be installed. Cities and States set warrants based on speeds, crashes, or other indicators. For example, there may need to be a certain number of crashes before a crosswalk becomes eligible for a signal or a combination of high rates of speeding and crash numbers may make a corridor eligible for a speed camera. The city's data team assisted with compiling the more difficult data types. The SSC equipment can collect speed data, but it's not typically collected except during pre-installation as part of an eligibility study and for speeding violations when the cameras are active.

Previous Evaluations: Retting and Farmer (2003) examined the effect of the Washington, DC, SSC program on vehicle speeds and found that the vehicles' mean speeds at Washington sites declined by a statistically significant 14% compared with Baltimore sites without SSC, and the proportion of vehicles exceeding the speed limit by more than 10 mph declined 82%. They did not evaluate the effect on crashes. DC DOT also does some speed studies. However, the speed data were not comprehensive of the whole area covered by SSC and were not provided for this evaluation.

Chicago, IL

Description: Chicago implemented SSC at approximately 100 locations as part of its *Children's Safety Zone Program*. City ordinance narrows the hours and locations of speed safety camera use that are allowed under State law and specifies certain limitations. The enforcement hours are limited from 7 a.m. to 7 p.m. in safety zones around schools on school days (Monday through Friday). The enforcement hours around parks are limited to only those hours parks are open (typically 6 a.m. to 11 p.m., 7 days a week) with a 30-mph speed limit. Fines for violations are $35 for vehicles traveling 6 to 10 mph over the posted speed limit while in a safety zone, and $100 for vehicles traveling 11 or more mph over the posted speed limit.

Scale of Implementation: At the time of inquiry, 150 locations were equipped with SSCs, 86 of which enforced speed in one direction of traffic and 64 enforced speed in both directions. All locations were either school zones or park areas. Most cameras were activated for enforcement in 2013 or 2014, depending on the specific site.

Site Selection Criteria: Camera locations were chosen based on available data regarding traffic, speeding, and crashes. The city established six geographical regions wherein no fewer than 10% of speed enforcement safety zones would be located in each region. Several crash types are considered in the safety zone selection process, namely, total (all crashes reported), bike/ped (vehicle crashes involving a bicyclist or pedestrian), serious/fatal (crashes resulting in a serious or fatal injury), youth (crashes involving a person 18 or younger), and speed (crashes where the reporting officer indicated speed as a cause of the crash).

Data Availability: Chicago provided a list of SSC locations with warning live and citation live dates. Before and after crash data are available in geospatial format for all treated sites and potential reference sites. Chicago roadway files contain AADT (average annual daily traffic) information for 2005, 2009, 2013, and 2015. Pedestrian count data are available for many locations in the downtown area but less available outside the downtown. Chicago makes much of its data available online through its website: www.cityofchicago.org/city/en/depts/cdot.html.

Previous Evaluations: Chicago conducted its own simple before-after study using speeds and crash data. It compared percent reductions in various crash types between the treated sites and the citywide average. Using a comparison of 1 year of before data to 1 year of after data, it found that total crashes decreased by 4% in the SSC locations compared to a 10% increase in crashes citywide and that fatal or serious injury crashes decreased 11% compared to a 2% increase citywide. It did not appear to control for traffic volume or other trends.

Other Information: Additional information about Chicago's *Children's Safety Zone Program* is available on the city's website at www.cityofchicago.org/city/en/depts/cdot/supp_info/children_s_safetyzoneporgramautomaticspeedenforcement.html.

Scottsdale, AZ

Description: Scottsdale uses SSCs on 6 corridors. This information was gleaned from an evaluation report delivered to the team by a contact in our initial program scan outreach familiar with Scottsdale's program, not through direct communication with Scottsdale staff. Additionally, the Scottsdale police operate mobile photo enforcement speed vans.

Scale of Implementation: Four corridors were activated in 2007; the other two were activated in 2013.

Site Selection Criteria: Unknown.

Data Availability: The report on Scottdale's SSC program contains a list of the corridor locations accompanied by the date of SSC activation. Crash data were used in a previous evaluation, but it is unknown whether reliable data on pedestrian and bicyclist crashes and volumes are available for these corridors.

Previous Evaluations: There was an evaluation study conducted by a consultant for the city of Scottsdale in 2016 that evaluated the effect of the SSC on crashes. This study examined the effect on total, rear-end, and speeding-related crashes but did not focus any specific analysis on pedestrian or bicyclist crashes. The study found that SSC reduced the total number of crashes compared to control corridors.

Other Information: For additional information about Scottsdale's SSC program, visit www.scottsdaleaz.gov/police/photo-enforcement.

Speed limit reductions

Portland, OR

Speed limit reductions on collectors and arterials

Description: Portland has reduced speeds on certain collectors and arterials. Arterial roadways cover longer-distance trips and often have several lanes and higher traffic volumes. Collectors cover shorter distances to connect local roads with arterials, so they have smaller volume capacity than arterials. Some speed limit reductions also involved street design changes like road diets and pedestrian island installations. However, many of the recent reductions did not include design changes. Most of the speed limit reductions consisted of 5 mph reductions.

Scale of Implementation: This strategy was implemented on 26 collector and arterial streets from 2013 to 2017.

Site Selection Criteria: This effort started through a high-crash corridors project where the streets targeted for speed reductions were high-crash corridors.

Data Availability: Portland maintained a spreadsheet of locations where this strategy was implemented; some of which have implementation dates. For certain corridors where they conducted a simple before-after evaluation, they collected before and after vehicle speeds, traffic volumes, and crash data. Crash data for all corridors are available through the statewide database maintained by Oregon DOT.

Previous Evaluations: Portland conducted individual evaluations on several of the treated streets, particularly on the streets where road design changes accompanied the speed limit reduction. Portland provided reports on these individual evaluations. Pedestrian and bicycle count data are available for some corridors. In three of the reports, the city evaluated speed limit reductions that occurred along with lane reconfigurations as well as other additions to the roadways. The three reports analyzed crash and speed data in the short-term after the changes and compared with past data. The city found reductions in crashes and overall reductions in speeds on the roadways for each.

Other Information: Portland did not typically conduct heightened enforcement efforts for these speed limit reductions.

Speed limit reductions on residential streets

Description: Portland reduced the speed limit on all its residential streets from 25 mph to 20 mph. At the time of the speed limit change, approximately 2,000 new speed limit signs were installed, including installations on streets that had not previously had any speed limit signs. This speed limit reduction was advertised heavily through a one-page flyer that described the speed limit reduction (sent with the property tax mailer to reach 350,000 households), yard signs reading “20 is plenty,” local media coverage, and social media.

Scale of Implementation: This reduction took effect in April 2018 and affected 70% of the Portland street network.

Site Selection Criteria: This was a citywide effort.

Data Availability: Crash data for all streets are available through the statewide database maintained by Oregon DOT.

New York City, NY

Speed limit reductions on city streets

Description: New York City reduced speed limits from 30 mph to 25 mph for almost all city streets and has been retiming signals on all the arterials for the slower progression. While speed limit changes have been enacted, signal retiming is still in progress. The speed reductions were accompanied by the installation of 4,700 new speed limit signs as well as an education campaign carried out by the NYC DOT and law enforcement to prepare residents for the changing speed limits.

Scale of Implementation: These reductions were implemented widely across the city largely in 2014.

Site Selection Criteria: This was a citywide effort.

Data Availability: Before and after data are available for crashes and traffic volumes. Pedestrian volumes are available in selected locations around the city. New York widely provides its transportation data through online portals.

Previous Evaluations: Evaluation of the citywide speed limit reductions is limited and has included vehicle speed reduction assessments and fatality and crash analysis but did not focus any specific analysis on pedestrian or bicyclist crashes. Zhai et al. (2022) found significant spillover effects in speed reduction and a decrease in fatal crashes.

Speed limit reduction on neighborhood streets

Description: NYC has been implementing a Neighborhood Slow Zone program, which enacts a 20-mph limit in neighborhoods, done primarily with speed humps and signs as shown in Figure 1.

Figure 1. Street in New York before and after conversion to a Neighborhood Slow Zone. Image credit: NACTO

Scale of Implementation: These reductions were implemented widely across the city largely in 2014.

Site Selection Criteria: This was a citywide effort.

Data Availability: Before and after data are available for crashes and traffic volumes. Pedestrian volumes are available in selected locations around the city. The city collected before and after speeds in Neighborhood Slow Zones.

Other Information: See the city's website for a list of the neighborhood slow zones and more information on the specific neighborhood efforts at www.nyc.gov/html/dot/html/-motorist/slowzones-list.shtml.

Seattle, WA

Description: Seattle reduced speed limits throughout the city. They enacted policy changes to reduce the statutory arterial speed limit from 30 mph to 25 mph and neighborhood streets from 25 mph to 20 mph as well as posted gateway signs on highways entering the city. In the downtown area, they retimed signals to a 25-mph progression speed in conjunction with lowering the default arterial speed limit. They also reduced speed limits in certain "urban village" areas, which are denser neighborhood centers throughout Seattle, outside of the downtown, that feature a mix of land uses as well as access to transit.

Scale of Implementation: The speed limit reductions were enacted in 2016. The neighborhood street speed limit reduction affected 2,400 miles of street. The urban village speed limit reduction occurred in 2017.

Site Selection Criteria: This was a citywide effort.

Data Availability: The city maintains a map showing arterials where speed limits were reduced and the downtown area where signals were retimed. Crash data are available before and after speed limit reduction, and citywide data on pedestrian and bicyclist crashes are available. They have modeled traffic volume estimates and pedestrian and bicyclist volume estimates for the entire network, including neighborhood streets.

Previous Evaluations: Seattle has conducted some internal evaluations of selected arterials and urban villages under its Vision Zero program. These evaluations were independent of the internal SSC evaluations.

North Carolina

Description: NCDOT reduced speed limits for many rural corridors from 55 mph to 45 mph. They installed new speed limit signs to indicate this change.

Scale of Implementation: The speed limit was lowered on 27 corridors, with implementation dates in either 2017 or 2018. These comprise 110 miles of road.

Site Selection Criteria: Unknown.

Data Availability: NCDOT collected before and after speed measurements for these corridors. They also collected before and after speeds on another 18 corridors where speed limits were not reduced. Before and after crash data and traffic volumes are available for the sites. Exposure data are not available for pedestrian or bicyclist activity.

Other Information: Given that almost all these corridors are rural roads, there is likely to be minimal pedestrian activity. There may be some bicycle activity in the form of recreational riding.

Boston, MA

Description: Boston reduced the default city speed limit from 30 mph to 25 mph (for any location with no speed limit sign) as part of its Vision Zero safety efforts. Additionally, they replaced old 30 mph speed limit signs with new 25 mph signs. They publicized this change through a widespread outreach campaign.

Scale of Implementation: This was a citywide effort, implemented in 2016.

Site Selection Criteria: Speed reductions were implemented widely across the city, but reductions did not include school and safety zones or areas where traffic-calming was in place. It also did not include larger streets such as limited access highways or major arterial streets where traffic is intended to travel faster.

Data Availability: Unable to determine data availability due to lack of response from city staff.

High-visibility enforcement

San Francisco, CA

Description: San Francisco conducted an HVE campaign aimed at speeding. It also conducted community engagement regarding speed reductions in which community groups raised awareness in its neighborhoods about speed and the enforcement campaign accompanying the speed reductions.

Scale of Implementation: Police conducted the HVE and collected data on 11 corridors and collected data as well on 11 control corridors. For the HVE effort, the police conducted focused events weekly over a period of one year (with 48 events planned), from October 2016 to September 2017.

Site Selection Criteria: San Francisco's treatment corridors were selected based on crash histories related to speed.

Data Availability: San Francisco collected a large amount of data suitable for this study. Before the campaign, they did pre-test data collection. Data collectors used lidar for speed readings on the same day as the HVE enforcement activity, an hour before, during, and then about a week after. They collected data during free flow, uncongested times. They also collected survey data using intercept surveys of pedestrians during the pre-enforcement and post-enforcement periods and data on the overall number of citations and rate of citations per hour that each corridor received during the targeted enforcement events.

Boston, MA

Description: The team received initial information from Massachusetts DOT that Boston has conducted HVE in priority areas. The State DOT contact indicated that Boston did not collect speed data as part of this effort. The city did not provide more information when asked.

Road conversions

Seattle, WA

Description: Seattle has implemented road diets consisting mostly of four-lane to two-lane conversions with two-way left turn lanes and bike lanes.

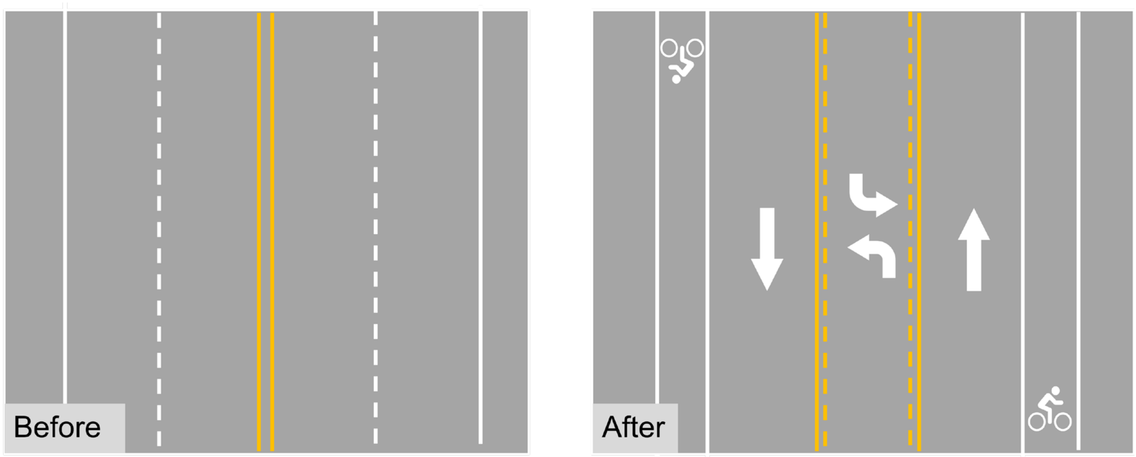

Figure 2. Example of four-lane to two-lane with center turn lane RC

Scale of Implementation: Road diets were implemented at 18 locations (total of 12 miles of road) with installation dates ranging from 2006 to 2014. There are an additional 21 locations where road diets were implemented a longer time ago (from 1972 to 2006) but the availability of data for this time period is not reliable.

Data Availability: Seattle has maintained a database of road diets with implementation years, before and after total crashes, traffic volumes, detailed pedestrian volumes, site conditions, and other data. They conducted before speed studies on most road diet projects but have not typically collected after data. Citywide data on pedestrian and bicyclist crashes are available. They have modeled traffic volume estimates and pedestrian and bicyclist volume estimates for the entire network, including neighborhood streets.

Minneapolis, MN

Description: Minneapolis implemented several projects to reduce both lane widths and the number of travel lanes through road diets and restriping. The major goal of these projects was to add bicycle facilities to these corridors. These projects all required special design exceptions (i.e., an experimental MUTCD (Manual on Uniform Traffic Control Devices) exception for the bike lane symbols and colors and below standard lane width for State standards) to be installed. Some locations were one-way streets that were reduced from two lanes to one lane.

Scale of Implementation: The city implemented 3 to 5 miles of projects per year beginning in the early 2010s, for a conservative estimate of 12 miles of treated streets.

Site Selection Criteria: These projects were implemented opportunistically when resurfacing or reconstructing on the corridor was already scheduled to occur.

Data Availability: The city does not maintain a centralized list of these projects, but such a list was developed based on its internal records and knowledge of agency staff. Speed data are available for some corridors. Crash data were available up to 2017. At the time the team held discussions and began collecting data this was the most recent time through which data were available because of the need for the city to manually code the crashes and the time it took for the State to review. Minneapolis maintains a web portal that provides a map of pedestrian and bicyclist daily traffic counts: www.minneapolismn.gov/bicycles/res/WCMS1P-135614. These pedestrian and bicyclist counts are available annually from 2007 to 2017.

Previous Evaluations: Minneapolis developed a report documenting the evaluation of 16 bicycle treatments and street design elements installed by Minneapolis Public Works in 2011 and 2013 (City of Minneapolis, 2017). The purpose of the Minneapolis report was to fulfill the final evaluation reporting requirements of FHWA's approval of six experiments under Experiment 9(09)-6, and the Minnesota Department of Transportation's approval of eight design exceptions under State Projects 141-091-020 and 141-091-022. This report included two additional local evaluations for bicycle-related projects installed in Minneapolis at the same time. Minneapolis evaluated projects to estimate safety performance and how they affected users all in relation to setting. Impacts considered included observed bicyclist behavior and motor vehicle driver behavior. Minneapolis also surveyed users to understand their perceptions of the treatment. For the treatments that converted roadways, either by lane width or lane reductions, to add lanes for bicyclists, the city found high rates of compliance with most motorists keeping out of bicycle lanes and most bicyclists riding in bicycle lanes.

Traffic-calming

Washington, DC

Description: Washington, DC, has implemented traffic-calming measures on many residential streets, including speed humps, speed tables, barriers, closures, neighborhood slow zones, and lane width reductions.

Scale of Implementation: DC staff estimate that more than 1,000 traffic-calming devices have been installed in recent years, mostly consisting of speed humps.

Site Selection Criteria: Warrants (requirements that must be met for installation) for speed humps use volume (minimum of 1,000 AADT) and minimum 85th percentile speed being 25%

higher than the posted speed and mean and pace speeds. The city has a process for citizens to request traffic-calming in its neighborhood.

Data Availability: Representatives from the city indicated that installation data are difficult to obtain. It is not known how many installations have complete records, but the city had recently inventoried all the signing and could be able to identify the locations. In addition, the installation dates may be difficult to determine. The dates should be available in its work order data, but the extent of the coverage for all traffic-calming installations is not accurately known at this time. For these reasons, moving forward with conducting an evaluation on the effectiveness of traffic-calming in the city would be difficult.

Final locality selection

Following delivery of the above program scan summary, the team discussed internally and with NHTSA staff, the countermeasures and agencies to potentially pursue for an evaluation. These discussions resulted in a shortlist of countermeasures and localities. For SSC: Seattle, Boulder, Washington, and New York City were considered for the shortlist. For RCs, Seattle, San Francisco, New York City, and Minneapolis were recommended for evaluation.
The project team pursued contacts at each locality to further identify which agencies and people would best serve as a point of contact for obtaining data. These conversations also served to formalize agreements with the agencies to provide data. The project team produced an official project description and offered data use agreements if necessary. Following discussions with agency contacts, the team decided that a lack of data availability would preclude New York City from supporting the project needs. In total, the program scan resulted in a selection of two countermeasures, SSC and RCs, and five localities: Seattle, Boulder, Washington, DC, San Francisco, and Minneapolis. Final selections and details are summarized in Table 1 and Table 2 below.

Table 1. Final localities for evaluation of SSC

Location	Countermeasure Details	Data Available	Years for Evaluation
Boulder, CO	Mobile vans	• Van deployment times/locations • Street characteristics • Crash data • Vehicle, pedestrian, and bicycle volumes	2009 to 2018
Seattle, WA	School zone cameras	• Street characteristics • Crash data • Vehicle, pedestrian, and bicycle volumes	2009 to 2018
Washington, DC	General, fixed camera deployment	• Street characteristics • Crash data • Vehicle volumes	• 2008 to 2018 (total crashes) • 2012 to 2018 (pedestrian/bicyclist crashes)

Table 2. Final localities for evaluation of RCs

Location	Countermeasure Details	Data Available	Years for Evaluation
Minneapolis, MN	• Three-lane to two-lane • Lane width narrowing without lane removal • Addition of bike lanes	• Street characteristics • Crash data • Vehicle, pedestrian, and bicycle volumes	2007 to 2017
San Francisco, CA	• Four-lane to two-lane with and without center left turn lanes • Three-lane to two-lane	• Street characteristics • Crash data	2008 to 2018
Seattle, WA	• Four-lane to two-lane with center left turn lanes	• Street characteristics • Crash data • Vehicle, pedestrian, and bicycle volumes	2009 to 2018

Data Collection

This section provides details of how data were collected for the study sites and illustrates the steps taken to process the collected data.

Data collection manual

A data collection manual was created to allow for consistency in identifying and coding study sites between the selected cities. Different approaches were taken for SSC and for RC sites.

Speed safety cameras

The SSC approach varied between cities during the study period. Boulder used mobile vans parked alongside street segments (including school and non-school segments) over varying lengths of time, Seattle used fixed cameras at school zones that operated only during school hours, while Washington, DC, used fixed location cameras. The study cities provided a list of SSC sites and the approach used.

Roadway data collection for SSC involved defining and coding the treatment sites, near-treatment sites, and reference sites. Treatment sites are roadway segments where the fixed camera or mobile van was placed, delineated by the nearest public street intersection on each side of the camera position. If major characteristics for one part of a treatment corridor differed (i.e., the speed limit or the number of lanes changed), then the treatment corridor was divided into two treatment segments. For each treatment segment, a group of near-treatment segments was identified, which are segments on either side of the treatment segment intended to capture any extension of the SSC effect. Near-treatment sites are segments starting at an end of the treatment segment and extending to the next public street intersection. Segments were defined in this way until 1,000 feet on either side of the treatment segment was captured. Reference sites are segments that match the number of lanes and traffic volume range of the treatment sites but did not see enforcement. In locations where SSC covered school zones, the reference sites are segments adjacent to school zones that did not have treatment.

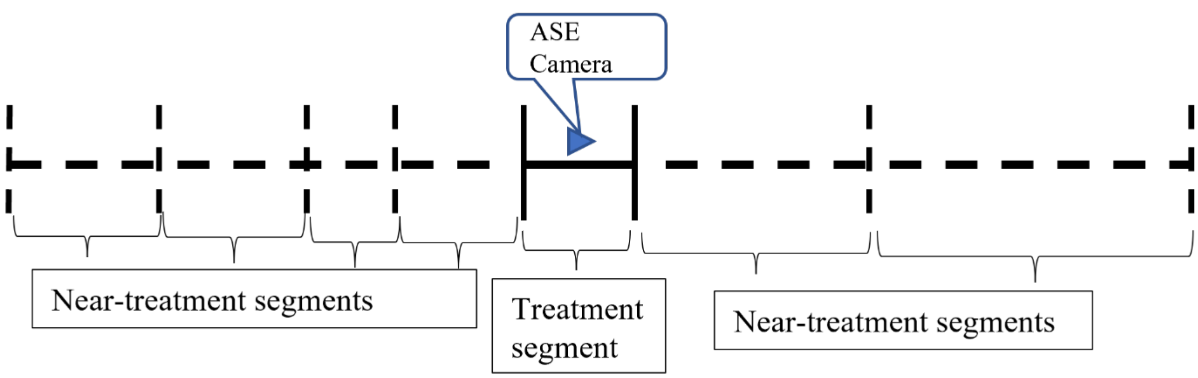

Figure 3. Diagram of SSC segment types with reference to camera location

Note: Solid lines and intersections are part of the treatment segment. Dashed lines and intersections are part of the near-treatment segments.

Intersection inclusion differed between segment types. Treatment segments were bounded by the first public street on each side. These segments included the two intersections on both ends as well as any intersections in the segment itself. Intersections within the treatment segments included driveways and parking lot entrances. Crashes that occurred at the two end intersections were coded as occurring on the treatment segment. Near-treatment segments were coded as having one intersection because the other intersection is included as part of the treatment segment. Crashes at the intersection at the farthest end from the treatment segment were coded as occurring on that near-treatment segment. For reference segments, if the segment is not bordered by another reference segment, both intersections were included in the data collection; however, if the reference segment is bordered by another reference segment, each intersection was assigned only to one reference segment, like the near-treatment site arrangement.

Road conversions

The specific RCs implemented varied between and among study cities. Examples of RCs include a reduction in the number of motor vehicle travel lanes, adding bike lanes, removing parking lanes, narrowing travel lane width, reducing the speed limit, removing a centerline, and adjusting traffic signal timing.

Treatment sites and reference sites were identified and coded for the three RC cities. The treatment sites are segments where the RC was implemented along the entire section of the roadway. If major characteristics for one part of a treatment corridor differed (i.e., the number of lanes before the RC was implemented), then the treatment corridor was divided into two separate segments. The reference sites are segments that match the treatment sites in terms of the distribution of the number of lanes, road division, traffic volume range, and the number of intersections before an RC was implemented. Near-treatment sites were not identified for RC.

Data Collection by Location

Boulder, CO

Boulder is an SSC city with mobile vans collecting speed data using photo radar over varying lengths of time per site. The project is managed by the Boulder Police Department and the vans are marked as official City of Boulder vehicles. A sign is deployed with the vans to warn drivers of the enforcement. The van operator programs the photo radar to activate when a vehicle is traveling at least 10 mph over the speed limit. There were 45 sites operating between 2012 and 2017 that were examined in the study, including sites within school zones and residential neighborhoods. Deployment in school zone sites only occurred during school hours. Each deployment site consisted of a street block, in cases where two or three adjacent blocks of the same street were enforced at different times, the blocks were combined into one treatment segment. Near treatment sites were identified by moving outward from treatment blocks or segments. Reference sites were identified by finding segments with similar characteristics to the deployment sites.

Boulder provided descriptions of SSC sites, dates of mobile van deployments, amount of time deployed in hours, the number of vehicles overall and per hour for each deployment, the number and percent of violations, and the highest speed recorded during deployment. Boulder also provided road segment GIS files and the 85th percentile speed before, during, and after deployment.

Boulder provided AADT volumes for 2013 only. To provide estimates of volume for later years, more complete sets of volume data from roads not included in the study to calculate growth factors were used. This involves using these data to find an average change from 2013, the base year for obtained observed volumes. Average annual daily pedestrian and average annual daily bicycle (AADP and AADB) volumes were collected and joined with existing study segment GIS files. AADP data were available for 2013 through 2015 only; AADB data were available as counts factored to 2013 values.

Crash locations from police crash reports were identified using Crash Magic,[1] an online graphic display and summary package. The study team was provided a login to access crash data by the vendor. The data from the program were exported into Excel, added as a table in ArcGIS Desktop,[2] and visualized in a map using provided latitude and longitude coordinates before being joined to the street segment file using a spatial join. A spatial join is a function in ArcGIS that links the collected data with the spatial data to create a database of the attributes or events at a site and can be represented on a map. These data were then exported back into Excel and sorted by year and severity. Crashes were from 2009 to 2018 and include all severities as well as pedestrian and bicyclist crashes.

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[1] Pd' Programming, Inc, Lafayette, CO. www.pdmagic.com

[2] Esri, Redlands, CA, originally founded as Environmental Systems Research Institute, Inc. www.esri.com

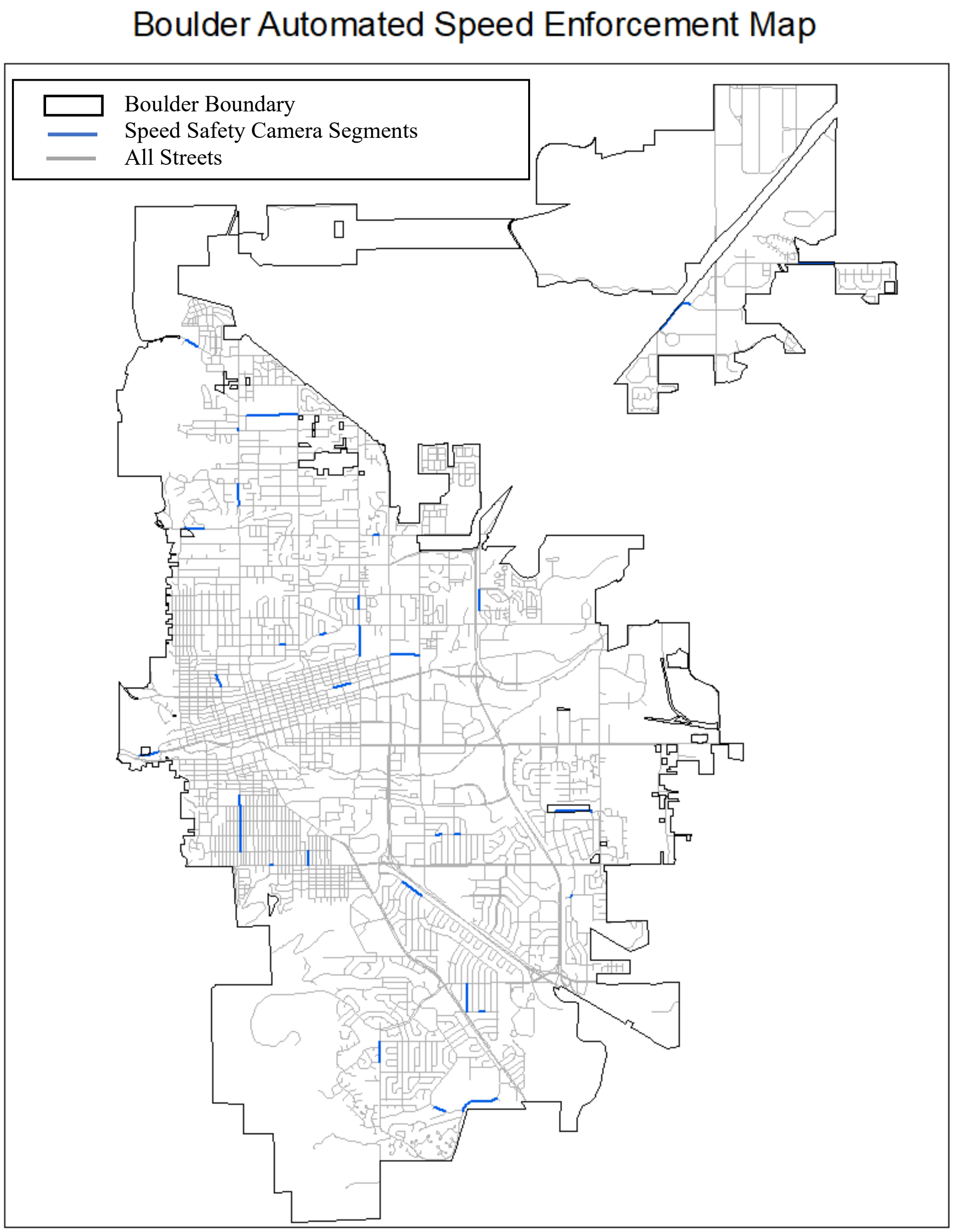

Figure 4. Map of SSC locations in Boulder, CO

Minneapolis, MN

Minneapolis RC used several approaches to lower speed including removing travel lanes, removing parking lanes, reducing lane width, and adding bicycle lanes. The city provided a list of 22 treatment sites along with specific details on installation, prior condition, treatment installation data, reason for installation, and road segment GIS shapefiles. The study team identified reference sites by examining street data for corridors that matched the treatment site conditions before RCs were implemented. Treatment and reference segments were identified in ArcGIS and saved as a separate shapefile.

The study team analyzed satellite imagery using Google Maps to identify road segment variables. Examples of these include the number of lanes before and after treatment, presence of parking lanes before and after treatment, travel lane width before and after treatment, whether the segment is one or two-way, the number of intersections and the count of signalized or unsignalized intersections, the number of transit stops and transit lines (bus and train), and the percent of bicycle lanes on one and both sides before and after treatment.

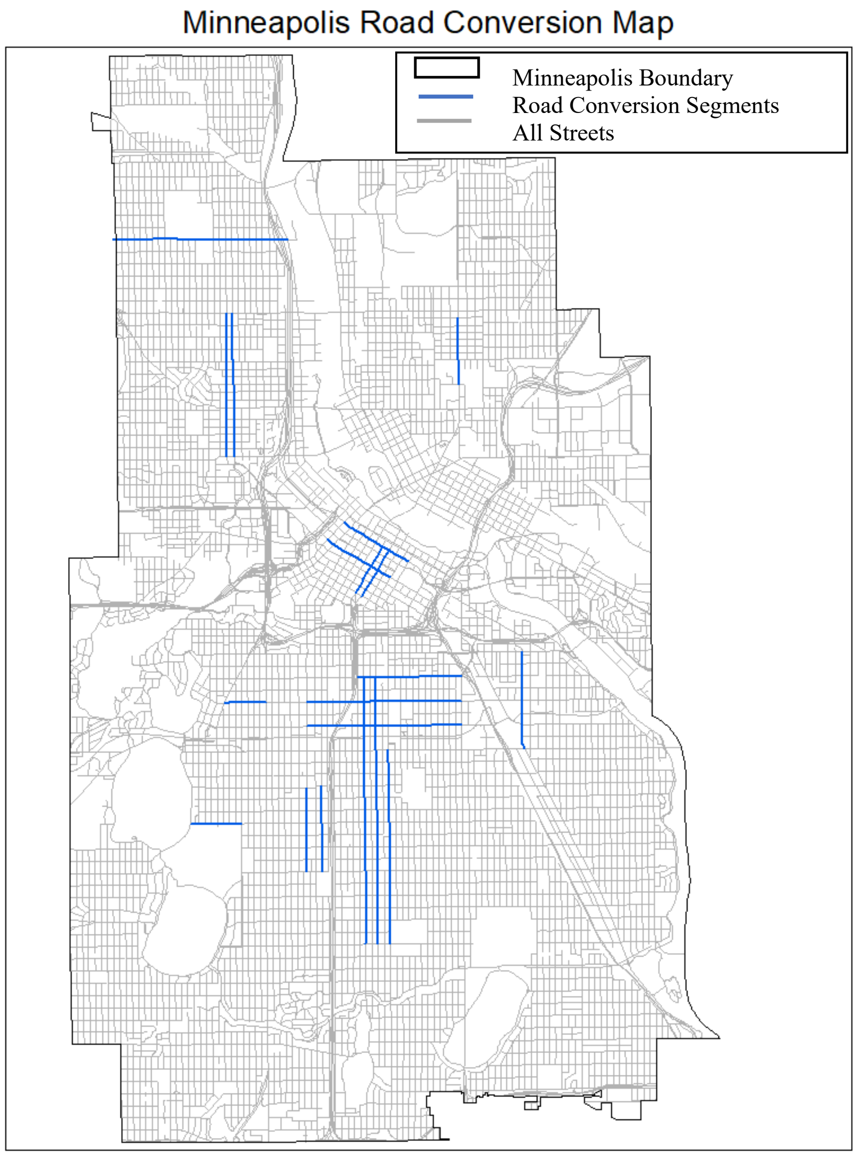

Figure 5. Map of RC locations in Minneapolis, MN

The MS2[3] Traffic Count Database System (TCDS) was used to find AADT volume. MS2 TCDS is an online platform that provides traffic count data for many locations throughout the United States. Data were recorded by study segment and year, an average value was calculated and used where several counts were recorded on a single segment in the same year. If clear differences in

[3] MS2, Ann Arbor, MI. www.ms2soft.com

road segments prevented the use of averages, then all AADT values were recorded in an east to west or north to south order. AADP and AADB volumes were found using the Minneapolis Online GIS portal.

Crash data were provided by Minneapolis for 2007 through 2017. The data were added to ArcGIS and saved as a shapefile. ArcGIS's Spatial Join tool was used to join the street segments shapefile to the crashes shapefile to identify occurrences on study segments. All severities, as well as pedestrian and bicyclist crashes, were provided.

San Francisco, CA

San Francisco used RC for its lower speed approach through removing travel lanes, narrowing travel lane width, removing parking lanes, and adding bike lanes including protected bike lanes. A total of 60 treated corridors were treated. The city compiled a list of street segments that underwent conversions in a Word document. Additionally, a link was sent to Transbase (https://transbase.sfgov.org/dashboard/dashboard.php), a website that links transportation systems to health. A database connection to Transbase was set up in ArcGIS to access a street shapefile, this shapefile was used to select RC segments and was also queried to determine reference sites that had similar characteristics to the treatment sites before any conversion.

Volume data for San Francisco were too limited to be useful for the study. AADT values were recorded for some street segments, but they were limited to one year only. The street shapefile included pedestrian volumes, but no year was provided. Bicycle volume was missing from the datasets.

Crash analysis for San Francisco was limited to injury or fatal crashes only. The city provided the study team with crashes occurring from 2008 to 2018, but property damage only crashes were excluded. ArcGIS was used to create a crash shapefile, then the RC shapefile was buffered by 5 feet to accommodate crash points not being directly on the street shapefile line. The Spatial Join tool was then run to join the crashes to the RC segment buffer. Pedestrian and bicyclist crashes were included.

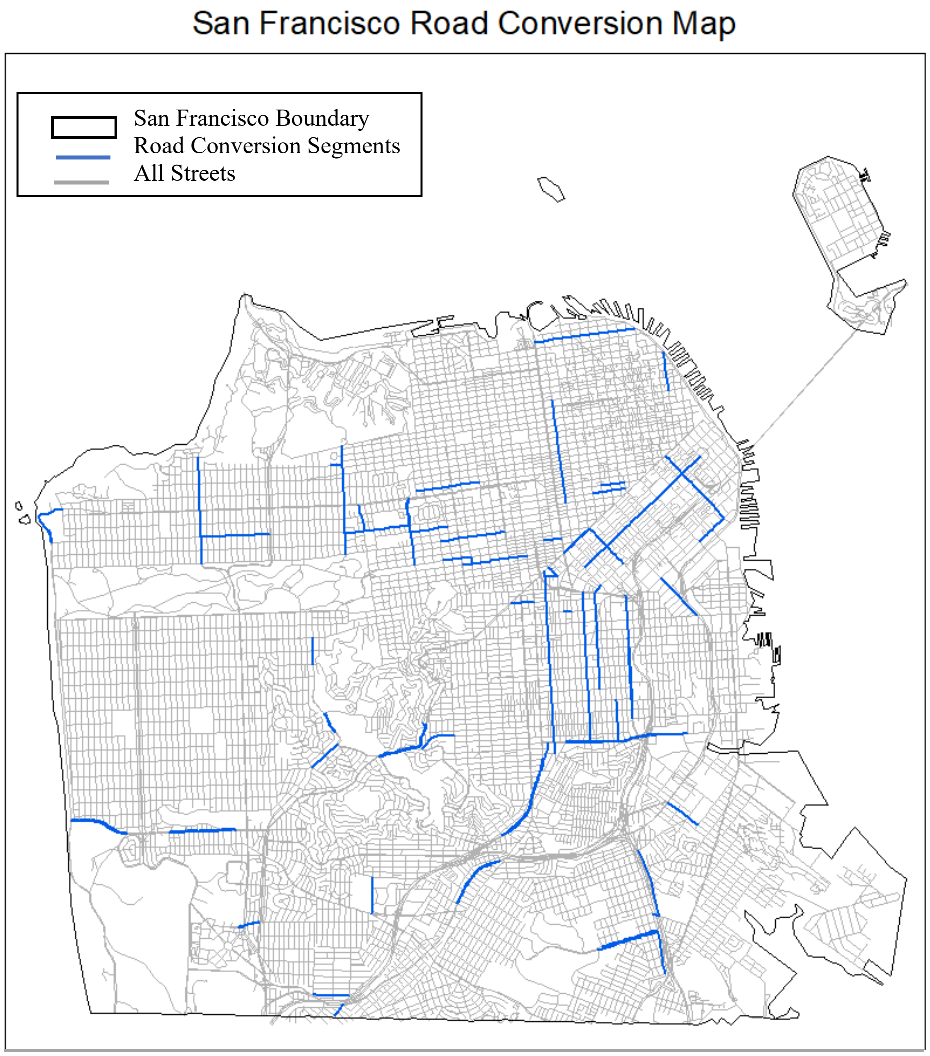

Figure 6. Map of RC locations in San Francisco, CA

Seattle, WA

Seattle used both SSC and RC for its lower speed approach. The study team analyzed both approaches separately. Seattle's third approach, reduced speed limits, was not selected for further evaluation in this project.

The SSC program in Seattle involved fixed cameras in school zones that operate during school hours. The criteria for implementing speed enforcement at a particular school were the number and percentage of drivers exceeding the school zone speed limit. For the project, the city provided data from 17 sites for analysis. These comprised of two-lane to four-lane streets and included "Photo Enforced" signs at the beginning of the zone. A Seattle streets shapefile was queried to identify treated sites. Additionally, the study team used the streets shapefile to select school zones most like the enforcement sites for reference sites.

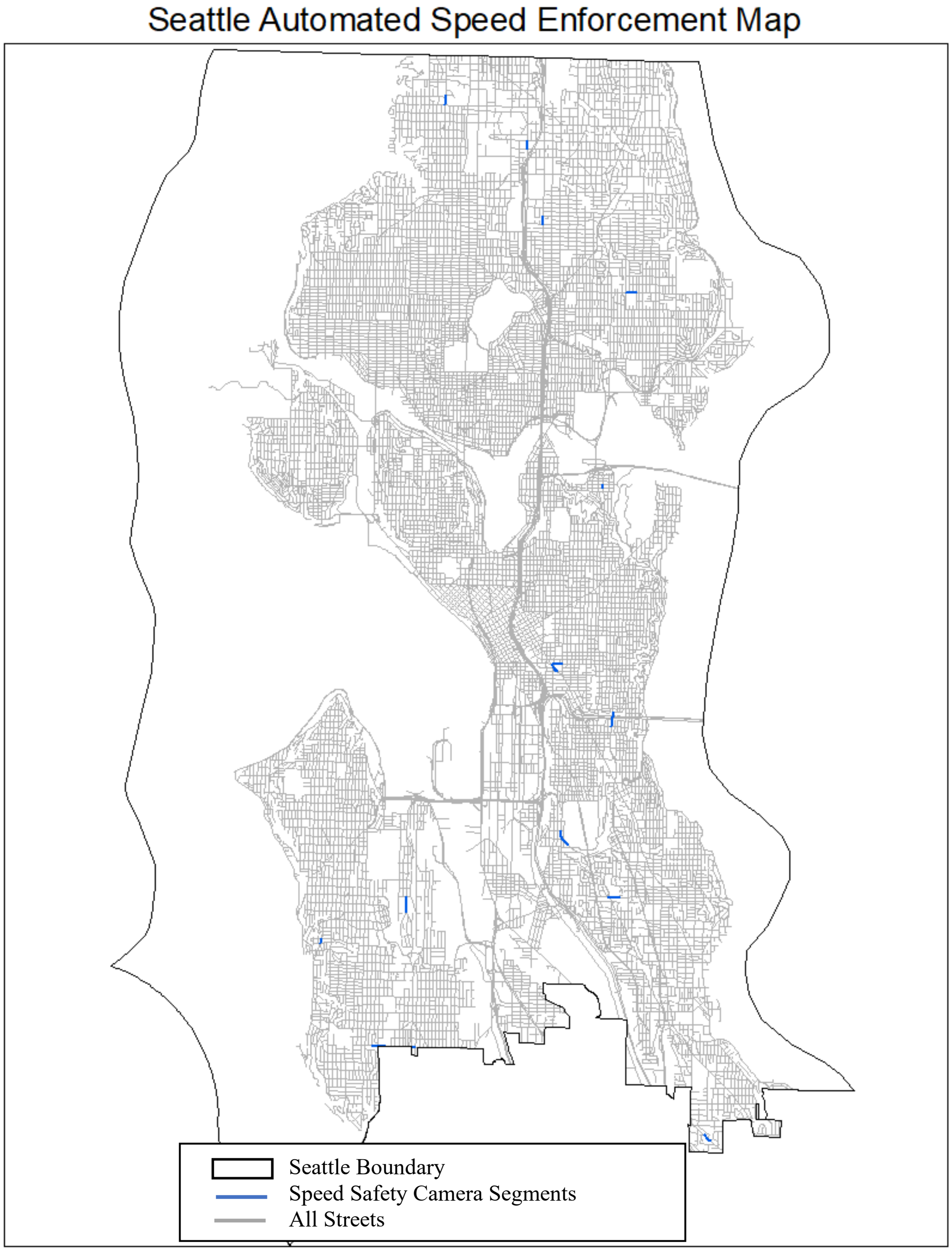

Figure 7. Map of SSC locations in Seattle, WA

Seattle's RCs approach involved removing travel lanes, reducing travel lane width, reducing speed limits, removing street centerlines, adding speed cushions, implementing transit improvements, and adjusting traffic signal timing. The Seattle Department of Transportation (SDOT) provided a list of 31 treated corridors. The study team selected four-lane roadways most like the treated segments for an initial list of reference sites, SDOT reviewed these and provided recommendations for suitable reference segments.

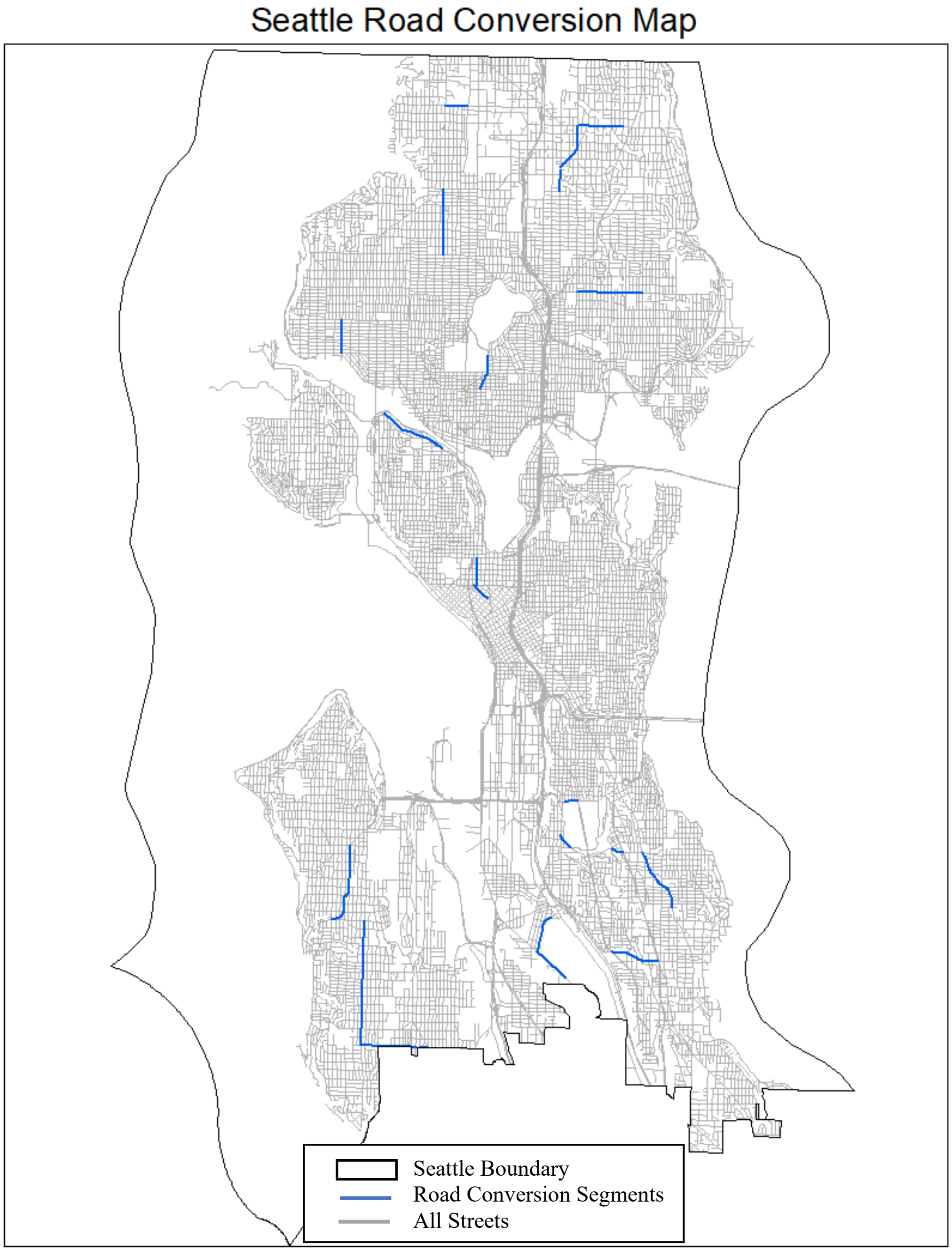

Figure 8. Map of RC locations in Seattle, WA

The approach to determine vehicle volume data for Seattle differed between SSC and RC datasets. For SSC sites, data from the SSC shapefile and from a traffic counts shapefile obtained from Seattle's Open Data web portal were intersected in ArcGIS to identify all study segments with Annual Average Weekday Daily Total (AAWDT) counts by year. These were then compiled by using a weighted average (by segment length) for each year within a given site. AAWDT values of neighboring treated segments were assumed to be representative of near treatment segments. For RC sites, data were taken from the Open Data web portal and merged into a single shapefile. This file was intersected in ArcGIS with the study sites to produce a dataset of all the AAWDT segments that overlap a study segment. These AAWDTs were then compiled using weighted averages for each segment by year.

Determining AADP and AADB values also differed between SSC and RC segments. For SSC sites, these were provided at the block level for Seattle and were joined with the SSC shapefile in ArcGIS using a common variable. Next, the values were compiled using a weighted average by segment length for each mode. For RC sites, individual blocks were provided with predicted values that were then combined for each mode to produce a weighted average by segment length for each study segment.

Crash data for Seattle were provided by the city for 2008 through 2018. To analyze, crash data were joined to the nearest study segment in ArcGIS using a Near operation, then a table join was used to eliminate double counting of crashes. Two 'EZ coding' fields were created to allow for an easier summary when exporting to Excel. PivotTable tools were used to summarize the crash data.

Washington, DC

Washington, DC's SSC program involves fixed cameras at sites that were selected from crash data, citizen requests, and other internal priorities. SSC locations are shown on the map in Figure 9. The study team analyzed data from road segments at 65 camera sites. The study team identified treatment, near, and reference sites as well as provided AADT volumes where available. AADP and AADB were not provided and could not be obtained.

Crash data were downloaded from the DC OpenData web portal (https://opendata.dc.gov) and included 2008 to 2018 for motor vehicles and 2012 to 2018 for pedestrians and bicyclists. To analyze, the data were projected in ArcGIS and joined to a shapefile of study street segments. The Near tool was then used to identify crashes that were plotted within 10 feet of a segment, and those identified segments were joined to the crash data using the common "Near_FID" field. The crash records were then exported to Excel where they were summarized using a PivotTable.

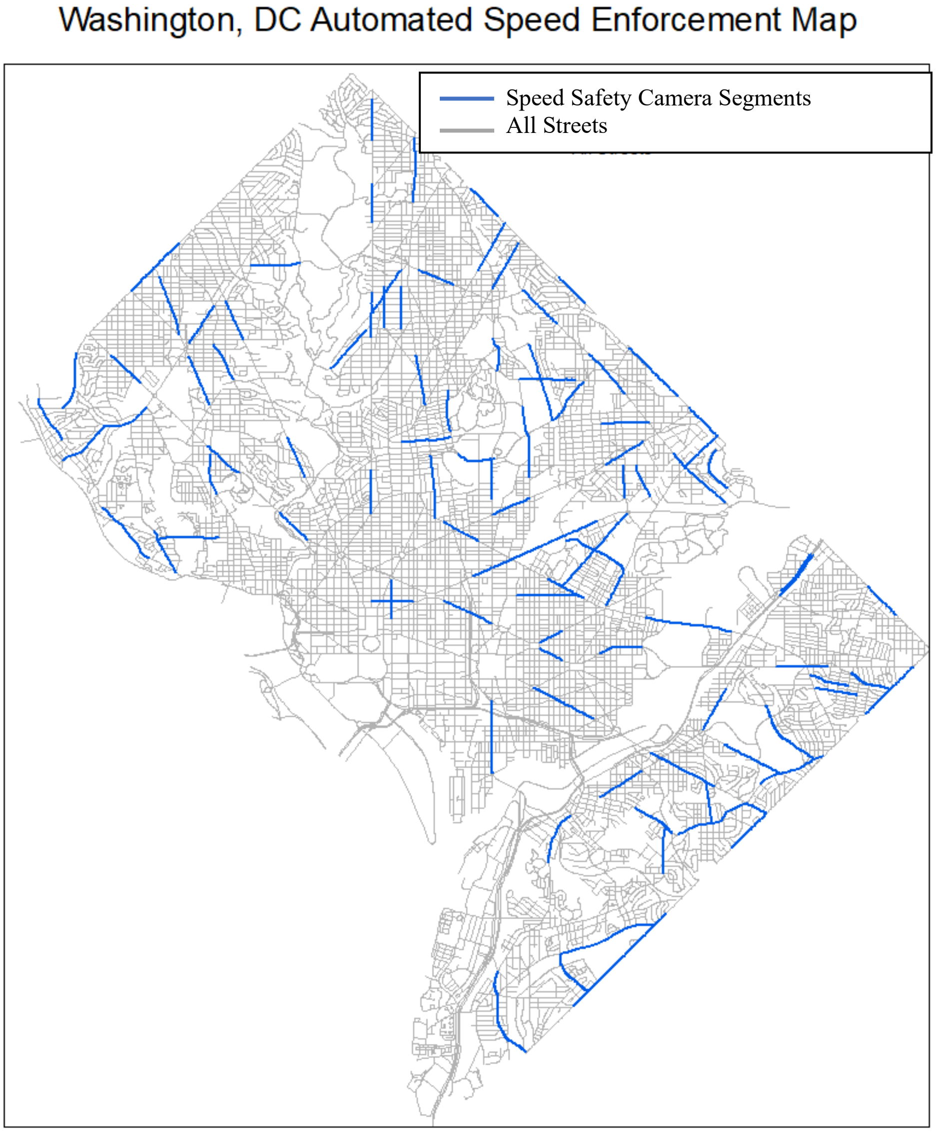

Figure 9. Map of SSC locations in Washington, DC

Methodology

General procedure for safety analysis

Step 1: Checked the data to identify any errors. If errors were found, then the data were revisited and rechecked.

Step 2: For AADT, if there were any missing values in the Seattle SSC and Washington SSC data files, default values were assigned to those sites without an AADT. For Minneapolis RCs, because missing years were not consistent across the study period, average volume from before the treatment and after the treatment period was used for treatment sites.

Step 3: Checked the distributions of the categorical variables, some categories might be combined based on the distributions.

Step 4: A few density variables were generated such as number of signalized or unsignalized intersections per mile.

Step 5: Processed the data to define the before and after periods for the empirical Bayes (EB) before-after or cross-sectional analysis.

Step 6: Developed negative binomial models.

Step 7: Obtained CMFs, a measure of the expected change in crashes associated with a specific treatment. For cross-sectional analysis, CMF values can be derived from the models. For the EB method, the SPFs can be used to calculate the EB estimate. SPFs estimate crash rates based on volume on the roadway using crash history. The CMFs can then be calculated using the equations.

Analysis methodology

The two common methods for estimating CMFs are cross-sectional and the EB before-after. Of these two the EB before-after method has now been accepted as one way of addressing the potential bias due to regression to the mean (Hauer, 1997). However, there are some treatments for which before-after studies may not be possible due to unavailability of data from the before or after period. In those cases, researchers rely on cross-sectional studies to develop CMFs. These two methods were used to evaluate the SSC and RC treatments according to the available data. For the Boulder SSC treatment evaluation, the EB method cannot be applied since there was not clear before and after data, and thus the cross-sectional method was applied instead. The study team used the EB method to evaluate the safety effects of the RC treatment in Seattle, Minneapolis, and San Francisco and the SSC treatment in Seattle and Washington, DC. The two methods are described below:

Empirical Bayes analysis

In the EB approach (Harkey et al., 2008; Hauer, 1997; Hauer et al., 2002), the change in safety for a given crash type at a location is given by:

$$\lambda - \pi \qquad (1)$$

where λ is the expected number of crashes that would have occurred in the after period without treatment and π is the number of reported crashes in the after period.

In estimating λ, the effects of regression to the mean and changes in traffic volume were explicitly accounted for using SPFs relating crashes to traffic flow and other relevant factors. Annual SPF multipliers were calibrated to account for the temporal effects on safety of variation in weather, demography, crash reporting, and so on.

In the EB procedure, the SPF is used to first estimate the number of crashes that would be expected in each year of the before period at locations with traffic volumes and other characteristics like the one being analyzed. The sum of these annual SPF estimates (P) is then combined with the count of crashes (x) in the before period at a treatment site to obtain an estimate of the expected number of crashes (m) before treatment. This estimate of m is:

$$m = w_1(x) + w_2(P), \qquad (2)$$

where the weights w_1 and w_2 are estimated from the mean and variance of the SPF estimate as:

$$w_1 = P/(P + 1/k) \qquad (3)$$

$$w_2 = 1/k(P + 1/k), \qquad (4)$$

where k is a constant for a given model and is estimated from the SPF calibration process with the use of a maximum likelihood procedure. (In that process, a negative binomial distributed error structure is assumed with k being the dispersion parameter of this distribution.)

A factor is then applied to m to account for the length of the after period and differences in traffic volumes between the before and after periods. This factor is the sum of the annual SPF predictions for the after period divided by P, the sum of these predictions for the before period. The result, after applying this factor, is an estimate of λ. The procedure also produces an estimate of the variance of λ, the expected number of crashes that would have occurred in the after period without treatment.

The estimate of λ is then summed over all sites in a treatment group of interest (to obtain λ_{sum}) and compared with the count of crashes during the after period in that group (π_{sum}). The variance of λ is also summed over all sections in the treatment group.

The Index of Effectiveness (θ) is estimated as:

$$\theta = (\pi_{sum}/\lambda_{sum}) \; / \; \{1 + [Var(\lambda_{sum})/\lambda_{sum}^2]\}. \qquad (5)$$

The standard deviation of θ is given by:

$$Stddev(\theta) = [\theta^2\{[Var(\pi_{sum})/\pi_{sum}^2] + [Var(\lambda_{sum})/\lambda_{sum}^2]\} / [1 + Var(\lambda_{sum})/\lambda_{sum}^2]^2]^{0.5} \quad (6)$$

The percent change in crashes is $100(1-\theta)$; thus a value of $\theta = 0.7$ with a standard deviation of 0.12 indicates a 30% reduction in crashes with a standard deviation of 12%.

Cross-sectional analysis

Like the SPF developments in the EB method, crashes are normally assumed to follow a negative binominal distribution to address the overdispersion nature of crash counts. In road safety, overdispersion means the variance of crash data are significantly greater than the mean, which is the normal case. In this approach the treatment group and the untreated group are pooled and a dummy variable indicating reference/treatment group is included in the models. The coefficient for this dummy variable is an indicator of the effectiveness of a treatment.

One of the primary challenges of cross-sectional studies is confounding, which is sometimes due to systematic differences between the reference and treatment groups. In the presence of uncontrolled confounding, any obtained CMFs from the treatment group cannot be attributed solely to a causal effect of the countermeasures, and thus the estimated CMFs may be biased and unreliable. Confounding in road safety studies can arise from a variety of reasons. The most common form of confounding arises from treatments based on some risk factors. The distributions of the risk factors in the treatment group may be completely different from those in the reference group. The observed difference will then be the result of both differing confounding factors and treatment choice, making it difficult to delineate the true effect of the treatment. The CMFs estimated by traditional cross-sectional methods could then be biased and unreliable.

For the Boulder SSC treatment evaluation, the EB method cannot be applied since discrete before and after data were not available. To control the potential confounding issue mentioned above, the team selected reference sites that were like the treatment sites to control other changes over the analysis period such as trend, environmental, and driver population.

Segment treatment can be used as an example to describe how to derive CMF from the crash models. Suppose a prediction model for the crashes is as below:

$$\lambda_{i,t} = \alpha \bullet aadt_{i,t}^{\beta_1} exp(\beta_2 Z + \varepsilon_i) \quad (7)$$

and,

$Y_{i,t}$ = observed number of crashes at site i in year t

$\lambda_{i,t}$ = expected number of crashes at site i in year t

$aadt_{i,t}$ = AADT on site i in year t

$\alpha = Intercept$

Z=Dummy variable, Z=1 for treatment site, and Z=0 for control site

β_1, β_2 =Coefficients for $aadt_{i,t}$, and Z, respectively

The CMF for signalization treatment is exp(β_2).

Since the cross-sectional method is not able to address the confounding issue, it may provide biased estimates. Gross et al. (2010) and Carter et al. (2012) describe the issue in more detail. Many statistical approaches can be used to remove the confounding effects of such factors if they are measured in the data. Since these factors were not measured in the data, the team, with the support of local agency contacts, tried to match the reference sites with the treatment sites to minimize the confounding effects. This involved identifying segments that had similar roadway characteristics, similar vehicular volumes, and similar attributes, such as location, presence of sidewalks, and presence of bike lanes, that would indicate pedestrian and bicyclist activity.

Road Conversion Evaluation

Site details

To develop CMFs for the RC countermeasures, data for the treatment were ultimately divided into two groups. Dividing into groups provided more consistency among the treatment types as there may be differences attributable to the treatment characteristics. These two groups were RCs from four lanes to two lanes and conversions from three lanes to two lanes. Table 3 and Table 4 show the treatment and reference site numbers for each type of RC for each location. All of Seattle's sites were four to two lane conversions and all of Minneapolis's sites were three to two lane conversions. San Francisco had a mix of types, so its sites were divided between the groups. For San Francisco, the team used the same reference sites for each group. This was done to ensure there were enough reference sites in total, with enough roadway data, to generate more accurate SPFs.

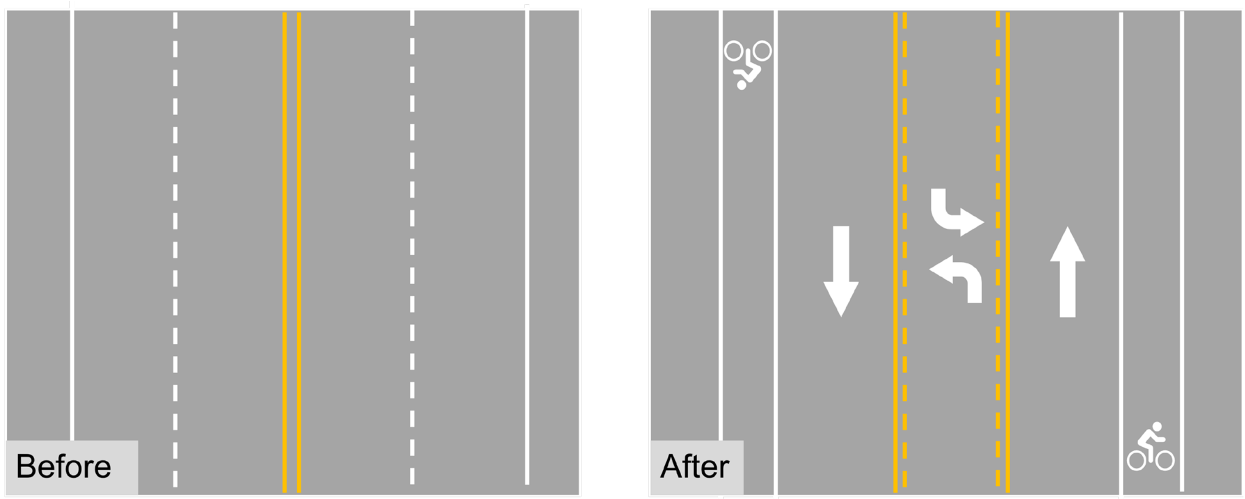

Figure 10. Four-lane to two-lane with center left turn lane RC

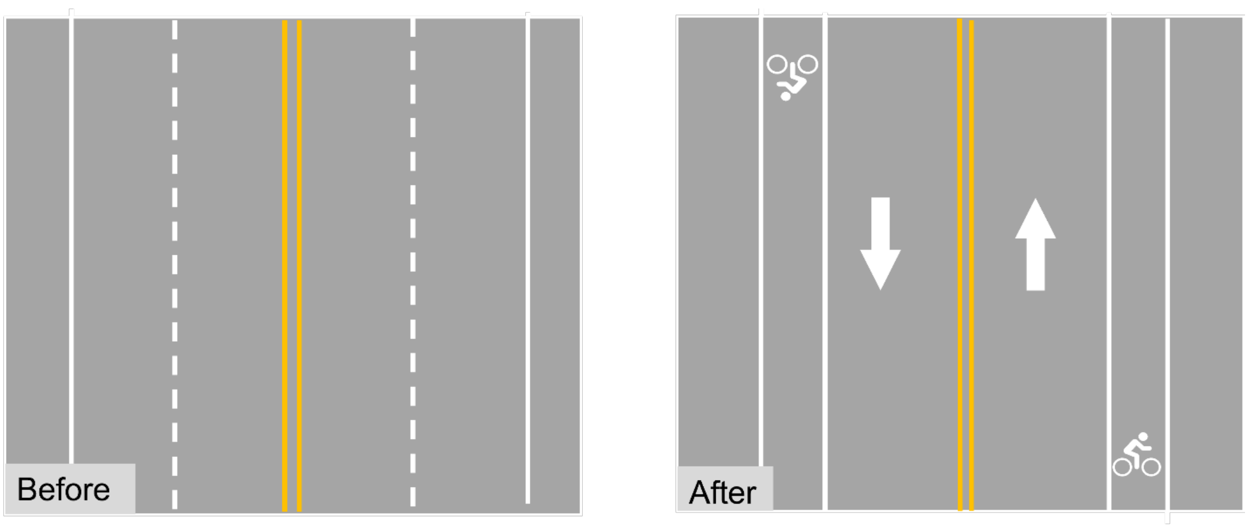

Figure 11. Four-lane to two-lane RC with no center turn lane

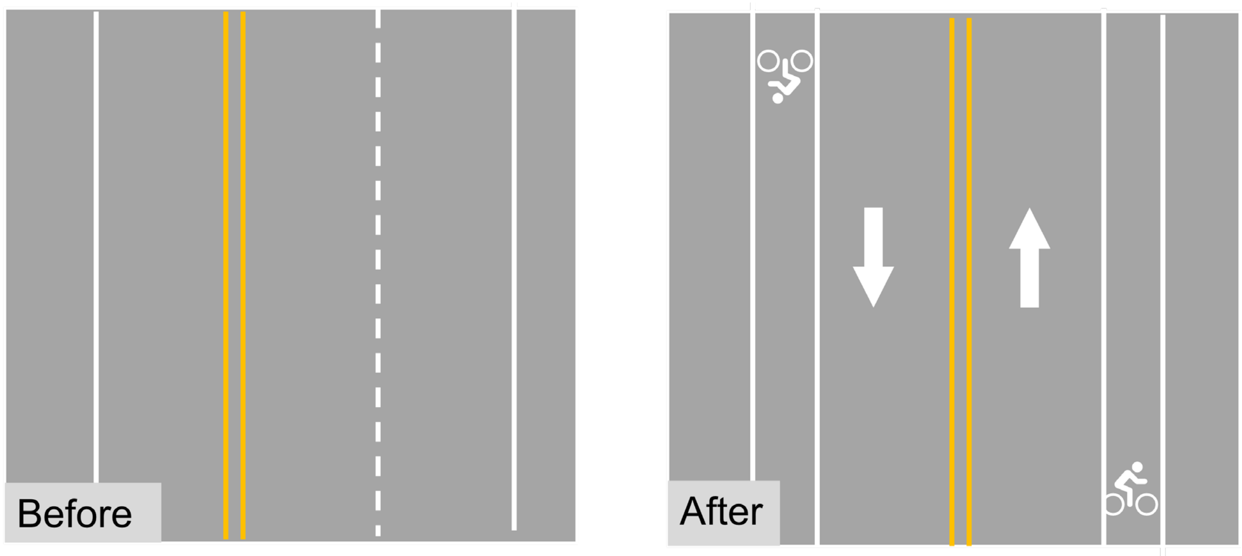

Figure 12. Three-lane to two-lane RC with no center turn lane

Table 3. Four-lane to two-lane RC sites

Road Conversions: Four-Lane to Two-Lane	Treatment Sites	Reference Sites
San Francisco, CA	4	119
Seattle, WA	12	105

Table 4. Three-lane to two-lane RC sites

Road Conversions: Three-Lane to Two-Lane	Treatment Sites	Reference Sites
Minneapolis, MN	5	30
San Francisco, CA	3	119

As noted before, the reference sites were selected as representatives of the treatment segments that maintain the characteristics from before the treatment. Reference segments were selected with the support of local agencies. They were not matched specifically to any one of the treatment segments, so a large number in each case provides enough data for comparison of the before and after crash data. For this reason, also, San Francisco has the same reference sites (n=119) for both types of RC (i.e., three-lane to two-lane and four-lane to two-lane conversions).

Table 5 through Table 12 show the overall crashes for each type of RC by location. Each location is further divided based on treatment sites and reference sites. The information for treatment sites includes details on the before and after periods, which differs because the RCs were implemented at different points within the study period. This study focused on measures of all crashes that resulted in injury and pedestrian/bicyclist crashes resulting in injury. The evaluation of treatments relies first on finding a measure of crashes across localities to measure in before and after conditions. Second, in order to generate an SPF and CMFs from the crash data, there need to be counts high enough to show some measurable impact. Due to relatively low counts of pedestrian or bicyclist crash counts as separate measures from year to year, the team decided to combine these counts to increase the likelihood of some measurable effect. While pedestrian and bicyclist crashes are different, by combining them, the impact the treatment had on non-motorized users could be investigated. Counts for these figures are included in Table 5 through Table 12 below.

Table 5. Three-lane to two-lane sites, San Francisco (3 segments)

Variable	Minimum	Maximum	Mean	Sum
Segment length (mile)	0.228	0.681	0.389	1.167
Years before installation	2	3	2.667	8
Years after installation	5	8	6	18
Injury crashes before installation	8	18	11.667	35
Injury crashes after installation	18	33	26.667	80
Pedestrian/bicyclist injury crashes before installation	1	7	3.667	11
Pedestrian/bicyclist injury crashes after installation	3	21	12.333	37

Table 6. Reference sites, San Francisco (119 segments)

Variable	Minimum	Maximum	Mean	Sum
Segment length (mile)	0.04	3.896	0.478	56.919
Injury crashes	0	581	66.118	7868
Pedestrian/bicyclist injury crashes	0	265	28.513	3393

Table 7. Three-lane to two-lane sites, Minneapolis (5 segments)

Variable	Minimum	Maximum	Mean	Sum
Segment length (mile)	0.429	2.720	1.034	31.015
Before years installation	7	8	7.4	37
After years installation	2	3	2.6	13
Injury crashes before installation	7	162	63	315
Injury crashes after installation	3	43	21.6	108
Pedestrian/bicyclist injury crashes before installation	2	29	12.4	62
Pedestrian/bicyclist injury crashes after installation	0	6	2.6	13

Table 8. Reference sites, Minneapolis (30 segments)

Variable	Minimum	Maximum	Mean	Sum
Segment length (mile)	0.517	2.723	1.591	7.953
Injury crashes	4	912	120.067	3602
Pedestrian/bicyclist injury crashes	0	237	30.4	912

Table 9. Four-lane to two-lane sites, San Francisco (4 segments)

Variable	Minimum	Maximum	Mean	Sum
Segment length (mile)	0.344	0.68	0.451	1.802
Years before installation	1	5	3	12
Years after installation	5	7	5.5	22
Injury crashes before installation	0	52	15.25	61
Injury crashes after installation	0	44	20.5	82
Pedestrian/bicyclist injury crashes before installation	0	16	5.25	21
Pedestrian/bicyclist injury crashes after installation	0	20	9	36

Table 10. Reference sites, San Francisco (119 segments)

Variable	Minimum	Maximum	Mean	Sum
Segment length (mile)	0.04	3.896	0.478	56.919
Injury crashes	0	581	66.118	7868
Pedestrian/Bicyclist injury crashes	0	265	28.513	3393

Table 11. Four-lane to two-lane sites, Seattle (12 segments)

Variable	Minimum	Maximum	Mean	Sum
Segment length (mile)	0.19	1.879	0.711	8.53
Years before installation	1	7	4	48
Years after installation	3	8	4.92	59
Injury crashes before installation	4	203	44.333	532
Injury crashes after installation	6	79	35.083	421
Pedestrian/bicyclist injury crashes before installation	0	20	6.333	76
Pedestrian/bicyclist injury crashes after installation	0	18	7.167	86

Table 12. Reference sites, Seattle (104 segments)

Variable	Minimum	Maximum	Mean	Sum
Segment length (mile)	0.028	2.683	0.48	50.4
Injury crashes	0	369	55.562	5834
Pedestrian/bicyclist injury crashes	0	115	10.905	1145

Results

As stated above the RC treatments were evaluated in two groups: four-lanes to two-lanes, both with and without a center left turn lane, and three-lanes to two-lanes. The EB analysis performed for each group takes into account common variables to generate expected values for crashes compared against the actual crash numbers. This allows for a comparison between before and after periods of unequal time and accounts for the differences between treatment sites and reference sites. For each treatment category, the team evaluated the effect on total crashes resulting in injury and total pedestrian and bicyclist crashes resulting in injury.

Four-lane to two-lane road conversions

The CMF results for four-lane to two-lane RCs are shown in Table 13. RCs resulted in an overall decrease in crashes resulting in injury from 593 to 503 crashes. Based on the data on roadway characteristics and volume, the expected post-treatment crash number was 530 crashes. This style of RC then resulted in a CMF of 0.95, meaning that crashes were reduced by around 5%. For this CMF, the 95% confidence interval would be between 0.82 and 1.07. This represents the range that contains 95% of the estimated values for the CMF given the model the team developed.

Table 13. CMFs for four-lane to two-lane RCs

Crash Type	Actual Before	Actual After	Expected Before	Expected After	CMF	SE of CMF	Naïve CMF
Total injury crashes	593	503	590.12	530.30	0.95	0.06	0.90
Pedestrian/bicyclist injury crashes	97	122	98.05	132.79	0.90	0.14	1.02

Pedestrian and bicyclist crashes resulting in injury increased overall from 97 to 122 in the study period. However, the analysis expected a larger increase to 133 over the same period. This results in a CMF of 0.90 for such crashes. In these cases, RCs led to a 10% decrease in the expected number of pedestrian and bicyclist injury crashes. The 95% confidence interval for this CMF is between 0.64 and 1.17. Note that pedestrian and bicyclist injury crashes were analyzed and not total pedestrian and bicyclist crashes as the focus on more severe crashes helps determine if there was a safety benefit rather than only an impact on overall crashes.

Three-lane to two-lane road conversions

Eight sites were evaluated for three-lane to two-lane RCs (five segments in Minneapolis and three segments in San Francisco), shown in Table 14 below. For all injury-related crashes, there were 350 before period crashes and 188 after period crashes. The expected after period crashes totaled 148, resulting in a CMF of 1.26. This would mean an increase in crashes over what would be expected of 26%. For this CMF, the 95% confidence interval is 0.93 to 1.59.

Table 14. CMFs for three-lane to two-lane RCs

Crash Type	Actual Before	Actual After	Expected Before	Expected After	CMF	SE of CMF	Naïve CMF
Total injury crashes	350	188	348.27	147.63	1.26	0.17	1.00
Pedestrian/bicyclist injury crashes	73	50	71.49	59.88	0.81	0.18	1.17

The pedestrian and bicyclist injury crash analysis showed a more positive result. There were 73 pedestrian and bicyclist injury crashes in the period before the RC and 50 crashes in the after-treatment period. The analysis predicted 60 after-treatment crashes. This results in a CMF of 0.81, a reduction in pedestrian and bicyclist injury crashes of nearly 20%. This CMF's 95% confidence interval is 0.45 to 1.16.

Discussion

For the participating localities, RCs were employed to both allocate more space on the roadway for pedestrians and cyclists and to reduce lane numbers and lane widths to slow vehicle speeds. With the data collected, the team sought to understand the RCs' impact on safety, focusing on the total number of injury crashes and the total number of pedestrian and bicyclist crashes resulting in injury. The study period attempted to capture data from before the installation of the first RC and after the installation of the most recent RC. Generation of the SPF in the analysis attempts to include what roadway characteristics contribute to crash outcomes in general. This relies on the roadway characteristic data collected that included presence of sidewalks, parking, bike lanes, type of road division, and transit presence. This also includes the locality-provided data on vehicle traffic, pedestrian, and bicyclist volumes. The CMF that results then controls for all the effects of these other elements to isolate the effects of the RC on crashes.

For RCs from four lanes to two lanes, with a center two-way left turn lane, the evaluation found a reduction in all injury-related crashes of 5% (CMF=0.95) and a reduction of pedestrian and bicyclist injury crashes of 10% (CMF=0.90). This result means that, controlling for all other factors on the roadway, an RC of this type would be expected to reduce both types of crashes. However, these results should be interpreted with caution as at the 95% significance level, the CMF confidence intervals included 1.0 indicating not statistically significant CMFs. Though the analysis of this type of RC suggests a reduction in both type of injury-related crashes, the mechanism causing this reduction is not clear. Speed data were not available for many of the corridors featured within the study, especially when the segments where RCs were implemented were shorter sections of longer corridors. The impact of speed reductions could be expected to lead to reduced risk of injury in the case of a crash. RCs may also reduce potential for conflict, whether by reducing the number of lanes to cross for a vehicle turning left at a driveway or intersection, by creating more separation for pedestrians or bicyclists, or reducing the distance over which a pedestrian is exposed to vehicles when crossing. These factors, coupled with reductions in speed could result in fewer crashes and fewer injurious crashes.

The three to two lane conversions saw a similar effect only for pedestrian and bicyclist injury crashes. For these crashes, the treatments showed a 19% reduction in crashes (CMF=0.81). However, for total injury crashes, the treatment showed a 26% increase in crashes (CMF=1.26). Again, these results should be interpreted with caution as the CMFs confidence intervals are not significant at the 95% significance level. One explanation for the discrepancy between pedestrian and bicyclist injury crashes and all injury crashes may be the lack of vehicle volume data for the sites in San Francisco. These sites account for three treatment sites and 119 reference sites. The large number of reference sites without volume data may make predicting the expected number of crashes less reliable. Any fluctuations in volume cannot be included in the model and increases in volume may contribute to an increase in crashes. In such an event, the treatment impact on crashes may change depending on how traffic volumes affect expected crash numbers.

Speed Safety Cameras

The three localities selected for evaluating the impact of SSCs on pedestrian and bicyclist safety each have programs with different deployment methods. Mentioned in detail in the Program Scan section, Boulder employs a mobile camera program with cameras mounted on vans and moved between sites throughout the city. Seattle's speed camera program is based in school zones and cameras are only operational during set times during the day and the year. Finally, Washington, DC, maintains a large, fixed camera program throughout the city with continuously running cameras. Due to the differences in program operations, combining the SSC treatment into a single evaluation was not feasible. The team then performed evaluations of each program separately.

Boulder, CO

The SSC program in Boulder, CO, relied on mobile cameras. The cameras were mounted on vans and moved among several locations. Due to the nature of the program, for any segment of roadway with the SSC treatment, there is no defined before or after period. Segments were considered treatment segments if at any point in the study period, they had a mobile camera in operation. Without a clearly defined before and after period, the team was not able to calculate a CMF for Boulder's program. Instead, the team attempted to generate an SPF for SSC. The model for evaluating Boulder's SSC included as variables: speed limit, vehicle volume, signalized intersections, roadway division, area type, and transit stops. In the end, for both measures of pedestrian and bicyclist injuries and total injury crashes, the model did not identify the presence of a camera as a factor in safety; however, this result yields caution given the aforementioned caveats.

Seattle, WA

Results

Seattle's SSC program is based solely in school zones and operates along with the school zone schedule. The evaluation included 17 segments with cameras and evaluated 100 segments adjacent to the treatment segments. Details on the treatment and near treatment, and reference sites are listed in Table 15 through Table 17. Results of the CMF estimates are listed in Table 18.

Table 15. Seattle, WA, near-treatment sites (N=100)

Variable	Minimum	Maximum	Mean	Sum
Segment length (miles)	0.01	0.19	0.07	74.5
Years before installation	4	7	6135	5.78
Years after installation	1	6	4163	3.92
Injury crashes before installation	0	22	3.4	333
Injury crashes after installation	0	19	2.1	208
Pedestrian/bicyclist injury crashes before installation	0	4	1.12	19
Pedestrian/bicyclist injury crashes after installation	0	4	0.65	11

Table 16. Seattle, WA, reference sites, (N=117)

Variable	Minimum	Maximum	Mean	Sum
Segment length (miles)	0.01	0.65	0.1	178.78
Injury crashes	0	6	0.58	615
Pedestrian/bicyclist injury crashes	0	3	0.1	109

Table 17. Seattle, WA, SSC treatment sites (N=17)

Variable	Minimum	Maximum	Mean	Sum
Segment length (miles)	0.02	0.33	0.11	3.28
Years before installation	2	8	5.48	170
Years after installation	1	7	3.52	109
Injury crashes before installation	0	15	4.88	83
Injury crashes after installation	0	16	4	68
Pedestrian/bicyclist injury crashes before installation	0	8	0.62	61
Pedestrian/bicyclist injury crashes after installation	0	6	0.35	34

Table 18. CMFs for Seattle SSC sites

Segment Type	Crash Type	Observed Crashes Before	Observed Crashes After	Expected Crashes Before	Expected Crashes After	CMF	SE of CMF	Naïve CMF
Treatment	Total injury crashes	83	68	84.08	50.93	1.32	0.21	1.25
	Pedestrian/ bicyclist injury crashes	19	11	18.92	12.95	0.82	0.28	0.7
Near treatment	Total injury crashes	333	208	331.46	199.76	1.04	0.09	0.96
	Pedestrian/ bicyclist injury crashes	61	34	61.36	35.47	0.95	0.18	0.904

Both types of sites were evaluated for impact on total injury crashes and pedestrian and bicyclist injury crashes. In the treatment sites a total of 83 injury crashes occurred in the before period and 68 occurred in the after period. The expected number of crashes following treatment was 50.93, giving the treatment sites a CMF of 1.32, with a 95% confidence interval of 0.91 to 1.73. This means treatment sites saw a 32% increase in total injury crashes. These sites had 19 pedestrian and bicyclist crashes before the treatments and 11 after. The model estimated that 12.95 crashes would occur after treatment. This results in a CMF of 0.82, with a 95% confidence interval of

0.27 to 1.37, indicating an 18% reduction in pedestrian and bicyclist injury crashes. Since the confidence interval includes 1.0, this CMF is not statistically different from 1.0.

For SSC, near treatment sites were also evaluated to determine if the cameras had any impact that lasted beyond their immediate location. Sites near the treatment had 333 total injury crashes before treatment and 208 after treatment while the expected crash number was 199.76. This results in a CMF of 1.04, with a 95% confidence interval of 0.86 to 1.22, an increase in crashes of 4%. For pedestrian and bicyclist injury crashes, near treatment sites had 61 crashes before and 34 crashes in the after period. The estimated number of crashes was 35.47. This produces a CMF of 0.95 that indicates a crash reduction of 5%. The 95% confidence interval for this CMF is 0.60 to 1.30.

Discussion

For both sites with SSCs and sites near these segments, the results suggest that SSCs reduced pedestrian and bicyclist injury crashes in Seattle. However, the standard deviation related to these CMFs, and those indicating an increase in total injury crashes, reveal limited predictive ability for these measures. The evaluation of Seattle's speed camera program may indicate some impact of cameras specific to Seattle but may not predict the same impact elsewhere. This may be the result of two factors related to the program and the data obtained from Seattle. First, Seattle's program is a school zone-based camera program. Cameras only operate within school zones and during specific times when the school zone sign beacons are flashing. Outside of these times, the cameras do not capture speeding violations. Crash report data, however, do not include a variable to identify whether the crash occurred when cameras were operational. This coupled with the small number of pedestrian and bicyclist crashes may be responsible for the result. In addition, many segments had incomplete volume data, either missing specific years or missing data altogether. To correct this, the team assigned a value based on the minimum volume in the dataset. This may not account correctly for volume changes during the study period and may impact the expected crash numbers that contribute to determining the CMF.

Washington, DC

Results

In Washington, DC, SSC operates on a fixed camera system. The evaluation consisted of 31 treatment sites along with 238 near-treatment segments as well as 769 reference sites. Details on the sites and injury-related crash numbers are shown in Table 19 through Table 21 below. Data on pedestrian and bicyclist injury crashes were not available before 2012. When estimating the treatment's effect on crashes, a long enough period of data from before the treatment is needed to capture the trends in crashes along with all other roadway data. The lack of pedestrian and bicyclist data available in this case would not lead to a valid estimate of the treatment's impact. The team was provided total crashes resulting in injury. This count included all modes reported. Although not ideal, these crashes were used because they first provide a more complete picture of crashes over time, and second, crashes resulting in injury may involve higher speeds, so results would point to potential reductions in crashes by reducing speeds.

Table 19. Washington, DC near-treatment sites (N=238)

Variable	Minimum	Maximum	Mean	Sum
Segment length (miles)	0.01	0.45	0.05	13.04
Years before installation	2	8	5.45	1296
Years after installation	1	7	3.55	846
Injury crashes before installation	0	37	2.16	515
Injury crashes after installation	0	45	2.39	568

Table 20. Washington, DC reference sites (N=769)

Variable	Minimum	Maximum	Mean	Sum
Segment length (miles)	0.01	0.54	0.06	46.89
Injury crashes	0	62	4.88	3754

Table 21. Washington, DC SSC treatment sites (N=31)

Variable	Minimum	Maximum	Mean	Sum
Segment length (miles)	0.02	0.33	0.11	3.28
Years before installation	2	8	5.48	170
Years after installation	1	7	3.52	109
Injury crashes before installation	0	25	3.58	111
Injury crashes after installation	0	36	5.45	169

For total injury crashes the SSC treatment sites produced a CMF of 1.37, with a 95% confidence interval of 1.04 to 1.70 (shown in Table 22). This can be interpreted as an increase of crashes on these segments of 37%. The naïve CMF shows the change in crashes based on absolute values of crashes without considering other changes over time. Naïve CMFs are calculated without the prediction of crash numbers because of shorter before periods and reflect the change in crashes between study periods. These provide an estimate of the change in crash rates over time between the changes in camera presence. The naïve CMF for sites with the SSC treatment was 1.66, showing that overall crashes increased by 66%. The difference between the CMF and naïve CMF shows that crashes increased above what was expected (CMF of 1.37) but by a lesser degree.

Table 22. CMFs for SSC treatment and near-treatment sites, Washington, DC

Segment Type	Crash Type	Observed Crashes Before	Observed Crashes After	Expected Crashes Before	Expected Crashes After	CMF	SE of CMF	Naïve CMF
Treatment	Total injury crashes	111	169	121.81	151.19	1.37	0.17	1.66
Near treatment	Total injury crashes	515	568	496.65	517.62	1.14	0.07	1.41

At the near-treatment sites, those segments adjacent to segments with SSCs, the CMF was 1.14, meaning an increase in crashes of 14%. The 95% confidence interval for this CMF was 1.00 to 1.28. Like the measure on the SSC treatment segment above, the CMF is lower than the naïve CMF.

Discussion

Washington, DC's widespread SSC program presented a promising option for evaluating the impacts of SSC. The evaluation produced a CMF that shows SSCs led to an increase in crashes in both treatment and near-treatment sites. As noted above, the CMF is lower than the naïve CMF, indicating the treatment may have some effect on lowering the degree to which crashes increased. Due to data availability issues, only total injury crashes were evaluated for these sites. The evaluation cannot separate out what the share of crashes is by mode to add more detail. Total injury crashes help indicate the number of crashes that would be at a high enough speed to cause injury of one or more of the involved parties. However, without information on modes, the evaluation cannot tell what share of these crashes only involved vehicles and which involved pedestrians or bicyclists. Furthermore, without speed data, the analysis cannot point to whether speed was a factor in the crashes.

Phase 1: Conclusion and Discussion

This project's aim was to evaluate efforts at lowering speeds and their impacts on pedestrian and bicyclist crashes. The initial program scan for the project uncovered the many ways that places have attempted to lower traffic speeds to improve safety. Efforts explored in the program scan include reductions in the posted speed limit, either across entire municipalities, on specific types of roads such as all arterials or neighborhood streets, or in defined areas such as school zones. The team also found in the scan localities that have made changes to road design to slow vehicles. These changes included traffic-calming programs that add elements like speed tables or reductions in lane width. Other physical changes were found in RCs that changed the layout of the roadway by eliminating lanes, reducing lane widths, adding facilities for bicyclists, or some combination of all these elements. Finally, the program scan found efforts in enforcement that included high-visibility enforcement and the use of SSCs to enforce speed limits by speed safety cameras.

The final evaluation piece of this project looked specifically at deployment of SSCs and the use of RCs across several localities. The CMFs generated for RCs show some potential crash reduction benefit related to both the three-lane to two-lane and four-lane to two-lane RCs. Crash reductions were noted for pedestrian and bicyclist injury crashes for both types of RCs and for all injury crashes for the four to two-lane reductions. Further research and more complete data would allow for a closer examination of the mechanisms through which RCs affect this change. This evaluation was limited by data quality and completeness. Relying on local agencies to provide data requires fitting data from the local agency format into some standard for the project. Though the team attempted to do so by following the data collection manual, issues of how crashes were counted and categorized and availability of volume data for all road users limits a full exploration of the impact of RCs. Calculating a reliable CMF requires data for a long period of time to capture trends over periods before and after a treatment. Changes in data gathering techniques and priorities impact what data become available. A further exploration of RCs' impacts would be served by localities maintaining more complete data on the characteristics of the roadway. In addition, maintaining records on when and where such treatments have been implemented would also support further evaluation. Finally, the ability to estimate pedestrian and bicyclist exposure by understanding travel volumes and crossing behavior would aid in estimating the treatment specific effect on pedestrian and bicyclist safety.

Unlike the RC results, SSCs only had one site where a crash-reduction CMF was generated, with Seattle seeing some reduction for pedestrian and bicyclist crashes. However, as noted above the results are not necessarily reliable enough to be generalizable to other locations. SSC deployment is largely reliant on the regulations that enable its use. Such rules determine where SSC is placed, when it is in operation, and the details on citations. In each of these cases, the particulars of the SSC program may be contributing to its impact on crashes. Further research could incorporate more speed data alongside crash rates to investigate how SSC's impact on speed affects crashes and crash severity. Research could also seek to further isolate the effect of SSC by looking more specifically at the causes of crashes on SSC corridors.

Though there were some limitations due to data availability, safety benefits of these speed-reduction efforts were uncovered. This evaluation looked specifically at the reduction in injury-related crashes with the understanding that by implementing countermeasures aimed at reducing speeds, the more severe crashes should decrease. The findings here point to the potential that these treatments can promote safety by reducing crashes resulting in injury for pedestrians and bicyclists.

Phase 2: Impact of Quick-Build Pandemic-Related Projects

Introduction

Phase 2 of the project built upon the findings of Phase 1 on RC crash impacts, recognizing speed's role in crash outcomes and the potential for RCs to reduce speeds and crashes. In early 2020, the COVID-19 pandemic spread throughout the United States leading to a series of shutdowns resulting in changing traffic patterns, reducing some volumes, and changing the makeup of what modes were on the road at what times. These changes initiated a rise in speeding among other unsafe behaviors (Wagner et al., 2020). In a series of reports tracking such behaviors from the beginning of the pandemic, March 2020, through the first half of 2021, NHTSA's Office of Behavioral Safety Research (2021a; 2021b; 2021c) found sustained increases in speeds even among the 1st percentile, those in the group of lowest speed travelers. Cities, both large and small, began responding to these changes by making accommodations on the roadway for different uses. In some cases these were to create extra space for pedestrians and in other cases these efforts resulted in temporary lanes for bicyclists (Steckler et al., n.d.). In these places, street space normally reserved for vehicles was reallocated for other uses.

The World Health Organization publication (Auert et al., 2020) saw how transportation networks could be reimagined to allow mobility while understanding how to reduce the spread of the virus. This included recommendations that create more space for walking and biking that allowed for maintaining appropriate physical distance while outside. Additionally, the World Health Organization (2020) effort recognized the need to walk and bike for exercise and called for actions to give priority to these modes. Other recommendations included accommodations for different city needs. In addition to space for those walking and biking, reallocating street space accommodated sidewalk dining to allow restaurants to reopen while maintaining space between diners, space for recreation, space for outdoor markets, or any other needs that moved outdoors to address pandemic concerns (NACTO & Global Designing Cities Initiative, 2020).

This phase investigated what safety benefits these changes might have had for pedestrians and bicyclists. Though temporary, these quick-build projects have similar changes to roadway allocations as more permanent roadway conversions. The aim was to identify places where these temporary installations have been used, describe the changes, and use available data to examine whether there have been any observed safety benefits related to the changes.

Method

Locality selection

In 2020, as places began to make a variety of transportation-related changes in response to the pandemic, researchers began compiling examples into the Shifting Streets dataset housed on the Pedestrian Bicycle Information Center website (Combs & Pardo, 2020). The Shifting Streets dataset was built from crowdsourced information that used social media, official government sources, news reports, or any other sources to report on changes to streets that were occurring in real-time as places adapted to needs emerging from the pandemic. Contributors to the dataset added locations, descriptions, and details to categorize and track the changes and purposes for these changes.

The current project used this crowdsourced Shifting Streets dataset to identify sites where lanes were reallocated to provide space for pedestrians and bicyclists. The team's focus on the list was any description of a place that created bike lanes, on-street multiuse lanes, or some other accommodation that removed a travel lane normally used for motor vehicles and provided more space for other modes of travel. The treatments in each locality, though temporary, still represented quick-build versions of the RC treatments evaluated in Phase 1 of the project. These types of changes have two potential benefits. First, creating separation for pedestrians and bicyclists reduces the potential for conflict with vehicles. Second, these interventions may reduce speeds on the roadway by reallocating space from wider lanes to other users. The team developed a long list of potential contacts and reached out to agencies at each locality.

The team contacted agencies to request participation in the study. These conversations included details about the data being requested as well as information sought to contribute to fuller descriptions of their temporary installations. After contacting agencies on the long list of potential participants, the team reduced the list to a short list of agencies with projects that fit the criteria requirement and willingness to provide data. The short list contained the following places, Atlanta, Chapel Hill, Miami Beach, New York City, and Los Angeles. After repeated outreach to each agency, the final list of places was reduced further due to some nonresponse by contacts. In the end, the team limited the study to Atlanta, Chapel Hill, and Los Angeles.

Data collection manual

Data collection for this phase used the same data collection manual and data collection sheet developed in Phase 1. This manual requested details on roadway characteristics including lanes, parking, presence of bike lanes or sidewalks, and speed limits. The team also requested information, where available, on prevailing speeds. Finally, each agency was asked to provide what crash data they had available.

Results by city

Atlanta, GA

Starting on October 5, 2020, Atlanta began a temporary lane reallocation on Lee Street SW. Before the project, Lee Street SW had three northbound travel lanes and two southbound travel lanes. The project used orange plastic jersey barriers to close one northbound travel lane for 2,150 feet (around 0.4 miles). Lee Street SW was considered a wide, higher speed road, so the city selected it for a lane reduction to reduce the overall width and help lower speeds. The lane closure created a pop-up, temporary shared-use lane from West Whitehall Street allowing cyclists or pedestrians to reach the West End Metropolitan Atlanta Rapid Transit Authority (MARTA) Station. The city originally planned to keep the pop-up lane for one week. However, because of the reception by users, the city kept the lane installed until July 31, 2021. For most of this time, there was a reduction in the number of bus routes along the corridor. Transit use was restored to normal levels on April 24, 2021, with 10 bus routes serving the corridor. During the initial part of the multiuse lane pop-up, only three lines served the route. With fewer bus routes available, and MARTA train lines still running, the bike lane offered a mode option for reaching the MARTA station by bike.

Figure 13. Temporary multiuse lanes on Lee Street SW, Atlanta, GA. Image Credit: Temporary multiuse lanes by Atlanta Department of Transportation. Permission to use granted by ATLDOT.

Data provided by the city outlined a period before the installation from January 1, 2020, to October 4, 2020, and the period during which the lane closure was in place, from October 5, 2020, to July 31, 2021, or about 10 months before and 10 months after installation. Details on speed, volume, and crashes are listed in Table 23 below.

Table 23. Lee Street SW, Atlanta, GA, before and after installation

Lee Street SW, Atlanta – Lane Reallocation (2,150 ft segment length)		
	Before installation (278 days)	**After installation (300 days)**
Speed limit (mph)	30	30
Average travel speed (mph)	19.5	22.4
Average daily vehicle volume	13,100	13,800
Average daily pedestrian volume	3,500	2,750
Average daily bicycle volume	100	70
Total crashes	14	12
Killed/serious injury crashes	1	0

The posted speed on Lee Street was 30 mph throughout the entire period. Both before and during the lane closure, average travel speed was below the speed limit, 19.5 mph before and 22.4 mph after installation. This shows a slight increase in speed while the lane was closed. Speed increased while average daily vehicle volumes also increased, from 13,100 to 13,800. Both pedestrian and bicycle volume saw a decrease between the two periods, from 3,500 average pedestrians per day to 2,750 and from 100 average bicycles per day to 70.

Atlanta only had overall crash data to share, which, while it does not specifically point to bicyclist and pedestrian safety, it does serve as an indicator of overall safety on the roadway. Crashes decreased between the before and after periods, from 14 to 12 total crashes. There was one crash categorized as fatal or serious injury in the before period and no such crashes in the period after installation. Despite the slight increase in speed and traffic volume both total and fatal or serious injury crashes were slightly reduced. While this shows a change at the time of the temporary installation, these measurements were over a brief amount of time and may not include variations in crash rates that a longer-term analysis would consider including whether the change was a regression to the mean number of crashes.

Chapel Hill

The Town of Chapel Hill started a pandemic-response street project in August 2020 to reallocate lanes in the town's downtown. Franklin Street had two vehicle travel lanes in each direction along with parallel parking on each side. The intent of the lane reallocations was to create a multiuse path on each side of the road. Allowing pedestrians to use the on-road path, would open space on the sidewalk for restaurants to have more seats for outdoor dining. The project was implemented by the town with approval from the NCDOT and support from Orange County. One lane in each direction was closed on Franklin Street and separated from vehicular traffic using a combination of plastic barriers and flexible bollards. Parking lanes were moved away from the curb and marked with temporary striping. The multiuse path was marked continuously with no parking symbols to indicate that they were not parking lanes along the curb but instead lanes for pedestrians and bicyclists. The temporary lanes were in place from August 2020 until Spring 2022 when they were removed for a repaving and restriping project that would make some of the lane reallocation permanent. The Town of Chapel Hill website (www.townofchapelhill.org) provides details of how each segment of the corridor was altered.

Figure 14. Temporary multiuse path on Franklin St., Chapel Hill, NC. (Image Credit: Town of Chapel Hill)

Data provided by Chapel Hill show the crash levels during a 1-year period before the installation, July 2019 to July 2020, and one year while the temporary lane reallocation was in place, August 2020 to August 2021. Table 24 shows the crash statistics for the corridor.

Table 24. Franklin Street, Chapel Hill, NC, before and after installation

Franklin Street, Chapel Hill – Lane Reallocation (3,950 ft segment length)		
	Before installation (1 year)	**After installation (1 year)**
Average daily vehicle volume	13,500	10,750
Total crashes	62	46
Pedestrian crashes	1	0
Bicycle crashes	2	2

Before the installation, the corridor saw 62 total crashes including one pedestrian and two bicyclist crashes. With the temporary multiuse lanes in place, the corridor experienced 46 total crashes with no pedestrian and two bicyclist crashes. None of the crashes involved fatalities or serious injuries. Due to the short term of the installation, it is not clear that the installation caused the reduction in crashes. Between the same two periods, the average daily vehicle traffic decreased from 13,500 to 10,750. It is possible that the lane reduction led directly to the drop in number of crashes or indirectly combined with the lower traffic volumes led to the crash reduction. In addition, the periods of time in the analysis, both before and after the treatment, were each one year. This short amount of time allows for a measure of crash rate at the time but is not long enough to account for normal fluctuations that impact rates over time. Furthermore, speed data were not available so the impact of the temporary multiuse lanes on speeds is unknown.

Los Angeles, CA

When approached about quick-build projects as part of their pandemic response, contacts from Los Angeles shared a project that implemented permanent lane reallocation in the city. High crash rates, 149 resulting in fatalities or serious injuries, along Avalon Boulevard in Los Angeles from 2009 to 2017 sparked the need for change on the roadway (Los Angeles Department of Transportation, n.d.). Of all serious and fatal crashes, 65 (44%) involved a bicyclist or pedestrian. The pre-project street had two vehicle lanes in each direction. After reallocating lanes with striping in the summer of 2020, the road had one vehicle travel lane in each direction, a center two-way left turn lane, and bike lanes on each side. The project covered a stretch of Avalon Boulevard of around six miles, from the intersection at East 120th Street to East Jefferson Boulevard.

Figure 15. Post-project lane configuration, Avalon Blvd, Los Angeles, CA. (Image Credit: Los Angeles DOT)

Data provided by the Los Angeles DOT shows crashes from 2019 to 2021, allowing for a comparison of crash data from 2019, the year before the project, and 2021, the full year after installation. Details are shown in Table 25 below. In 2019, the corridor on Avalon Boulevard experienced 318 total crashes. Of these, 221 were categorized as injury related, and 53 involved pedestrians or bicyclists. Total crashes in 2021 decreased to 125. Injury related crashes also decreased to 91, and crashes involving pedestrians or bicyclists were reduced to 30. Based on these values, the team calculated naïve CMFs. CMFs estimate the effect of a treatment based on the normal safety performance of a location by comparing a prediction of crash numbers against what actually occurred. Naïve CMFs are calculated without the prediction of crash numbers because of shorter before periods and reflect the change in crashes between study periods. These provide an estimate of the change in crash rates over time between the changes in lane allocation. For total crashes the naïve CMF was 0.39, indicating a reduction in crashes overall of 61%. For injury-related crashes, the team found a naïve CMF of 0.41, showing a 59% decrease in this category of crash. And, finally, for pedestrian or bicyclist crashes, the naïve CMF was 0.57, meaning these crashes were reduced by 43% (all reported in Table 26). (Note: these analyses are a simple year to year change in crashes, not a predictive function. As such, there are no confidence intervals.)

Table 25. Avalon Blvd., Los Angeles, CA, before and after installation

Avalon Blvd, Los Angeles – Lane Reallocation (6 mi segment length)		
	Before installation (1 year)	**After installation (1 year)**
Speed limit (mph)	35	30 to 35
Average travel speed (mph)	38.5	34.1
Average daily vehicle volume	22,824	15,467
Total crashes	318	125
Killed/serious injury crashes	221	91
Pedestrian/bicyclist crashes	53	30

Table 26. Avalon Blvd., Los Angeles, CA, changes in crashes between 2019 and 2021

Crash Type	**2019**	**2021**	**Naïve CMF**
Total crashes	318	125	0.39
Injury crashes	221	91	0.41
Pedestrian/bicyclist crashes	53	30	0.57

The data from the Avalon Boulevard lane reallocation indicate a potential drop in crashes overall and also injury and pedestrian or bicyclist crashes specifically. While the evaluation method, and lack of longer-term data cannot point specifically to the lane allocation as the reason for these decreases, several changes also occurred between 2019 and 2021 that may have contributed to this crash outcomes. Before the treatment, the 85th percentile speed on the corridor was 38.5 mph while the entire corridor had a speed limit of 35 mph. After the treatment, in 2021, the 85th percentile speed had decreased to 34.1 mph. This occurred after lanes were reduced from four to two while some sections of the corridor had a speed limit decrease to 30 mph. Other segments maintained the previous 35 mph speed limit. This all happened while average daily vehicle traffic volume decreased from 22,824 in 2019 to 15,467 in 2021. These may also be related to the lane reallocation, though the direction of causality may not necessarily be determined.

Phase 2: Conclusion and Discussion

With shifts in travel patterns altering times, locations, and modes of travel as the COVID-19 pandemic affected lives across the country, cities saw the opportunity to modify travel lanes to accommodate these changes. For reasons including supporting local business, promoting healthy distances between people outside, and accommodating increases in pedestrian or bicyclist activity, cities made changes to their roadway designs. This project investigated a subset of these changes by looking at reallocated lanes that allowed space for those walking or on bikes. Utilizing a crowdsourced database (Combs & Prado, 2020), the team ultimately identified three cities to investigate: Atlanta, Chapel Hill,, and Los Angeles. Two projects were quick-build, temporary installations that created multiuse paths on the roadway by reducing the number of vehicle travel lanes. A third project was a restriping project that added bike lanes that occurred during the pandemic, summer of 2020.

The projects described in this report were all initiated in 2020, so data after their installation is limited to one year or shorter. With such a short amount of post-installation data, a robust analysis to predict the potential effects of these treatments in other environments was not possible. Furthermore, the upheaval in travel behavior since 2020 makes isolating a single treatment as a cause of crash changes difficult. However, the data provided by each location selected does point to some crash reduction both in overall crashes and fatal or serious crashes. For the sites where data were available, there was also a decrease in pedestrian and bicyclist crashes. The quick-build projects led to changes in volume and reduced exposure to vehicles; however, the limited data hinder isolating the specific causes of the crash differences pre- versus post-implementation. These treatments not only have potential for safety, but also serve as demonstrations of quick-build projects that allow localities to test out a roadway design before doing a permanent implementation. In further applications, measuring speed, volume, and crashes throughout an installation is recommended to evaluate the project impact itself as well as the potential to be made more permanent in later road designs.

Conclusion and Discussion

Efforts to manage vehicles' speeds involve many different approaches. The speed reducing countermeasures evaluated in this project to determine their impact on pedestrian and bicyclist safety included SSC and road reconfiguration.

In Phase 1 both RCs and SSCs showed potential for crash reduction for pedestrian and bicyclist injury-related crashes. While the CMFs reveal crash reductions, more data would inform the reasons for these decreases. More complete volume data, for vehicles, bicyclists, and pedestrians, may add insight to fluctuations in use on the roads being evaluated. A major limitation with the report is the inability to making conclusions about the impact of speed reductions when in several cases there are no data to determine if speeds were actually reduced. With speed data, the evaluation would go further to link these treatments with speed reductions and thus improvements in safety.

Phase 2 of the project presented case studies of quick-build transportation projects in response to the COVID-19 pandemic. Based on the available data, these projects combined show the potential short-term benefits in terms of crash reduction from quick-build projects. The changes may impact some of the variables involved in crashes such as vehicle speed and volume, and pedestrian and bicyclist exposure and volumes. In addition, quick-build projects offer the chance to test designs that could lead to longer-term changes. Nationwide many temporary quick builds aimed at accommodating social distancing and reduced vehicle traffic became permanent changes supported and valued by the public.

As more agencies focus on ways to reduce and eliminate crashes, countermeasures that make travel safer for all road users are increasingly discussed and implemented. Individual countermeasures become part of the transportation system and help build layers of protection to prevent crashes from happening and minimize harm in the event of a crash. Reducing vehicle speeds is one part of the system and a frequently used solution that aids in reducing crash severity as well as decreases the likelihood of fatal and severe injury pedestrian and bicyclist involved crashes.

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