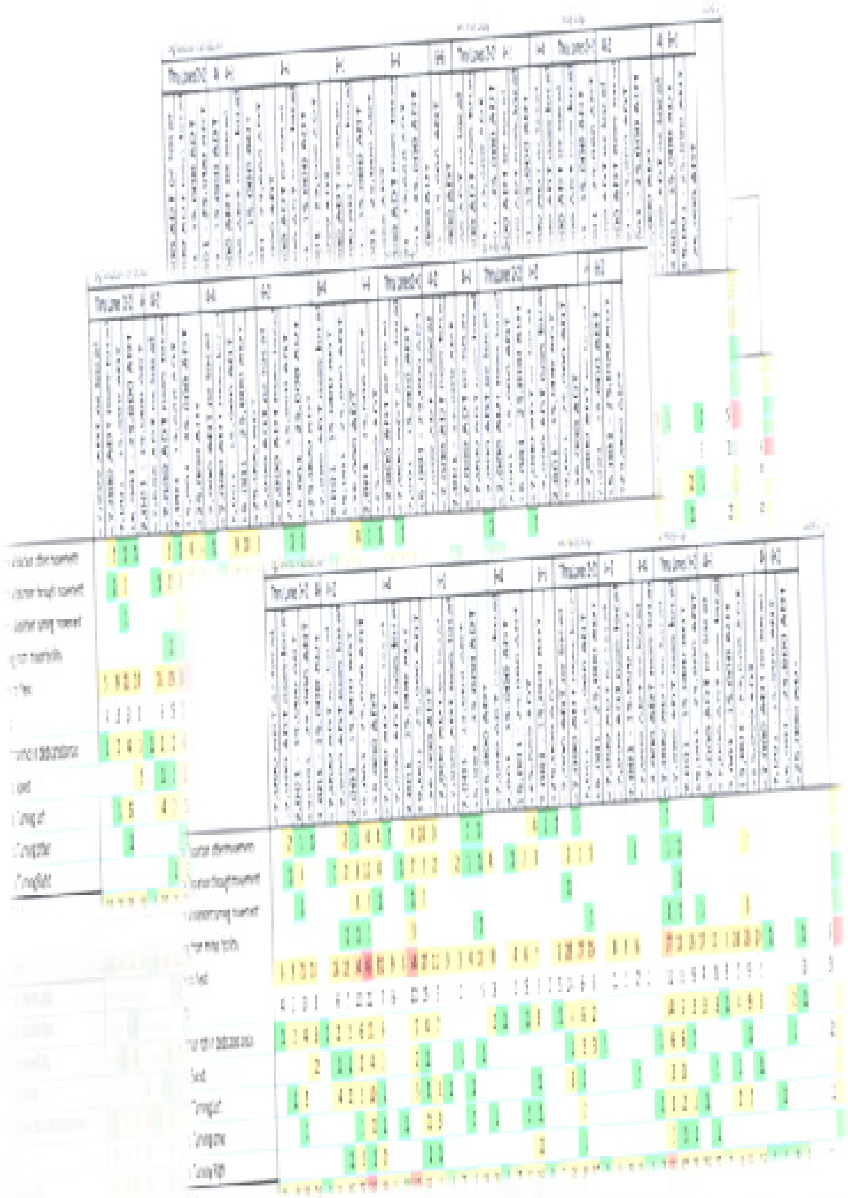
Systemic Safety

THE DATA-DRIVEN PATH TO VISION ZERO

Education • Enforcement • Engineering



April 2019

The City of
SAN DIEGO

Contents

Contributors

The City of San Diego

Julio Fuentes
Philip Rust
Everett Hauser, AICP, PTP
Angel F. Morales, EIT

Chen Ryan

Monique Chen, PE
Matt Capuzzi, PE
Andrew Prescott, AICP
Sasha Jovanovic
Nick Mesler, EIT

SafeTREC

Offer Grembek, PhD

City of San Diego at a Glance

The City of San Diego is best known for its ideal climate, beautiful beaches, and an array of world-class attractions. As the eighth-largest city in the nation and the second largest city in California, the City's total population was estimated at over 1.4 million people as of 2018. San Diego's population grew by approximately 7% between the 2000 Census and the 2010 census.

The City of San Diego presently covers 325 square miles of land area. Within this area there are over 2,800 miles of streets, with over 1,500 signalized intersections. The coast has 70 miles of beaches, including famous destinations such as Mission Beach and La Jolla Shores. The topography is generally composed of mesas intersected by canyons with elevations ranging mostly from sea level to 600 feet. Summer high temperatures average in the low 70s near the beach areas to the mid to upper 80s in the inland areas, with over 260 annual days of sunshine. Annual normal rainfall is approximately 10.3 inches per year.

A Vision Zero Focused Approach

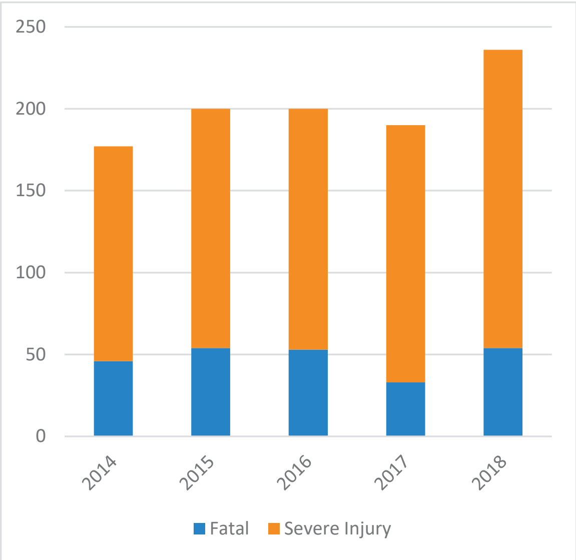
Vision Zero is a street safety policy that promotes safe roadway design that is forgiving against driver mistakes, with a goal toward preventing collisions that result in severe injury or death. Most Vision Zero programs currently in place have focused their attention on a “High Injury Network.” This is an effective approach, and it has already yielded significant decreases in fatal and severe injuries in many Vision Zero communities, including the City of San Diego. However, SSARP gives us a new perspective to forecast future crash events. Instead of creating a high injury network, the City of San Diego is focusing on network-wide sets of intersections with common physical traits like control type, traffic volumes, or number of lanes. This is because a high concentration of fatal and severe crashes happen at or near intersections (similar to injury crashes), and because intersections make up such a small proportion of the roadway network. This combination significantly improves our effectiveness compared to the high injury network/corridor strategy.

It is important to analyze all injury crashes keeping in mind that any injury crash can be potentially a severe injury or fatality. However, the wealth of data that we have collected for this analysis allows for a more focused examination of the data to understand where fatal and severe crashes are occurring and identify a systemic approach towards reducing and eliminating fatal and severe injuries.

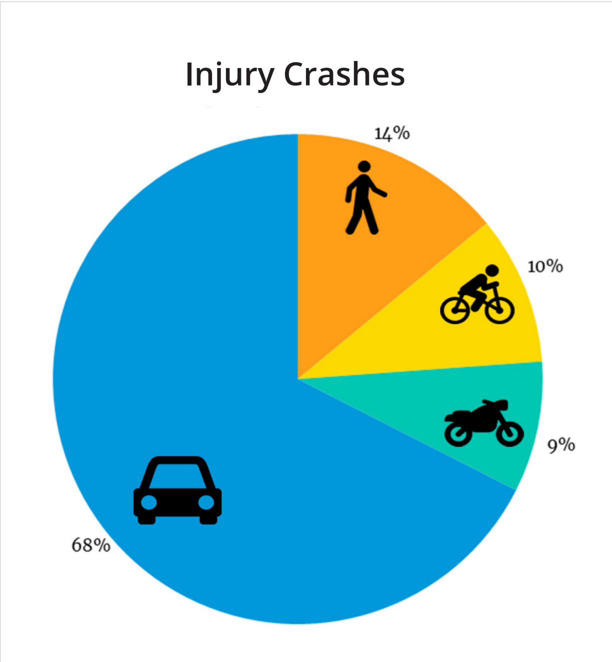
Traffic Fatalities and Severe Injuries

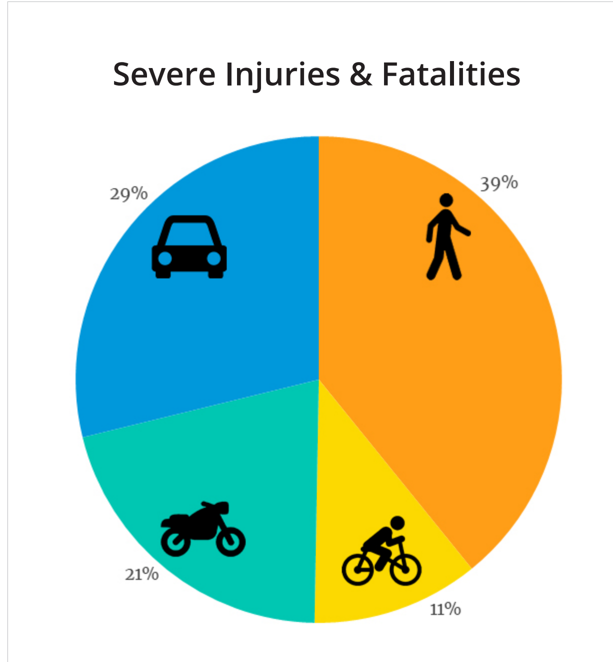
In San Diego, 182 people suffered severe injuries in crashes in 2018. 54 people lost their lives.

Fatalities and Severe Injuries by Year in San Diego (all modes)



Although vehicles hitting other vehicles is the most frequent crash by far, vehicles hitting pedestrians is the most frequent Fatal/Severe crash.





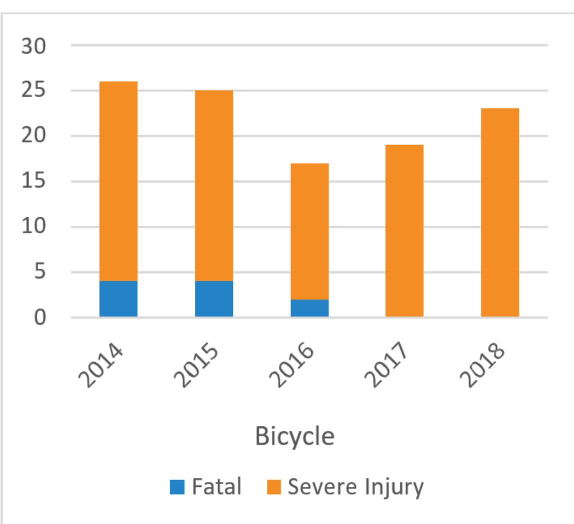
People walking and bicycling are over-represented among traffic deaths in San Diego. (2014-2016)

Collision Trends - Bicycle Fatal & Severe

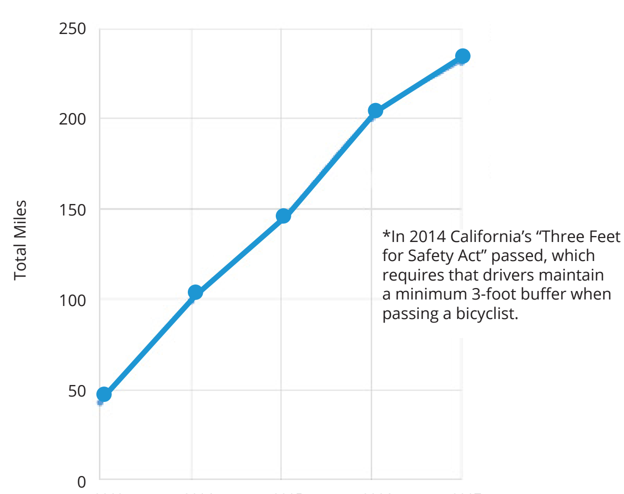
No __Fatal__ Bicycle Collisions in 2017 and 2018

Over the last several years, the City has made great efforts to improve safety for all modes of transportation. A multi-modal team has added hundreds of new and improved bicycle facilities throughout the City, which include green and buffered bike lanes and cycle tracks. An extensive bicycle network is currently under construction in the downtown community, which will serve as the backbone of a new expanded regional bicycling network.

City of San Diego - Fatal and Severe Collisions



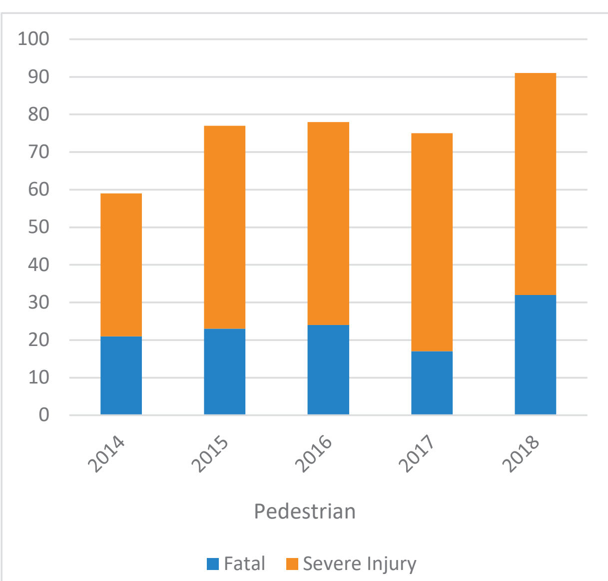
City of San Diego - Improved Bicycle Facilities (mi.)



Collision Trends - Pedestrian Fatal & Severe

For pedestrians, the City implemented a new uncontrolled crosswalk policy in 2015, which gave engineers the tools to install more pedestrian crosswalks throughout the City. The new policy takes advantage of the significant technological advances that have been made in the last decade towards improving pedestrian safety such as the Rapid Rectangular and Pedestrian Hybrid Beacons. Furthermore, the City adopted the high visibility "Continental Crosswalk" as the new standard. Hundreds of new high visibility crosswalks have been installed in the last 3 years, thus further enhancing pedestrian safety city wide. However, as this analysis demonstrates, much more needs to be done to reduce and eventually eliminate severe injury and fatal crashes in the City.

City of San Diego - Fatal & Severe Collisions



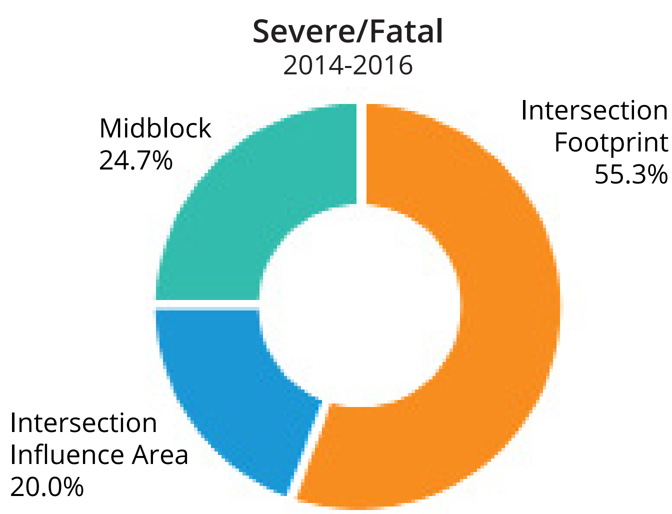
Pedestrian Safety Systemic Actions:

- Countdown timers installed at over 50 intersections every year
- Since 2014, about 100 pedestrian activated flashers have been installed
- Policy change in 2015 made it easier to qualify for marked crosswalks
- In 2015 a new standard to install high visibility crosswalk markings was implemented
- Accelerated upgrade of pedestrian crosswalk ramps throughout the City

Deadly Crash Locations

Our analysis found that fatal/severe crashes are far more frequent at or near intersections. Since intersections are such a small proportion of the area of City streets, this concentration allows us to focus our efforts, eliminating more crashes while reducing the countermeasure cost and deployment time.

75% of Severe/Fatal Crashes in San Diego occur at or near intersections



Common Deadly Crash Types

The top three fatal and severe crash types are:

1. Vehicles proceeding straight and running the red (broadside)
2. Pedestrians crossing outside the intersection near traffic signals
3. Pedestrians crossing against the signal

Overlapping Results Raise Priority

The broadside fatal/severe category matches the category of crashes identified in the Systemic Safety Analysis Reporting Program (SSARP) (see following sections), and therefore should be prioritized/ emphasized. This also allows us to leverage the vastly greater number of crashes in the systemic analysis to help identify effective countermeasures and locations for application. The fatal/severe analysis identified the same four broadside hotspots identified through the SSARP.

Several locations with multiple fatal and severe pedestrian crashes identified by our 5-year High pedestrian crash analysis also matched hotspots identified in the SSARP.

How Will We Use This Information?

We'll use the results of our research to implement effective projects to address those factors and improve safety, by applying Engineering, Education and Enforcement countermeasures on an ongoing basis. We'll track performance to gauge how well our safety strategies are working, by monitoring locations where we've made safety improvements. We'll continually improve our data and our methods, to improve safety where we need it most.

Short Term

Short term, we will use cost-effective strategies to address potential safety issues system-wide. This strategy will include locations with or without a recent crash. This allows us to address future safety risks before they become an issue.

Long Term

The City is still developing it's long range Vision Zero Strategic Plan, but when older traffic signals must be rebuilt, the City incorporates safe systems like roundabouts and medians into standard planning and practice. Safe systems assume drivers will still make mistakes but prevent those mistakes from being fatal by reducing the energy of a crash with slower speeds and eliminating crash prone left turn conflicts. The safe systems approach is to slow and seperate conflicting paths by design so the consequence of a collision is not severe injury or death.

One long term countermeasure that incorporates the safe systems approach is converting signalized intersections to roundabouts. Implementing a roundabout is generally high cost, and can be challenging to implement systemically. However, as existing signals reach the end of their useful life, conversion of the intersection to a roundabout should be considered. Well-designed roundabouts have been proven to significantly reduce the severity of crashes. This is because it is not possible for broadside and left turn crashes to occur in roundabouts. The geometry of a well-designed roundabout forces drivers to reduce speeds as they proceed through the intersection. This helps dramatically reduce the severity of all crashes including pedestrian and bicyclist crashes.

Focus on Injury Crashes

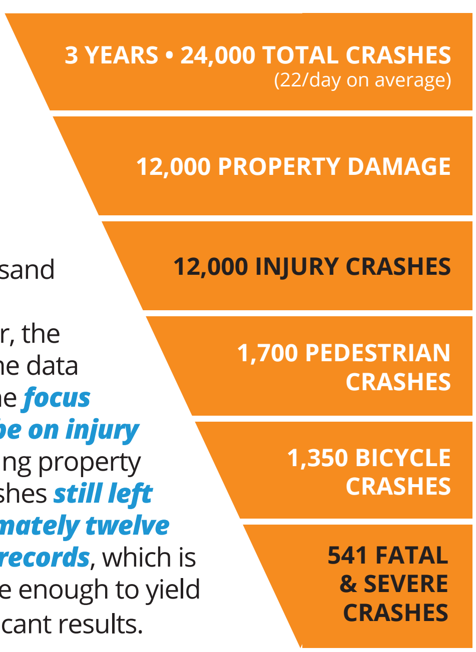
Prior to 2016, the City's practice had been to focus only on specific locations every year that had a history of crashes the previous year.

In a 2016 report titled "PERFORMANCE AUDIT OF THE CITY'S PROGRAMS RESPONSIBLE FOR IMPROVING PEDESTRIAN SAFETY", the City Auditor recognized that pedestrian crashes are not well represented in annual evaluations. This is because vehicle to vehicle crashes are far more frequent than vehicle to pedestrian crashes. Therefore, using our previous methodology, one year of crash data was not sufficient enough for pedestrian patterns to emerge at any one location.

In September 2017, Caltrans selected the City of San Diego for a $250k Highway Safety Improvement Grant to implement a city-wide Systemic Safety Analysis Reporting Program (SSARP) developed by UC Berkeley SafeTREC. The SSARP is intended to develop a standardized process for performing collision analysis, identifying safety issues, and developing a list of systemic cost-effective countermeasures. The systemic analysis approach evaluates an entire roadway network – rather than individual site-specific analysis of high-collision locations – to identify high-risk roadway features correlated with common crash types and recommend system-wide countermeasures.

SSARP by the Numbers

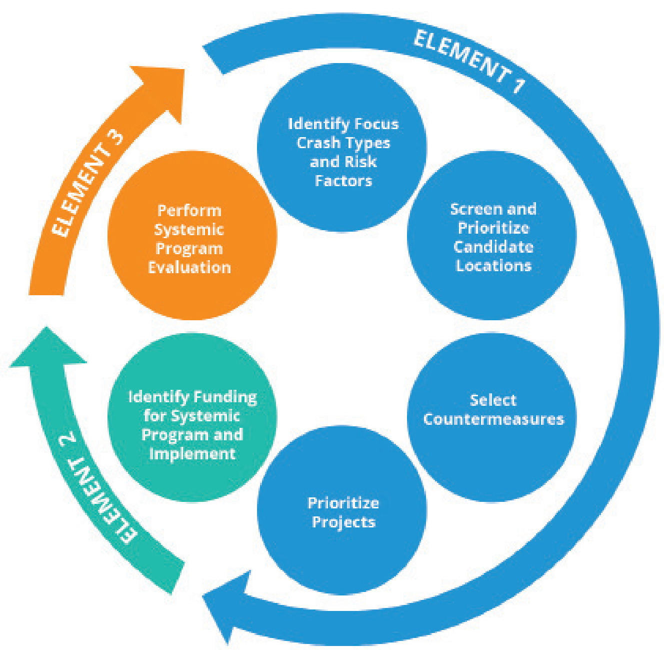
Initially this program involved 3 years of crash data (2014-2016) containing approximately twenty-four thousand individual crash reports. However, the initial review of the data suggested that the ***focus can and should be on injury crashes.*** Removing property damage only crashes ***still left us with approximately twelve thousand crash records***, which is a population large enough to yield statistically significant results.



The most common property damage crashes are different from the most common injury crashes, so mixing them together does not add statistical weight, it only clouds results. Furthermore, property damage only crashes are not reported as reliably as injury crashes. For each analysis that compares numbers of crashes, focusing on the injury crashes improves accuracy. The cost of injury crashes is much higher to our communities, and for that reason it made sense to focus our analysis on injury crashes.

In the City of San Diego, there are typically about 11 crashes each day that involve an injury. Every two days on average, one of those injuries is fatal or severe. While we are unable to prevent people from making mistakes while driving on city streets, SSARP analysis provides to us tools to identify environments and locations (hotspots) where there is a higher likelihood of injury crashes based on existing conditions, thus enabling us to establish a program of countermeasures to substantially reduce crashes at these locations.

Systemic Analysis Methodology



The focus of SSARP is to identify environments where injury crashes are most likely to occur, and subsequently improve those locations before a crash happens.

Grouping by Crash Type to Reveal Patterns

The SSARP methodology includes the grouping of locations that have similar traits (systemic). Instead of looking at each location by itself and trying to find patterns in crash type, we look at each crash type across the city and try to find common physical features associated with it among the various locations where it occurs.

A key benefit of systemic safety analysis is that the results yield a large number of locations. Combined with low-cost countermeasures, the same total investment casts a wider net. It may not be quite as effective as more expensive options at a given location, but since it is effective at so many more locations, the potential return on investment is greater. It should be noted that SSARP is not expected to replace the previous high crash analysis methodology that focuses on specific locations, but rather it will supplement the past high crash analysis practices, thus providing our City with additional tools and options to meet our goals to provide safe and reliable mobility choices for all our residents and meet our stated Climate Action and Vision Zero goals.

The Majority of Crashes Happen at or Near Intersections

Roadway location crash analysis usually separates crash locations into two categories: intersection and mid-block. Preliminary data shows that a large proportion of reported crashes are occurring at intersections or at distances close to the intersections. Analysis performed by the National Center for Statistics and Analysis of the National Highway Traffic Safety Administration reveals that "Crashes often occur at intersections because these are the locations where two or more roads cross each other and activities such as turning left, crossing over, and turning right have the potential for conflicts resulting in crashes." Furthermore, preliminary data also shows that a large proportion of "mid-block" crashes occur near the intersections. Considering that areas near intersections have unique characteristics, when compared to other "mid-block" areas, and considering that potential countermeasures for intersections can be related to countermeasures at locations near intersections, it was determined that the "mid-block" analysis should be further divided between areas close to the intersection or what we will call the "intersection influence area" and the more traditional "mid-block" areas further away from the intersections.

This report analyzes crash data for three separate roadway locations with similar characteristics.
The three categories are: intersection, intersection influence area and mid-block, and they are defined as follows:

- **Intersection (Footprint):** the space within the intersection bounded by all stop bars (or the extension of the curb line if there is no stop bar).
- **Intersection Influence Area:** the space between the intersection and the upstream end of any turn pocket (or 100 feet if there is no turn pocket).
- **Midblock:** the space along a roadway between the intersection influence areas.

Roadway Location Analysis

The three primary roadway locations: intersection footprint, intersection influence area, and midblock form the basis for the subsequent systemic safety analysis performed. Approximately 65% of the total crash records occurred in the intersection footprint, 17% in the intersection influence area and 17% mid-block.

Digging Deeper into the Data

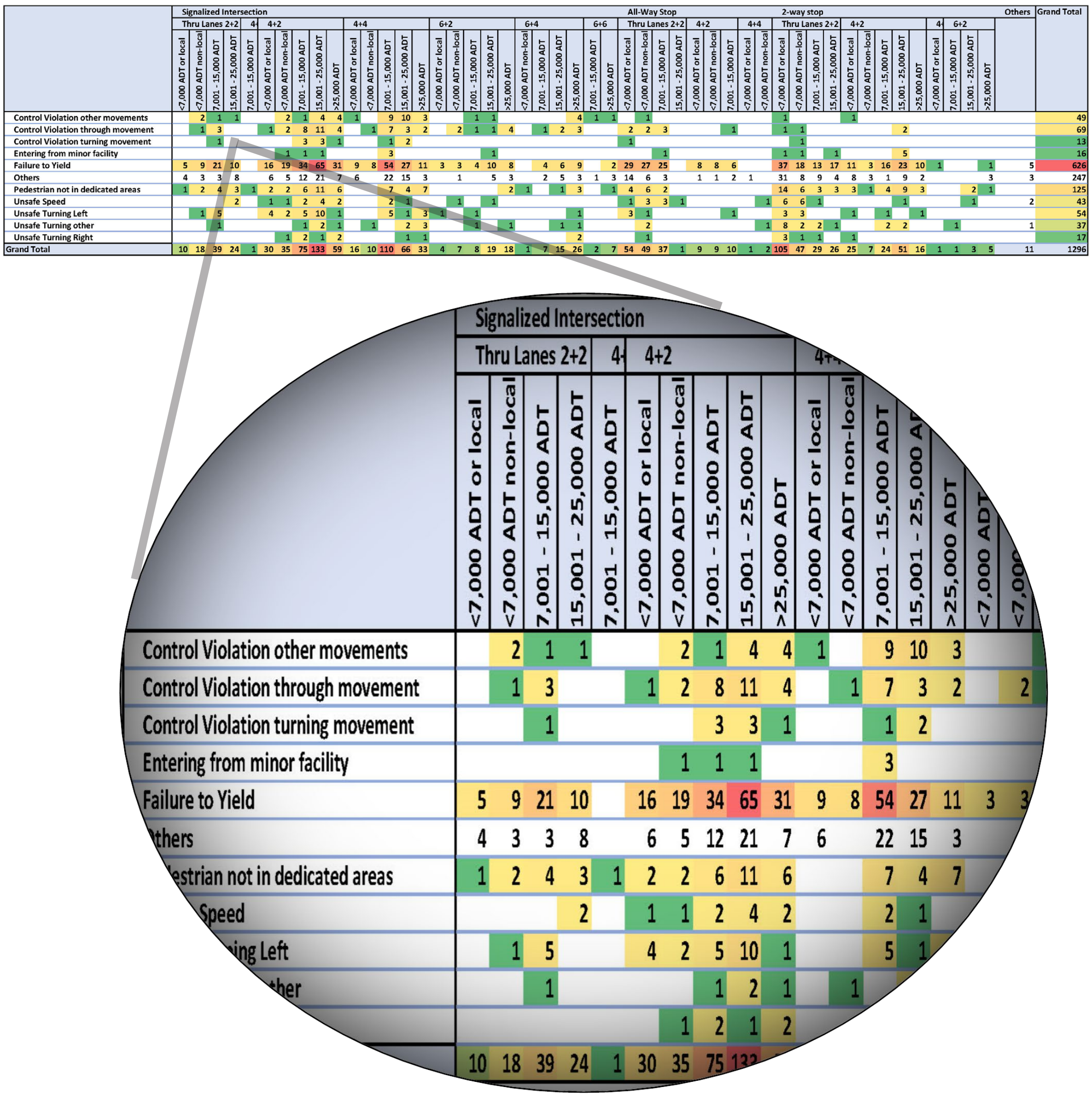
How Hotspots are Found

The San Diego SSARP project builds off of various systemic approaches to road safety that have been implemented in the United States at the federal as well as the state and local levels. Considering that a systemic approach is data driven while aiming to be flexible enough in order to adapt to varying degrees of data availability, a matrix approach has been adopted. It follows schemes established by two previous initiatives: Federal Highway Administration's (FHWA) Systemic Safety Project Selection Tool and California's Systemic Pedestrian Safety Analysis. Both approaches consist in building a matrix, whose rows and columns are determined to best illustrate the infrastructure-related dynamics behind road collisions.

The FHWA tool has been regularly used to guide road safety analyses in the country and help prioritize locations. The process developed by FHWA starts with the identification of focus crash types and facility types based on crash data and infrastructure information. This principle was adopted by the Californian analysis, where the crash matrix had columns representing locational characteristics understood to influence the collisions and based on data availability, and rows corresponding to crash types, understood as primary collision factors and behaviors thought to influence the crash.

The San Diego SSARP effort follows the same logic, but the structure of the matrix is specific to the San Diego context. The following will detail what matrices have been built and the reasons behind every choice that has been made, by listing all alternatives considered and why they have been selected or rejected. Appendix B - Matrix Development details the final variables included in each of the matrix structures. **Table 1-1** provides a summary of the analysis data sources.

Pedestrian Collisions - Intersection Footprint



This is an example of one of the matrices used in the study. Each row represents a unique crash type or violation code. Each column represents a unique roadway environment. The number in each cell represents the number of crashes of that type in that roadway environment. Green cells represent the lowest number of crashes and red cells represent the highest number of crashes. The red cells with the highest numbers represent hotspots.

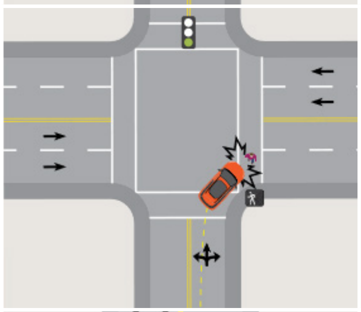
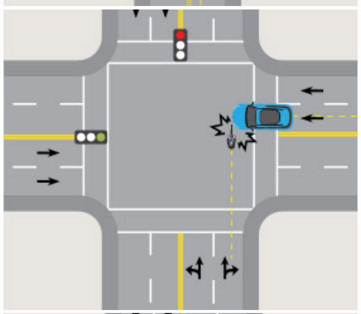
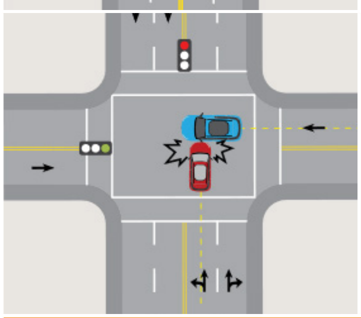
TABLE 1-1: DATA THAT ARE CORRELATED WITH CRASHES

MODE	LOCATION	CRASH FACTORS (ROWS)	ROADWAY FACTORS (COLUMNS)
VEHICLE COLLISIONS	Intersection Footprint	1. Collision type 2. Violation type	1. Traffic control type 2. Number of lanes of the primary and secondary roads 3. Traffic volume of the primary road 4. Traffic volume of the secondary road
	Intersection Influence Area	1. Collision type 2. Violation type	1. Traffic control type 2. Speed limit 3. Median presence and type
	Mid-block	1. Collision type 2. Violation type	1. Median presence and type 2. Speed limit 3. Traffic volume of the primary road
PEDESTRIAN COLLISIONS	Intersection Footprint (Shown Above)	1. Violation type 2. Pedestrian action 3. Movement of party 1	1. Traffic control type 2. Number of lanes of the primary and secondary roads 3. Traffic volume of the primary road
	Intersection Influence Area	1. Violation type	1. Traffic control type 2. Number of through lanes of primary road in both directions 3. Traffic volume of the primary road
	Mid-block	1. Violation type 2. Pedestrian action	1. Speed limit 2. Number of through lanes of primary road in both directions 3. Traffic volume of the primary road
BICYCLE COLLISIONS	Intersection Footprint	1. Party at fault 2. Violation Type	1. Traffic control type 2. Number of lanes of the primary and secondary roads
	Mid-block (Combined Intersection Influence Area & Midblock)	1. Party at fault 2. Violation type	1. Bike lane presence 2. Speed limit 3. Parking presence

The final result of this analysis is a series of distinct environments where the likelihood of types of crashes is expected to be higher. These locations are described as SSARP Hotspots. The next challenge is to identify possible low-cost countermeasures that can mitigate the crash types at the identified locations, and then identify funding to apply countermeasures to as many locations as it is economically feasible considering budget constraints.

Key Results

The SSARP results yielded hotspots or environments where there may be a higher likelihood of injury crashes. These are described in detail in Appendix C - Identification of Systemic Hotspots. The identified hotspots had similar safety issues associated with each individual mode. This allows for an approach to implement low-cost countermeasures systemically throughout the roadway network. The lower the cost of the countermeasure, the larger the number of hotspots that can be treated with a proven countermeasure. The following tables highlight the hotspots, the safety issues, and the proposed countermeasures.

EXAMPLES	HOTSPOTS	COUNTERMEASURES
 	• Turning vehicle fails to yield to **pedestrian** crossing in the crosswalk at a traffic signal • Signalized (permitted left turn) • 3x3 (both 1-way), (1-way) 3x4, 4x2 • Primary Roadway ADT: 7,001 – 25,000 (varies by lane configuration)	**Low-cost Recommendations** • Leading Pedestrian Interval (LPI) with blank-out turn restriction signs (expect 60% drop in crashes)* • High Visibility Pedestrian Crosswalks (expect 40% drop in crashes)* • Pedestrian Countdown Signal Heads (expect 25% drop in crashes)* • Left Turn Lane • Other improvements as appropriate **Higher-cost Recommendations** • Left Turn Lane and Protected Left Turn Phase (expect 55% drop in crashes)* • Flashing Yellow Arrows (expect 36.5% drop in crashes)* • Roundabout (expect 35-67% drop in crashes)*
	• **Bicyclist** proceeding straight and not stopping at a red light or stop sign • Signalized 4x4, 4x2 • Stop-controlled 2x2	**Low-cost Recommendation** • Robust detection and robust detector maintenance • Other bicycle infrastructure as appropriate **Higher-cost Recommendation** • Roundabout (expect 35-67% drop in crashes)* or other bicycle infrastructure as appropriate
	• **Vehicle** proceeding straight and not stopping at a red light. • Signalized 4x2, 4x4, 6x4, 3x3 (both 1-way) • Primary and Secondary Roadway ADT varies by lane configuration	**Low-cost Recommendation** • Reflective border around traffic signal heads (expect 15% drop in crashes)* • Other improvements as appropriate **Higher-cost Recommendation** • Roundabout (expect 35-67% drop in crashes)* • Other improvements as appropriate

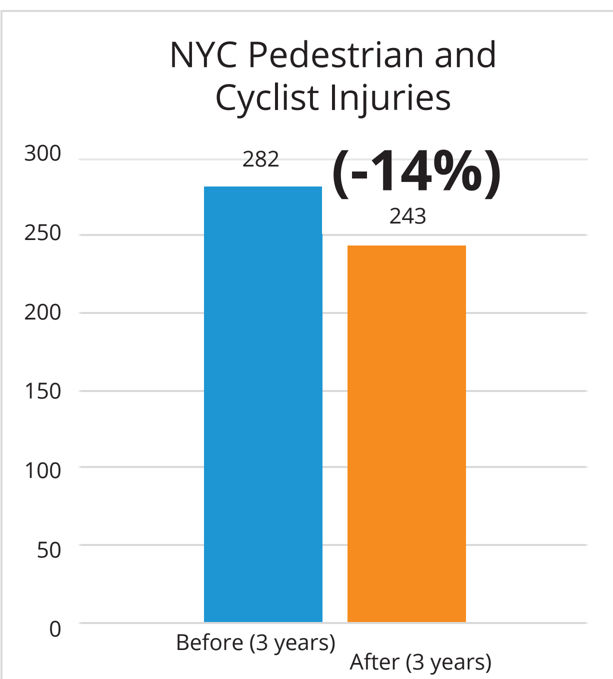
**Expected drop in crashes are taken from the California Local Roadway Safety Manual. http://www.dot.ca.gov/hq/LocalPrograms/HSIP/2016/CA-LRSM.pdf*

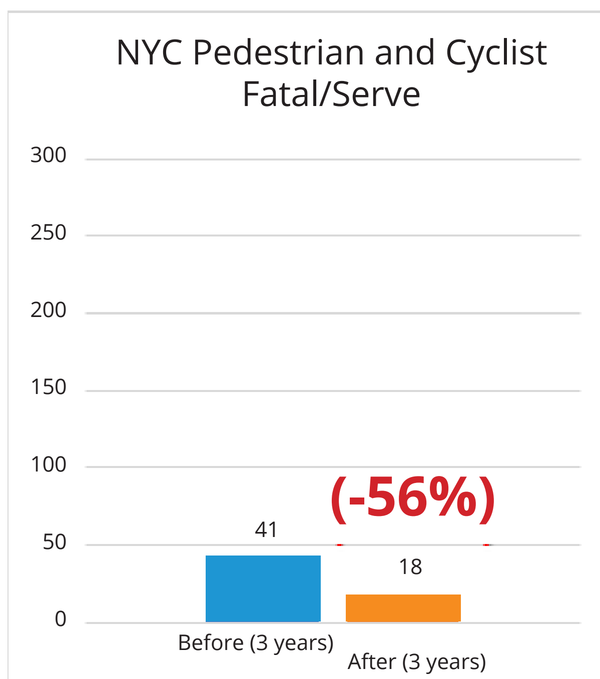
Actions to Reduce Injury Crashes

The Vision Zero approach to eliminating fatal and severe crashes and reducing injury crashes in the City involve a joint effort of Engineering, Education, and Enforcement Countermeasures. Appendix "C" describes in detail all Hotspots and Countermeasures that can be considered for each particular environment. The following section will detail examples of Engineering, Education, and Enforcement Countermeasures that can be considered for the Hotspots that have been identified.

- **Lead Pedestrian Interval (LPI)** gives pedestrians the opportunity to enter an intersection 3-7 seconds before vehicles are given a green indication. With this head start, pedestrians can better establish their presence in the crosswalk before vehicles are allowed to turn. LPIs provide the following benefits:
  - Increased visibility of crossing pedestrians.
  - Reduced conflicts between pedestrians and vehicles.
  - Increased likelihood of motorists yielding to pedestrians.
  - Enhanced safety for pedestrians who may start slower at the intersection

New York City found LPIs reduced their pedestrian and cyclist injury crashes by 14%, but reduced their pedestrian and cyclist fatal and severe crashes by 56%, as shown in the chart below.





- **High Visibility Crosswalks**, to increase awareness of pedestrian crossing locations at intersections by using highly visible marking patterns. High-visibility crosswalks help alert turning vehicles to the presence of a dedicated pedestrian crossing area that conflicts with their intended movement.

- **Pedestrian Countdown Signal Heads**, to provide crossing pedestrians with a countdown timer display to inform them of the number of seconds left to finish crossing a signalized pedestrian crossing. Countdown signals provide information for pedestrians so they can better assess risk during the flashing "DON'T WALK" interval. They have been successful in encouraging more pedestrians to use the pushbutton rather than not using the crosswalk to cross or crossing against a red light.

- **Loop Detectors for Vehicles and Bikes**, to enhance compliance at signalized intersections. When a signalized intersection does not have loop detectors or the loops require maintenance, the signal is placed into recall mode for vehicles and bikes. In these cases, users on the main street may get used to a traffic signal serving the side street or left turns when there is no traffic present. This situation can lead to non-compliance, which can lead to injury collisions. Robust loop detectors enhance signal operations and decrease driver and cyclist frustration. The implementation of robust loop detectors and a program to quickly and efficiently fix broken systems will reduce delay at signalized intersections, enhancing compliance and safety.

- **Backplates with Retroreflective Borders**, to enhance visibility of traffic signal indications. Studies have shown this countermeasure to be particularly effective at reducing broadside collisions. Drivers will sometimes run a red light at a signalized intersection because they do not notice the traffic signals sufficiently in advance. This can result in a broadside collision (one of the most dangerous collision types). The enhanced visibility and conspicuity provided by backplates with retroreflective borders can aid drivers' advance perception of the upcoming signalized intersection. A Kentucky Transportation Cabinet before and after study of 30 intersections with backplates with retroreflective material showed broadside crashes declined by 44-percent.

Education Countermeasures

- **Intersection Control Awareness Campaign**, to develop and distribute information related to collision statistics and safe behaviors for vehicles at signalized intersections. A variety of media will be considered including social media, radio, and print.

- **Public Safety Campaign**, to develop and distribute information related to collision statistics and safe behaviors for drivers of vehicles, pedestrians, and bicyclists at signalized intersections. Focus will be on how drivers and vehicles, pedestrians, and bicyclists should obey pedestrian signals, and why they should take the time to cross safely by using marked crosswalks. A variety of media will be considered including social media, radio, and print.

Enforcement Countermeasures

- **Pedestrian Safety Zones**, target enforcement of turning vehicles at signalized intersections. Enforcement would be most effective immediately following the installation of the initial phase of LPIs and blank out signs.

- **Red Light Running Enforcement**, drivers, pedestrians, and bicyclists running red lights are more likely to experience broadside collisions from crossing traffic. Targeted hotspots enforcement of hotspots will most effectively reduce this traffic violation.

Next Steps

In December 2018, Caltrans awarded the City a $1.2 million Highway Safety Improvement Program (HSIP) grant. That grant application was the direct result of the early findings of this systemic analysis; one of the first in California. With these funds, the City will install countermeasures mentioned earlier in this report: Leading Pedestrian Intervals, supplemented with Blank Out Signs, Countdown timers, and Continental Crosswalks at 66 hotspot intersections covering many neighborhoods citywide. Maps and lists of these countermeasures will soon be available on the City's Vision Zero website.

Over the next several months, City Engineers will continue to identify specific hotspot locations, match them with appropriate Countermeasures, and identify sources of funding to implement such countermeasures. These efforts will be coordinated with planning efforts and new public works and development projects citywide. Engineers will remain focused on the timely implementation of the countermeasures that have already been funded and coordinating efforts with the Police Department and Communications Department to deploy developed Education and Enforcement countermeasures.

This entire process is expected to be repeated in two years when new crash data becomes available. At that time, staff will be able to assess the impact of our Systemic Safety efforts, and at the same time identify new hotspots locations and new countermeasures. This process is expected to yield significant safety improvements for our City and is expected to help us on the path toward our Vision Zero goals.

Appendices

Appendix A

Systemic Collision Analysis Literature Review

Systemic Collision Analysis Literature Review

Introduction

The Systemic Safety Analysis Report Program (SSARP) is intended to develop a standardized process for performing collision analysis, identify safety issues, and develop a list of systemic cost-effective countermeasures that can be used to prepare future Highway Safety Improvement Program (HSIP) and other safety program applications. The systemic analysis approach evaluates an entire roadway network – rather than individual site-specific analysis of high-collision locations – to identify high-risk roadway features correlated with collisions and recommend system-wide countermeasures.

This Best Practices Review examines systemic safety analysis methods utilized by other jurisdictions. It is intended to fortify the understanding of previous efforts' successes and challenges in conducting systemic analyses, and ultimately help shape the analysis approach used for this project. The review covers documents from public agencies, interviews conducted with industry professionals, and findings from case studies.

The documents included in the review consist of the following:

- Caltrans, *Strategic Highway Safety Plan*
- Caltrans, *Systemic Pedestrian Safety Analysis – Introduction to Systemic Tool V0.9*
- Caltrans, *Systemic Safety Analysis Report Program (SSARP) Guidelines*
- Caltrans, *User Manual: Systemic Pedestrian Safety Analysis*
- Cowlitz County Department of Public Works, *Cowlitz County Strategic Risk-Based Assessment*.
- FHWA, *State-Specific Highway Safety Manual and Systemic Safety Analysis in Illinois*
- FHWA, *Systemic Safety Project Selection Tool*
- FHWA, *Thurston County, Washington Public Works Department Applies Systemic Safety Project Selection Tool*
- Illinois Department of Transportation, *Systemic Safety Improvements Analysis, Guidelines and Procedures*
- Minnesota Department of Transportation, *County Roadway Safety, Hennepin County Roadway Safety Plans*
- Minnesota Department of Transportation, *Final Report for the Minnesota County Roadway Safety Plans*
- Washington State Department of Transportation, *Strategic Highway Safety Plan: Target Zero*

Interviews were also conducted with staff from agencies that had completed systemic analysis project, including Matthew Enders from Washington State Department of Transportation, William Stein from the Federal Highway Administration – Minnesota Division, and Mark Vizecky from the Minnesota Department of Transportation.

The following set of questions guided the review process and helped shape the literature review organization, with sections dedicated to analysis approach, variable selection, collision severity, roadway location, and countermeasures. The various processes related to each of these topics are discussed throughout the remainder of this document along with descriptions of how the topics relate to the City of San Diego's current SSARP efforts.

Are there other methods besides the matrix approach?
The FHWA *Systemic Project Selection Tool* was regularly used to guide analysis approaches. The systemic analysis approaches reviewed utilized a table or matrix approach to examine collision records, identify emphasis areas, and/or prioritize individual locations.

Are there weaknesses to the matrix approach?
The most common weakness or difficulty identified was a lack of data points. Five-years of collision data was a common data analysis time period that help achieved a balance between the number of records with potential changes in the roadway network or travel patterns. The five-years of data was commonly used to compare annual changes in collision types and environments where they occur.

How do they determine their rows and columns?
Initial collision record analyses are used to identify roadway environments where collisions are occurring and the most predominant crash types. This initial analysis was commonly performed using descriptive statistics in the form of a table or a "crash tree" and compared the jurisdiction to the state as a whole or an average across all counties. Crash types found to be more frequent then become the focus for further analysis and help shape the matrix format. Columns are typically defined through an initial evaluation of characteristics understood to contribute to the crash types being analyzed (rows). However, existing data availability and the ability to collect the data were also factors in column selection.

How do they determine if they have enough data?
Five-years of collision data was a common time period analyzed. The justification for the five-year period, when provided, was related to achieving a balance between maximizing data points while considering potential roadway network or travel pattern changes.

Do they try to minimize empty cells?
Discussions of empty cells were not found in the review.

How do they include severity?
All approaches reviewed largely focused on collisions resulting in severe and fatal injuries. However, it was very common for the initial collision analysis to summarize collision types by severe/fatal records and all collision records. These two summaries were commonly compared to statewide collision records or county averages.

Do they use separate matrices, or weight them in combination?

Separate matrices were found to be used for each roadway environment, with the most common being intersection, segments, and curves along segments. This allowed for the columns to be catered to the specific environment type and for a more focused data collection approach for the records falling into each category.

How do they handle intersection vs. segments?
Intersections and segments were found to be one of the initial factors used to separate the data for further analysis. This initial categorization also dictated which variables were collected for each collision.

How do they select the boundary between the two, do they normalize by segment length?
Intersection collisions generally consist of those reported as occurring within the intersection footprint, whereas midblock or segment collisions consist of any collision occurring along the roadway outside of the intersection footprint. The FHWA *Systemic Safety Project Tool* advises for the separation of segment and intersection collisions, as a means to focus the identification of risk factors and select relevant countermeasures. In Illinois, segments were broken into 1- to 3-miles long sections. Illinois also used curves as a location type, identified as any curve with a radius of 3,000 feet or smaller.

Minnesota categorized the data by urban and rural for intersections, segments, and horizontal curves (those with a curve radius between 500 and 1,200 feet), resulting in six roadway environment categories. Roadway segments were defined by cross-section changes, while considering speed limits, ADT, and geometrics. Minnesota normalized the rural segment collisions by roadway departure crashes per mile, whereas the urban segments were not normalized.

Do they group intersections that are close to each other into corridors?
No, this approach was not found in the review.

How do they rank or group countermeasures?
Countermeasures were commonly found to be ranked using the CMF value reported in the FHWA CMF Clearinghouse. Multiple countermeasures may be applied to an individual location to form a safety project. Safety projects were found to be ranked using a benefit/cost calculation.

Analysis Approach

Each approach reviewed was generally based on the four-step process identified in the Federal Highway Administration's (FHWA's) Systemic Safety Project Selection Tool, which consists of 1) identify focus crash types and risk factors; 2) screen and prioritize candidate locations; 3) select countermeasures; and 4) prioritize projects.[1] As such, most systemic analysis approaches reviewed utilized a tabular approach to examine collision records, identify emphasis areas, and/or prioritize individual locations. In lieu of a matrix or table, data was found to be presented in a "crash tree" format. Crash trees provide for a clear visual comparison of collision frequencies under various conditions but were generally found to display fewer layers of data when compared to a matrix or table. Examples of data organized in tabular, matrix, and crash tree formats are provided in the following pages.

The process most consistent with the approach proposed for the City of San Diego Systemic Safety Analysis Report Program is Caltrans' Systemic Pedestrian Safety Analysis. This approach utilized a matrix structure with the rows consisting of pedestrian movements/locations and primary collision factors, while the matrix columns align with roadway characteristics. However, as the City of San Diego effort expands beyond pedestrians, the roadway characteristics collected and analyzed include those relevant to vehicle-vehicle collisions as well as those involving bicyclists. One of the major benefits of the matrix approach is that it allows all records to be retained within the tool itself, enabling further examination of collision groupings in an expedited manner. Each cell represents a specific set of roadway characteristics and specific set of collision details. The number within the cell represents the number of records, each of which can be quickly retrieved. Figure 1 displays a sample matrix from Caltrans' Systemic Pedestrian Safety Analysis.

An alternative tabular approach was recommended by Illinois DOT (IDOT) that relies on extensive data gathering. Collisions are grouped together based on where they occurred, such as multiple collisions at a single intersection or along a single segment. A variety of data inputs are then collected for the segments and assembled into a table, with rows representing a single intersection or segment and the columns representing roadway characteristics. Points are then awarded based on the roadway characteristics, resulting in a total score which allows for ranking and prioritization. Figure 2 shows the IDOT tabular organization for intersection records.[2]

One limitation of the tabular approach is that, while it analyzes all collision records, it does not analyze them together, but rather by location. This approach does not provide for the identification of systemwide issues, but rather identifies which systemwide locations may be of the greatest safety concern.

The Hennepin County (Minnesota) Roadway Safety Plan relied on crash trees developed by breaking down the data initially by area (rural vs. urban), then by crash location (intersection vs. segment crashes), followed by crash type (right angle, rear end, pedestrian, bicycle, run off the road), and finally speed (high speed > 45mph vs. low speed < 45mph). Figure 3 displays the Hennepin County crash tree.

Urban and Urbanized, Conventional Highway and City One-Way Street, 2009-2013	Control Type (STEP 2 FILL IN MATRIX)	Unsignalized					Signalized (STEP 3 SYSTEMIC HOTSPOTS)												Total
	# of Lanes - Main	<=3		>3			<=3				>3								
	# of Lanes - Cross	<=3		<=3		>3	<=3		>3		<=3				> 3				
	AADT - Main	<50,000	>=50,000	<50,000	>=50,000	<50,000	< 50,000		< 50,000		<50,000		>=50,000		< 50,000		>= 50,000		
	AADT - Cross	<12,000					<12,000	>=12,000	<12,000	>=12,000	<12,000	>=12,000	<12,000	>=12,000	<12,000	>=12,000	<12,000	>=12,000	
# of Intersections		1197	15	2347	335	3	166	22	23	21	901	54	148	15	271	208	56	67	5876
Pedestrian Movements	Primary Collision Factors																		
Xing Xwalk – Intersection	Influence of Alcohol	1		1					1						1				4
	Following too close			1															1
	Failure to Yield	45	1	67	5	2	34	3	1	3	94	4	12	1	28	28	4	16	348
	Improper Turn			6							2					2		1	11
	Speeding	1		2							2		1						6
	Other Violations	12		36	1		12		4	2	35	3	9	2	14	14	4	8	156
	Failure to Yield			2	1			1										2	6
	Improper Turn			1															1
	Other Violations			1						1									2
Xing – Not Xwalk	Influence of Alcohol			1															1
	Failure to Yield	6		10	2						3				1				22
	Improper Turn			1								1	1					1	4
	Speeding	4		2							1					1			8
	Other Violations	31		51	1	2	3	2	1		22	1	4		16	3	1	4	142
Roadway – Include Shoulder	Influence of Alcohol	3									1				1		1		6
	Failure to Yield	1		1	1								1			2			6
	Improper Turn	4		3							1								8
	Speeding	5		4							1								10
	Other Violations	11	1	9	1				1		5		1		2	3		1	35
Not in Roadway	Influence of Alcohol												1			1			2
	Failure to Yield	3		1	1						7				1	2		3	18
	Improper Turn	2		1	1										3				7
	Speeding	2		4			1									2			9
	Other Violations			2			1				6	1	2		1	1			14
Total		131	2	207	14	4	51	6	8	6	180	10	32	3	68	59	10	36	827
Rate (crashes/intersection)		0.11	0.13	0.09	0.04	1.33	0.31	0.27	0.35	0.29	0.20	0.19	0.22	0.20	0.25	0.28	0.18	0.54	0.14

Figure 1: Matrix Data Organization – Caltrans, *Systemic Pedestrian Safety Analysis* (Draft 2017)

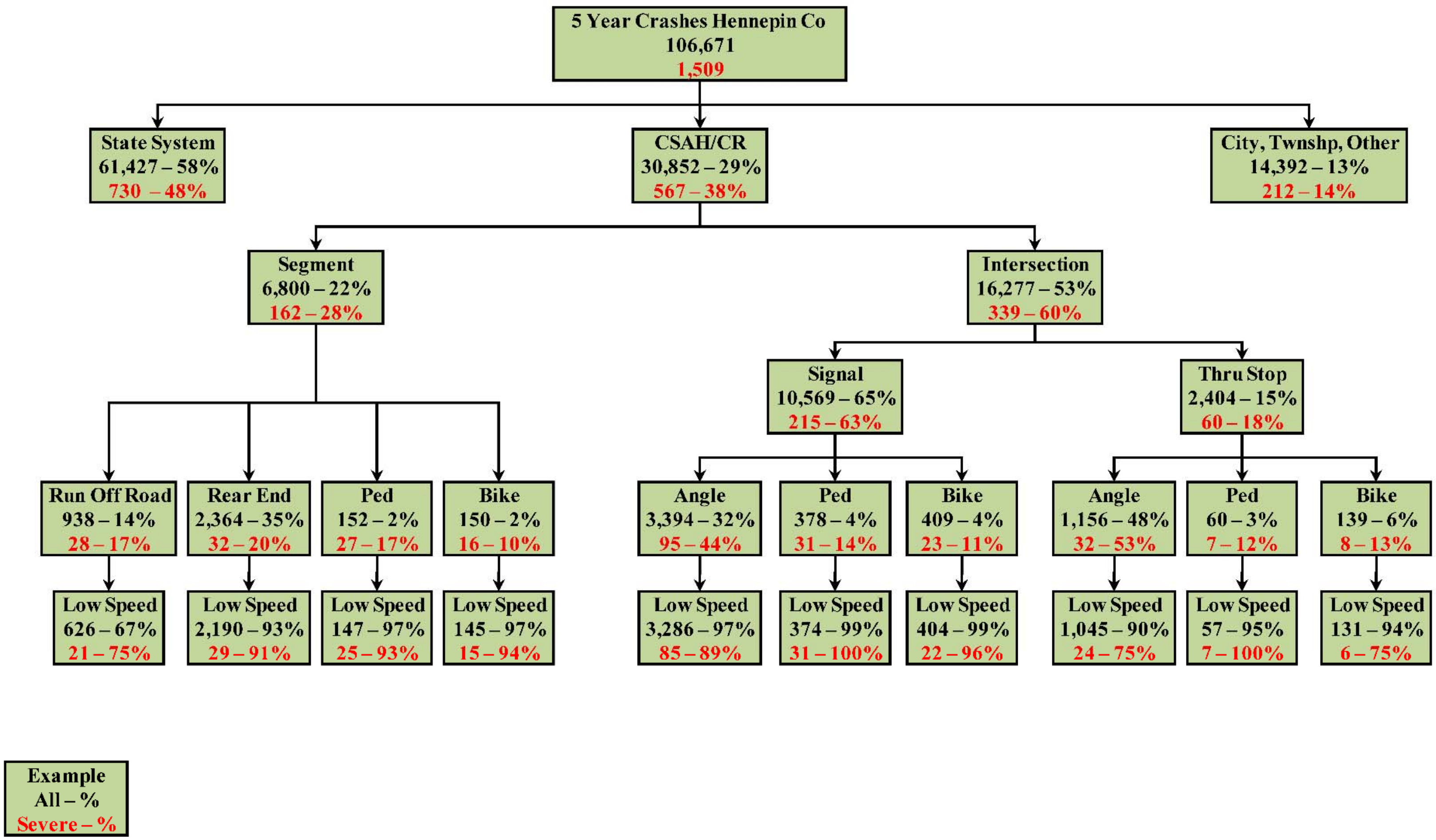
TABLE 4-5

Data Collection Excel Intersection Layout 1

Intersection Data Sheet

Intx ID	Intersection Streets	Rural/Urban	Traffic Control	Leg Count	Township	Right Turn Lane Present	Left Turn Lane Present	Major Route Through Lanes	Minor Route Through Lanes	NB AADT	SB AADT	NB/SB Max	EB AADT	WB AADT	EB/WB Max	Major AADT	Minor AADT	Total Entering Vehicles	Min/Maj Ratio Value	Street Lights	Flashers	2007-2011 Crashes Crash Severity				
																						K	A	B	C	PDO
06-03	CH 6 & Hwy 10	Rural	1 or 2 Way Stop	4	Scott	No	No	2	2	150	1,500	1,500	2,800	1,900	2,800	2,800	1,500	3,175	0.536	No	No	0	2	0	0	2
25-03	CH 25 & Hwy 10	Urban	Signalized; Mulit-Phase; Actuated	4	Champaign	Yes	Yes	2	2	5,800	9,200	9,200	7,900	5,500	7,900	9,200	7,900	14,200	0.859	Yes	No	0	2	0	0	13
50-06	CH 50 & US Hwy 150	Rural	Signalized; 2-Phase; Actuated	4	Mahomet	Yes	Yes	2	2	7,900	450	7,900	7,700	9,700	9,700	9,700	7,900	12,875	0.814	Yes	No	0	1	2	1	14
01-01	CH 1 & CH 20	Rural	1 or 2 Way Stop	4	Hensley	No	No	2	2	3,850	2,700	3,850	1,200	800	1,200	3,850	1,200	4,275	0.312	No	No	0	1	3	1	2
18-07	CH 18 & IL 130	Rural	1 or 2 Way Stop	4	Philo	No	Yes	2	2	10,700	9,700	10,700	4,200	200	4,200	10,700	4,200	12,400	0.393	Yes	No	0	1	2	0	3
22-01	CH 22 & US Hwy 136	Rural	1 or 2 Way Stop	4	Kerr	No	No	2	2	275	1,300	1,300	2,050	2,250	2,250	2,250	1,300	2,938	0.578	No	No	0	1	0	1	3
06-02	CH 6 & CH 18	Rural	1 or 2 Way Stop	4	Colfax	No	No	2	2	700	950	950	2,650	2,250	2,650	2,650	950	3,275	0.358	Yes	No	0	1	0	0	0
09-02	CH 9 & US Hwy 45	Rural	1 or 2 Way Stop	4	Ludlow	No	No	2	2	3,300	3,450	3,450	650	550	650	3,450	650	3,975	0.188	Yes	No	0	0	0	0	4
11-01	CH 11 & US Hwy 45	Rural	1 or 2 Way Stop	4	Rantoul	No	No	4	2	8,650	10,350	10,350	1,550	2,000	2,000	10,350	2,000	11,275	0.193	Yes	No	0	3	2	3	8
55-01	CH 55 & US Hwy 136	Urban	Signalized; 2-Phase; Fixed	4	Ludlow	Yes	Yes	4	4	9,500	7,800	9,500	7,100	9,900	9,900	9,900	9,500	17,150	0.960	Yes	No	0	1	4	5	13
15-01	CH 15 & Hwy 130	Rural	1 or 2 Way Stop	4	Philo	No	Yes	2	2	7,400	5,800	7,400	4,200	79	4,200	7,400	4,200	8,740	0.568	Yes	No	1	0	0	1	8
18-02	CH 18 & CH 25	Rural	1 or 2 Way Stop	4	Tolono	No	No	2	2	2,050	275	2,050	4,000	3,300	4,000	4,000	2,050	4,813	0.513	No	No	0	1	1	2	1
16-02	CH 16 & Hwy 130	Rural	1 or 2 Way Stop	4	Crittenden	No	No	2	2	3,300	3,550	3,550	150	750	750	3,550	750	3,875	0.211	No	No	0	1	0	0	1
18-04	CH 18 & I-57 NB Ramps	Rural	Unknown	4	Tolono	Yes	Yes	2	0	0	500	500	4,900	4,900	4,900	4,900	500	5,400	0.102	Yes	No	0	1	0	0	1
11-03	CH 11 & CH 32	Rural	1 or 2 Way Stop	3	Compromise	No	No	2	2	2,100	275	2,100	1,050	250	1,050	2,100	1,050	1,838	0.500	No	No	0	0	0	1	1
15-02	CH 15 (West) & Hwy 49	Rural	1 or 2 Way Stop	4	South Homer	No	No	2	2	3,100	2,650	3,100	250	2,700	2,700	3,100	2,700	4,350	0.871	Yes	No	0	0	0	0	0
25-02	CH 25 & Kirby Rd	Urban	Signalized; 2-Phase; Actuated	4	Champaign	Yes	Yes	2	2	7,200	5,800	7,200	4,600	2,950	4,600	7,200	4,600	10,275	0.639	No	No	0	2	2	0	8
20-03	CH 20 & US Hwy 45	Rural	1 or 2 Way Stop	4	Somer	Yes	Yes	4	2	10,350	8,550	10,350	800	2,900	2,900	10,350	2,900	11,300	0.280	Yes	No	0	2	2	1	6
12-01	CH 12 & CH 20	Rural	Unknown	4	Stanton	No	No	2	2	850	1,100	1,100	1,000	950	1,000	1,100	1,000	1,950	0.909	No	Yes	0	2	2	0	1
14-01	CH 14 & Hwy 49	Rural	1 or 2 Way Stop	4	South Homer	No	No	2	2	2,800	2,800	2,800	200	450	450	2,800	450	3,125	0.161	No	No	0	2	0	0	2
18-06	CH 18 & US Hwy 45	Rural	1 or 2 Way Stop	3	Tolono	Yes	Yes	4	2	9,700	8,500	9,700	200	2,900	2,900	9,700	2,900	10,650	0.299	No	No	0	1	1	0	8
18-01	CH 18 & CH 19	Rural	1 or 2 Way Stop	4	Tolono	No	No	2	2	75	750	750	3,300	1,000	3,300	3,300	750	2,563	0.227	Yes	No	0	1	1	0	3
18-05	CH 18 & US Hwy 45	Urban	Signalized; 2-Phase; Fixed	3	Tolono	Yes	Yes	4	0	11,500	10,500	11,500	0	4,200	4,200	11,500	4,200	13,100	0.365	Yes	No	0	0	2	1	10
51-04	CH 51 & US Hwy 136	Urban	Signalized; 2-Phase; Fixed	3	Rantoul	Yes	Yes	4	0	4,100	0	4,100	9,900	10,000	10,000	10,000	4,100	12,000	0.410	Yes	No	0	0	0	0	4
51-01	CH 51 & US Hwy 136	Urban	1 or 2 Way Stop	4	Rantoul	No	Yes	4	2	1,200	500	1,200	12,600	12,600	12,600	12,600	1,200	13,450	0.095	Yes	No	0	0	1	1	1
32-01	CH 32 & US Hwy 136	Rural	1 or 2 Way Stop	4	Harwood	No	No	2	2	1,200	2,400	2,400	2,250	3,100	3,100	3,100	2,400	4,475	0.774	Yes	Yes	0	0	1	0	2
50-02	CH 50 & CH 54 West	Rural	1 or 2 Way Stop	4	Mahomet	Yes	No	2	2	2,300	3,600	3,600	2,100	250	2,100	3,600	2,100	4,125	0.583	Yes	No	0	0	1	1	1
01-02	CH 1 & CH 11	Rural	1 or 2 Way Stop	3	Hensley	No	No	2	0	0	2,350	2,350	750	2,850	2,850	2,850	2,350	2,975	0.825	No	No	0	0	0	0	1
13-01	CH 13 & CH 15	Rural	1 or 2 Way Stop	4	South Homer	No	No	2	2	250	700	700	2,500	2,700	2,700	2,700	700	3,075	0.259	No	No	0	0	0	0	0
11-02	CH 11 & CH 12	Rural	1 or 2 Way Stop	4	Compromise	No	No	2	2	450	800	800	1,050	1,200	1,200	1,200	800	1,750	0.667	No	No	0	0	0	0	0
15-03	CH 15 (East) & Hwy 49	Rural	1 or 2 Way Stop	4	South Homer	No	No	2	2	3,100	3,100	3,100	2,150	250	2,150	3,100	2,150	4,300	0.694	Yes	No	0	0	0	0	0
06-01	CH 6 & CH 17	Rural	1 or 2 Way Stop	4	Sadorus	No	No	2	2	1,100	25	1,100	700	1,600	1,600	1,600	1,100	1,713	0.688	No	No	0	0	0	0	0
08-02	CH 8 & CH 30	Rural	1 or 2 Way Stop	4	East Bend	No	No	2	2	300	650	650	400	400	400	650	400	875	0.615	No	No	0	0	0	0	0
17-01	CH 17 & CH 19	Rural	1 or 2 Way Stop	4	Pesotum	No	No	2	2	900	250	900	1,100	1,150	1,150	1,150	900	1,700	0.783	No	No	0	0	0	0	0
51-03	CH 51 (East) & Hwy 45	Urban	Signalized; 2-Phase; Fixed	4	Ludlow	Yes	Yes	4	2	5,300	7,100	7,100	4,550	4,300	4,550	7,100	4,550	10,625	0.641	Yes	No	0	0	2	0	10
01-03	CH 1 & US Hwy 136	Rural	1 or 2 Way Stop	4	East Bend	No	No	2	2	750	2,600	2,600	2,650	2,500	2,650	2,650	2,600	4,250	0.981	No	No	0	0	2	0	8
50-04	CH 50 & I-74 WB Ramps	Rural	Unknown	4	Mahomet	Yes	Yes	2	0	9,700	9,700	9,700	0	1,300	1,300	9,700	1,300	11,000	0.134	Yes	No	0	0	0	1	8
18-03	CH 18 & I-57 SB Ramps	Rural	Unknown	4	Tolono	No	No	2	0	900	0	900	4,000	4,000	4,000	4,000	900	4,900	0.225	Yes	No	0	0	1	0	5
50-01	CH 50 & US Hwy 150	Rural	1 or 2 Way Stop	3	Mahomet	No	Yes	2	0	2,550	0	2,550	10,400	10,400	10,400	10,400	2,550	11,675	0.245	Yes	No	0	0	0	1	5
17-02	CH 17 & US Hwy 45	Rural	1 or 2 Way Stop	4	Pesotum	Yes	Yes	2	2	8,500	3,650	8,500	300	1,300	1,300	8,500	1,300	6,875	0.153	Yes	No	0	0	1	0	3
50-05	CH 50 & I-74 EB Ramps	Rural	Unknown	4	Mahomet	No	Yes	2	0	7,900	7,900	7,900	0	1,200	1,200	7,900	1,200	9,100	0.152	Yes	No	0	0	1	0	3
50-03	CH 50 & CH 54 East	Rural	All-Way Stop	4	Mahomet	No	No	2	2	6,500	9,700	9,700	650	2,550	2,550	9,700	2,550	9,700	0.263	Yes	No	0	0	0	1	2
20-02	CH 20 & I-57 NB Ramps	Rural	Unknown	4	Hensley	No	No	2	0	0	950	950	5,600	5,600	5,600	5,600	950	6,550	0.170	No	No	0	0	0	0	2
51-02	CH 51 (West) & Hwy 45	Urban	Signalized; 2-Phase; Fixed	4	Rantoul	Yes	Yes	4	2	7,100	7,100	7,100	700	450	700	7,100	700	7,675	0.099	Yes	No	0	0	0	0	2
25-01	CH 25 & Windsor Rd	Urban	All-Way Stop	4	Champaign	No	Yes	2	2	5,600	2,650	5,600	5,400	2,850	5,400	5,600	5,400	8,250	0.964	No	No	0	0	0	0	1
20-05	CH 20 & CH 22	Rural	1 or 2 Way Stop	4	Ogden	No	No	2	2	950	800	950	650	1,050	1,050	1,050	950	1,725	0.905	Yes	No	0	0	0	0	1
20-04	CH 20 & CH 24	Rural	1 or 2 Way Stop	4	Stanton	No	No	2	2	275	400	400	950	800	950	950	400	1,213	0.421	No	No	0	0	0	0	1
30-01	CH 30 & US Hwy 136	Rural	1 or 2 Way Stop	3	Brown	No	No	2	0	1,800	0	1,800	2,500	2,500	2,500	2,500	1,800	3,400	0.720	No	No	0	0	0	0	1
08-01	CH 8 & Hwy 47	Rural	1 or 2 Way Stop	4	Brown	No	No	2	2	3,400	3,550	3,550	175	250	250	3,550	250	3,688	0.070	No	No	0	0	0	0	1
09-04	CH 9 & CH 22	Rural	1 or 2 Way Stop	4	Kerr	No	No	2	2	175	175	175	75	200	200	200	175	313	0.875	No	No	0	0	0	0	1
55-02	CH 55 & US Hwy 45	Rural	1 or 2 Way Stop	4	Ludlow	No	No	2	2	3,450	3,300	3,450	600	375	600	3,450	600	3,863	0.174	Yes	No	0	0	0	0	1
20-01	CH 20 & I-57 SB Ramps	Rural	Unknown	4	Hensley	No	No	2	0	1,500	0	1,500	1,350	1,350	1,350	1,500	1,350	2,850	0.900	No	No	0	0	0	0	0
09-01	CH 9 & CH 23	Rural	1 or 2 Way Stop	4	East Bend	No	No	2	2	1,050	950	1,050	250	59	250	1,050	250	1,155	0.238	No	No	0	0	0	0	0
09-03	CH 9 & CH 32	Rural	All-Way Stop	4	Harwood	No	No	2	2	200	450	450	550	400	550	550	450	800	0.818	No	No	0	0	0	0	0
16-01	CH 16 & US Hwy 45	Rural	1 or 2 Way Stop	3	Pesotum	No	Yes	2	2	3,650	3,650	3,650	250	0	250	3,650	250	3,775	0.068	Yes	Yes	0	0	0	0	0
23-01	CH 23 & US Hwy 136	Rural	1 or 2 Way Stop	3	Condit	No	No	2	0	500	0	500	2,850	2,650	2,850	2,850	500	3,000	0.175	No	No	0	0	0	0	0
24-01	CH 24 & US Hwy 150	Rural	1 or 2 Way Stop	4	St Joseph	No	No	2	2	650	200	650	4,950	5,700	5,700	5,700	650	5,750	0.114	Yes	No	0	0	0	0	0

Figure 2: Tabular Data Organization – Illinois Department of Transportation, *Systemic Safety Improvements Analysis, Guidelines and Procedures* (2014)



Source: MnCMAT Crash Data, 2005-2009
-Severe is fatal and serious injury crashes (K+A)
-Numbers are not additive
-Other comprises of Left Blank, "Unknown" etc.
High Speed > 45
Low Speed <= 45

Figure 3: Crash Tree Data Organization – Minnesota Department of Transportation, Hennepin County, *County Roadway Safety Plans* (2011)

The populated crash diagram led to the identification of five priority crash types to focus on and document any locations where the priority crash type occurs at a rate of one or more per year (high crash location) as well as identify basic roadway and traffic characteristics at crash locations. The Hennepin County Roadway Safety Plan priority crash type analysis also took into account the inventory of facility types, enabling the development of crash rates.[3] This process is recommended to local agencies statewide by the MnDOT for preparation of their respective County Roadway Safety Plans.[4] The roadway characteristics and collision variables used to group records in Hennepin County are similar to those being use in San Diego, however, rather than limit the crash types to five, all crash types are being analyzed in San Diego so as to maintain the ability to still potentially identify trends among less frequent crash types.

Variable Selection

For the City of San Diego effort, the variables selected for analysis will form the matrix rows and columns. Understanding how and why various approaches select certain variables is intended to further inform the matrix row and column development. Variable selection was found to rely predominantly on existing information either included in collision reports, in available GIS databases, or via aerial imagery review.

In the absence of detailed data for variables of interest, Washington State DOT (WSDOT) staff advises agencies to explore the use of a qualitative ranking factor. In the absence of average daily traffic volumes, an understanding of the roadway network could be used to inform a qualitative ranking of high volume, medium volume, and low volume. This approach enables the inclusion of those variables with lacking data, while limiting the amount of time spent collecting additional data.[5]

The Systemic Crash Matrix, developed in support of Caltrans' Systemic Pedestrian Safety Analysis, categorizes columns by roadway or locational characteristics such as AADT, number of lanes and intersection control. The rows are classified by the pedestrian movement/location (crossing not in crosswalk, crossing not at intersection, roadway, not in roadway, approach/leave school bus, etc.) and by primary collision factor (improper turn, speeding, following to close, etc.). The selected variables rely on widely available data.[6,7]

Hennepin County also relied on existing, available data for the initial data analysis. Although a more focused analysis on priority crash types was performed using variables specific to the respective crash type. For example, when analyzing pedestrian collisions at intersections, both the vehicle movement and the pedestrian movement were identified in the crash tree, whereas rear end crashes considered the movement of only the vehicle hit.[8]

IDOT was the only process that required extensive, supplemental data collection at each collision location. Some of the variables required by IDOT for intersection analysis include the number of vehicles travelling through the intersection, the angular skew of the intersection, presence/absence of crosswalks, access points within 500' of the intersection, bus stop presence, right- and left-turn lane presence. Segment inputs included length, shoulder type and width, number of lanes, median width, posted speed limit, on-street parking presence, street lighting, and two-way left-turn lane presence. Inputs unique to curves consisted of horizontal curve length and radius, chevron presence, curve warning/speed signage, visual trap presence, and a Roadside Hazard Rating (RHR) score derived from an FHWA process.[9]

Data Range

Many of the approaches reviewed were intended for more rural environments, such as county or state roadway systems, and therefore did not have many collisions during a single year, requiring the use of multiple data years. Three to five years of collision data were used in all analyses reviewed. This range helps achieve a balance between two key considerations, 1) providing enough data points to analyze and spot trends, and 2) limiting the range to avoid or minimize changes to the roadway environments or travel patterns.

Collision Severity

The vast majority of the systemic analysis approaches were intended to identify strategies to reduce crashes resulting in severe injuries or fatalities. Many of the documents reviewed were cited as helping to achieve greater policy goals aligned with the Vision Zero campaign or equivalent. While severe injuries and fatal crashes were generally the focus of the collision analyses and the resulting recommendations, a review of all collisions was also common for comparison purposes. For example, in Hennepin County, the crash tree diagrams included values for both severe/fatal collisions and all collisions, however, the severe/fatal collisions were the subject of the subsequent analyses and resulting safety project development process.[10]

Roadway Location

The location of a collision with respect to the roadway was a defining characteristic in nearly all the approaches reviewed. Separate matrices, tables, or crash trees were commonly found to be used for each roadway environment, with the most common three categories being intersection, segments, and curves along segments.

The Hennepin County/MnDOT approach did not use separate crash trees to display intersection and segment collisions, but rather used that as one of the initial layers or branches of the crash tree, effectively separating the collision records by roadway location.[11]

Similarly, Illinois defines collisions as occurring within an intersection or segment, within the segments, collisions are categorized as either corridors or curves. [12]

Caltrans provides the option for applicants to focus on a subset of locations, such as the top 3 to 10 high-risk corridors and top 5 to 20 intersections, however, a review of the overall network is still required.[13] It is important to note that the focused analysis separates the collision records by roadway location (corridor or intersection). This is done considering different priority collision types, causes and countermeasures are found within the different roadway environments.

Caltrans' Systemic Pedestrian Safety Analysis incorporates all potential roadway locations where a pedestrian-involved collision may occur (crossing elsewhere than in a crosswalk, crossing elsewhere than at an intersection, in roadway, not in roadway, approaching/leaving school bus, etc.) into a single matrix. Two orders of matrix rows are used in this approach, with the first order being the pedestrian movement and location, followed by the primary collision factor.[14]

In Minnesota, County Roadway Safety Plans provide separate analyses for roadway segments, horizontal curves, and stop-controlled intersections. Roadway segments were defined by cross-section changes, while considering speed limits, ADT, and geometrics.[15]

Countermeasures

State level guidance was commonly found to direct agencies to specific resources for identifying and evaluating countermeasures. The FHWA's Crash Modification Factor (CMF) Clearinghouse was the most commonly referenced single resource. Additionally, state DOTs in California, Washington, and Illinois all provide sets of recommended countermeasures for a variety of priority or focus crash types.

Additional countermeasure resources that may be useful include:

- Caltrans Local Roadway Safety Manual[16]
- National Cooperative Highway Research Program (NCHRP) 500 Series Reports – Guidance for Implementation of AASHTO's Strategic Highway Safety Plan[17]
- National Highway Traffic Safety Administration: Countermeasures that Work[18]
- Illinois Department of Transportation Systemic Safety Improvements: Analysis, Guidelines and Procedures

The FHWA CMF Clearinghouse was also referenced as a source to determine countermeasure effectiveness. While UC Berkeley SafeTREC's TIMS B/C Calculation Tool was identified as a tool to calculate a safety project or countermeasure's benefit/cost.[19]

The Minnesota DOT (MnDOT) recommends a unique approach to initiate the countermeasure selection process, advising local agencies to convene key stakeholders in safety meetings to assist in identifying a list of critical strategies.[20]

Key Findings

The City of San Diego project is different from the locations reviewed in that it is a much more urban environment. Efforts were made to identify systemic analyses performed by agencies in more urban environments, however, they were limited. The recent Caltrans grant funding made available for systemic safety analyses has led to the initiation of analyses in more similar environments. However, these efforts were found to be behind or parallel to the City of San Diego's project.

Analysis Approach

Each approach reviewed was generally based on the four-step process identified in the Federal Highway Administration's (FHWA's) Systemic Safety Project Selection Tool, which consists of 1) identifying focus crash types and risk factors; 2) screening and prioritizing candidate locations; 3) selecting countermeasures; and 4) prioritizing projects.

Variable Selection

The process used to identify focus crash types was commonly found to be through a crash tree, separating collisions out by location and then other roadway characteristic variables. Analysis approaches were generally found to be dependent on existing roadway environment data. With the exception of the Illinois DOT, supplemental data collection was not extensively conducted.

Data Range

Data ranges analyzed were between 3 – 5 years, justified by seeking to limit changes to the roadway network during the analysis period.

Collision Severity

All studies reviewed had some focus on severe injuries and fatalities. However, all collision records were commonly included in the analysis and used to compare against severe injuries and fatalities. The focus on severe injuries and fatalities was found to be used in support of the growing initiative to eliminate all severe injuries and fatalities resulting from collisions.

Roadway Location

In all studies reviewed, the roadway environment in which a collision occurred – such as an intersection, segment, or curve along a segment – was used to separate collisions during the analysis. This was commonly one of the first layers or branches on a collision crash tree.

Countermeasures

Countermeasure identification and selection was generally found to rely on the respective state's guidance, while the FHWA's Crash Modification Factor Clearinghouse was the most commonly referenced single resource to determine effectiveness. The Minnesota Department of Transportation was the exception, which used safety workshops comprised of key stakeholders to select priority safety strategies from a larger, comprehensive list of safety strategies.

---

[1] FHWA. *Systemic Safety Project Tool*. July 2013.
[2] Illinois Department of Transportation. *Systemic Safety Improvements Analysis, Guidelines and Procedures*. May 2014.
[3] Stein, W., Federal Highway Administration – Minnesota Division. Vizecky, M., Minnesota Department of Transportation. Personal Interview. January 2018.
[4] Minnesota Department of Transportation. Hennepin County. *County Roadway Safety Plans*. December 2011.
[5] Enders, M., Washington State Department of Transportation. Personal Interview. October 2017.
[6] Caltrans. Systemic Pedestrian Safety Analysis. *Introduction to Systemic Tool V0.9*. Draft 2017.
[7] Caltrans. *User Manual: Systemic Pedestrian Safety Analysis*. Draft 2017.
[8] Minnesota Department of Transportation. Hennepin County. *County Roadway Safety Plans*. December 2011.

[9] Illinois Department of Transportation. *Systemic Safety Improvements Analysis, Guidelines and Procedures*. May 2014.
[10] Minnesota Department of Transportation. Hennepin County. *County Roadway Safety Plans*. December 2011.
[11] Minnesota Department of Transportation. *Final Report for the Minnesota County Roadway Safety Plans*. January 2014.
[12] Illinois Department of Transportation. *Systemic Safety Improvements Analysis, Guidelines and Procedures*. May 2014.
[13] Caltrans. Division of Local Assistance. *Systemic Safety Analysis Report Program (SSARP) Guidelines*. February 2016.
[14] Caltrans. Systemic Pedestrian Safety Analysis. *Introduction to Systemic Tool V0.9*. Draft 2017.
[15] Minnesota Department of Transportation. *Final Report for the Minnesota County Roadway Safety Plans*. January 2014.
[16] Caltrans. Division of Local Assistance. *Systemic Safety Analysis Report Program (SSARP) Guidelines*. February 2016.
[17] Minnesota Department of Transportation. Hennepin County. *County Roadway Safety Plans*. December 2011.
[18] Minnesota Department of Transportation. *Final Report for the Minnesota County Roadway Safety Plans*. January 2014.
[19] Caltrans. Division of Local Assistance. *Systemic Safety Analysis Report Program (SSARP) Guidelines*. February 2016.
[20] Ibid.

Appendix B

Matrix Development

Matrix Development

1. General Rationale of the Matrix Building and Variable Selection Process

The San Diego SSARP project builds off of various systemic approaches to road safety that have been implemented in the United States at the federal as well as the state and local levels. Considering that a systemic approach is data driven while aiming to be flexible enough in order to adapt to varying degrees of data availability, a matrix approach has been adopted. It follows schemes established by two previous initiatives: FHWA's Systemic Safety Project Selection Tool and Caltrans' Systemic Pedestrian Safety Analysis. Both approaches consist of building a matrix, whose rows and columns are determined to best illustrate the infrastructure-related dynamics behind road collisions.

The FHWA tool has been regularly used to guide road safety analyses in the country and help prioritize locations. The process developed by FHWA starts with the identification of focus crash types and facility types based on crash data and infrastructure information. This principle was adopted by the Caltrans Systemic Pedestrian Safety Analysis, where the crash matrix had columns representing locational characteristics understood to influence the collisions and based on data availability, and rows corresponding to crash types, understood as primary collision factors and behaviors thought to influence the crash.

The San Diego SSARP effort follows the same logic, while modifying the structure to better reflect the local environment. The following will detail what matrices have been built and the reasons behind the variable selection process, by listing the alternatives considered and why they have been selected or rejected. The documentation details the final variables included in each of the matrix structures.

The effort resulted in eight matrices, divided among the three modes, pedestrian (3 matrices), bicycle (2 matrices) and vehicular (3 matrices). Table 1-1 provides a summary of the final matrix structures and lists the variables that comprise the rows and columns for each matrix.

Table 1-1: Summary of Final Matrix Structures

Matrix Mode	Roadway Environment	Rows	Columns
Pedestrian	Intersection footprint	1. Violation type 2. Pedestrian action 3. Movement of party 1	1. Traffic control type 2. Number of lanes of the primary and secondary roads 3. Traffic volume of the primary road
	Intersection influence area	1. Violation type	1. Traffic control type 2. Number of through lanes of primary road in both directions 3. Traffic volume of the primary road
	Mid-block	1. Violation type 2. Pedestrian action	1. Speed limit 2. Number of through lanes of primary road in both directions 3. Traffic volume of the primary road
Bicycle	Intersection footprint	1. Party at fault 2. Violation type	1. Traffic control type 2. Number of lanes of the primary and secondary roads
	Mid-block (Combined Intersection influence area & Midblock)	1. Party at fault 2. Violation type	1. Bike lane presence 2. Speed limit 3. Parking presence
Vehicular	Intersection footprint	1. Collision type 2. Violation type	1. Traffic control type 2. Number of lanes of the primary and secondary roads 3. Traffic volume of the primary road 4. Traffic volume of the secondary road
	Intersection influence area	1. Collision type 2. Violation type	1. Traffic control type 2. Speed limit 3. Median presence and type
	Mid-block	1. Collision type 2. Violation type	1. Median presence and type 2. Speed limit 3. Traffic volume of the primary road

2. Matrix Categories

The San Diego SSARP project will ultimately lead to the development of three matrix categories:

1. Vehicular-only collisions (excludes property damage only collisions, pedestrian- and bicycle-involved collisions)
2. Pedestrian-involved collisions (all collisions involving a pedestrian that resulted in an injury)
3. Bicycle-involved collisions (all collisions involving a bicyclist that resulted in an injury)

Four of the considerations leading to the matrix category selection are covered within this section.

Party Type

Separating the matrices by party type or mode helps to better distinguish between the safety concerns for each mode. Such a differentiation better reflects the dynamics specific to each collision and allows for the development of mode-specific countermeasures. If at least one pedestrian was involved in a collision, it is considered a pedestrian crash. Similarly, if at least one bicycle was involved in a collision, it is flagged as a bicycle crash. Vehicular collisions are crashes where neither pedestrian nor bicycle were involved.

Severity

There is wide consensus that severity should be included in the systemic analysis of road safety – be it for prioritization purposes or as a means to address the City of San Diego's recent Vision Zero initiative, a commitment to eliminate all traffic fatalities and severe injuries. But subdivisions based on party type (vehicular, pedestrian, or bicycle) lead to a drastic reduction of the number of crashes when it comes to pedestrian-involved and bicycle-involved collisions. The review of past systemic safety efforts has shown a common focus on severe and fatal injuries, while still analyzing all records regardless of injury, for comparison purposes. However, the corresponding small sample size has a downside, as small changes can skew the data. It was, therefore, decided to include all collisions that resulted in some form of injury in the matrices in order to allow for an analysis based on enough data points. This results in the exclusion of collisions reported as property damage only (PDO).

Timeframe

One way of mitigating the lack of data points is to expand the number of years for which the crash data is being used. While three- to five-years of collision data were common time periods analyzed, there should be a balance between maximizing data points and considering potential roadway network changes, or travel pattern modifications evolutions. For example, in recent years the City of San Diego initiated widespread implementation of continental crosswalks, which may lead to misrepresentations if older data was utilized. Similarly, the transportation system in San Diego has experienced increased demand in recent years as the region rebounded from the economic downturn. In this perspective, it was agreed to consider the most recent three years of collision data for the SSARP San Diego project: from 2014 to 2016.

Location categorization

The prioritization of locations is usually best enabled by splitting road segments into different categories: midblock, intersections, and horizontal curves are examples of categories applied in previous analysis efforts. This allows for a consistent crash analysis and the application of corresponding countermeasures. Consequently, in the San Diego SSARP project, separate matrices are built for each roadway environment, however, the categories utilized were different to better reflect the more urban environment in San Diego.

In order for the columns to be set to the specific environment type and for a more focused data collection approach, it was decided to create three crash location categories: (a) the intersection footprint; (b) the intersection influence area; and (c) the mid-block. Collisions falling in any part of the roadway past the limit line were categorized as within the intersection footprint. Records reported as occurring in the part of the roadway where left- and/or right-turn lanes are present were identified as occurring within the intersection influence area. In the absence of turning pockets, the intersection influence area is defined as 100 feet from the center of the intersection. As for the mid-block, it corresponds to any location beyond the intersection influence area. For each of the three matrix categories previously listed, three crash matrices were developed – one for each location – with the exception of bicycle-involved collisions. While reviewing the bicycle matrices, it was found that the distribution of collisions within the mid-block and intersection influence area rows were very similar. This finding was leveraged by combining the two matrices into a single mid-block matrix, which also increased the number of data points in the matrix, which will allow for stronger conclusions to be drawn. In total, eight matrices were developed.

3. Representing Crash Dynamics: Row Selection

In order to illustrate how crashes are influenced by the built environment, the rows of the matrix need to represent crash dynamics. These dynamics are specific to each transportation mode involved, as crashes between a vehicle and a pedestrian are typically much different from crashes between two vehicles. Similarly, the countermeasures may vary based on the mode they are trying to address. The row arrangement was therefore tailored to each matrix category described in the previous section.

The structure of the San Diego matrix follows the same logic as the Californian pedestrian tool developed for California Department of Transportations (Caltrans), with rows corresponding to crash types and movements. However, these were further enhanced by the violation codes reported as contributing to the respective collisions. Since the SSARP guidelines allow us to focus on the top 3 to 10 crash types responsible for fatal or severe collisions on the overall network, a new variable based on collision records was created to define a limited list of crash types. In an attempt to focus on the most prevalent crashes, violations codes covering about 80% of all crashes of a specific matrix category (respectively, vehicular, bike, pedestrian) were grouped into new subcategories best describing them. The resulting crash types were then applied across matrix categories to allow for meaningful comparisons when trying to describe the dynamics behind any particular hotspot. The remainder of the violation codes were put into a default category named "Others", not to exceed 20% of the total crashes for any location within a matrix category. These mode-specific violation groupings are laid out in Table 3-1 for pedestrians, Table 3-2 for bicycles, and Table 3-3 for vehicles.

Table 3-1: Pedestrian Violation Code Groupings

Violation Crash Type (pedestrian)	Violation Code	Movement (party1)
Control Violation through movement	21451, 21453, 21456, 21460, 21461, 22450, 22453	Proceeding Straight
Control Violation turning movement	21451, 21453, 21456, 21460, 21461, 22450, 22453	Making Left Turn, Making Right Turn
Control Violation other movements	21451, 21453, 21456, 21460, 21461, 22450, 22453	Any
Entering from minor facility	21663, 21804	Any
Failure to yield (entering through highway)	21800, 21802, 21803, 21950, 21952, 22106	Any
Following too closely	21703	Any
Pedestrian not in dedicated areas	21954, 21955, 21956	Any
Unsafe Speed	22350, 22400	Any
Unsafe Turning Left	21717, 21801, 22100, 22101, 22102, 22103, 22107	Making Left Turn
Unsafe Turning Right	21717, 21801, 22100, 22101, 22102, 22103, 22107	Making Right Turn
Unsafe Turning other	21717, 21801, 22100, 22101, 22102, 22103, 22107	Any
Others	All others	Any

Table 3-2: Bicycle Violation Code Groupings

Violation Crash Type (bicycle)	Violation Code	Movement (party1)
Control Violation through movement	21451, 21453, 21456, 21460, 21461, 22450, 22453	Proceeding Straight
Control Violation turning movement	21451, 21453, 21456, 21460, 21461, 22450, 22453	Making Left Turn, Making Right Turn
Control Violation other movements	21451, 21453, 21456, 21460, 21461, 22450, 22453	Any
Entering from minor facility	21663, 21804	Any
Equipment of vehicles	24002	Any
Failure to yield (entering through highway)	21800, 21802, 21803, 21950, 21952, 22106	Any
Following too closely	21703	Any
Pedestrian not in dedicated areas	21954, 21955, 21956	Any
Unsafe Door Opening	22517	Any
Unsafe Operation of Bicycle	21200, 21201, 21202, 21208, 21209, 21212	Any
Unsafe Overtaking	21750, 21754, 21755, 21760	Any
Unsafe Speed	22350, 22400	Any
Unsafe Turning Left	21717, 21801, 22100, 22101, 22102, 22103, 22107	Making Left Turn
Unsafe Turning Right	21717, 21801, 22100, 22101, 22102, 22103, 22107	Making Right Turn
Unsafe Turning other	21717, 21801, 22100, 22101, 22102, 22103, 22107	Any
Wrong lane	21650, 21651, 21657, 21658	Any
Others	All others	Any

Table 3-3: Vehicle Violation Code Groupings

Violation Crash Type (vehicle)	Violation Code	Movement (party1)
Control Violation through movement	21451, 21453, 21456, 21460, 21461, 22450, 22453	Proceeding Straight
Control Violation turning movement	21451, 21453, 21456, 21460, 21461, 22450, 22453	Making Left Turn, Making Right Turn
Control Violation other movements	21451, 21453, 21456, 21460, 21461, 22450, 22453	Any
Entering from minor facility	21663, 21804	Any
Failure to yield (entering through highway)	21800, 21802, 21803, 21950, 21952, 22106	Any
Following too closely	21703	Any
Unsafe Speed	22350, 22400	Any
Unsafe Turning Left	21717, 21801, 22100, 22101, 22102, 22103, 22107	Making Left Turn
Unsafe Turning Right	21717, 21801, 22100, 22101, 22102, 22103, 22107	Making Right Turn
Unsafe Turning other	21717, 21801, 22100, 22101, 22102, 22103, 22107	Any
Others	All Others	Any

Following the typical process adopted by other agencies to determine their rows in order to maximize their crash profile[1], collision records were then used for each matrix category to establish whether the violation type was the leading determinant behind the collision or not – or at least the best describer.

When it comes to crashes involving vehicles only, it appeared that the crash type – that is, whether it was a broadside, rear-end, sideswipe, etc. – is the primary describer of the collision. When paired with the violation type, it allows for differentiation between meaningful crash dynamics such as a broadside crash due to a failure to yield or a rear-end crash due to unsafe speeds.

For pedestrian crashes, the crash type is predominantly reported as “Vehicle – Pedestrian” which is not descriptive of the events contributing to the collision. The decision was made to utilize the violation code groupings as the initial layer in the pedestrian matrix rows. Considering the reduced overall number of collisions captured for each location with only three years of data, breaking down every violation type with another layer did not make sense for every location. In the intersection footprint, the “failure to yield” violation largely outweighed the other violation categories, representing 624 of the 1,282 pedestrian collisions within that location. Therefore, the “failure to yield” violation category was further broken down by the pedestrian action (crossing in crosswalk at intersection, crossing not in crosswalk, in road, etc.). Considering the significant imbalance that remained between one of the subcategories and the other rows in

[1] The maximization of the crash profile was the main concern, while no discussion of empty cells minimization was found in the review that was undertaken.

terms of crash records, a third layer was added for collisions due to a failure to yield, with the pedestrian crossing in the crosswalk at the intersection, to describe the vehicle's movement at the time of the crash (proceeding straight, making left turn, etc.). The repartition of crashes among rows was more balanced for the intersection influence area matrix, where a single layer of violation types was sufficient. As for the mid-block matrix, similar to the intersection footprint, an additional variable was needed to get a more fine-grained description of dynamics behind the most prevalent violation types, which is why pedestrian movements were used to break down instances of failure to yield or where pedestrians were not in their dedicated areas (sidewalk or crosswalk).

Lastly, for bicycle-involved collisions, the story behind a particular crash changes dramatically depending on which party is at fault: different countermeasures will be taken if in a crash with a failure to yield, the bike was at fault, or if it was the vehicle, regardless of the location. Therefore, it was decided to use the party at fault as the first layer of rows, and then add the violation type as the second explanatory factor.

All the row structures outlined above were chosen after multiple iterations, based on the three years of crash records available. It is important to note that a different dataset might have led to different arbitration between options for selecting the matrices' rows.

4. Defining Infrastructure Profiles: Location-Based Column Selection

In the systemic matrix, columns represent location attributes of the infrastructure that help predict the likelihood of the occurrence of a crash. This section describes the data collected for each location and mode. The initial motives to collect these variables for some modes and some locations rather than others is detailed in the following section. Then, the reasoning around their selection or rejection will be detailed in a concluding matrix.

Initial data collection for roadway characteristics – all modes and locations

The present section describes the rationale behind the collection (or not) of variables for each party type and location. Table 4-1 presents the variables that were considered to help define corresponding facility types.

Table 4-1: Roadway Characteristic Variables

	Attributes	Variables	A) Vehicular-Only			B) Pedestrian-Involved			C) Bicycle-Involved		
			Intersection Footprint	Intersection Influence Area	Mid-Block	Intersection Footprint	Intersection Influence Area	Mid-Block	Intersection Footprint	Intersection Influence Area	Mid-Block
Number and type of lanes	1- Number of Through Travel Lanes Primary Road	# Lanes	x	x	x	x	x	x	x	x	x
	1A - Number of through lanes, both directions, primary road	# Lanes	x			x			x		
	2 - Number of Through Travel Lanes Secondary Road	# Lanes	x			x			x		
	2A - Number of through lanes, both directions, secondary road	# Lanes	x			x			x		
	3 - Number/Type of Turn Lanes Primary Road	# Left Turn Lanes, # Right Turn Lanes	x	x		x	x		x	x	
	3A – Number of left turn lanes	# Lanes		x			x			x	
	4 - Number/Type of Turn Lanes Secondary Road	# Left Turn Lanes, # Right Turn Lanes	x			x			x		
	4A – Number of right turn lanes	# Lanes		x			x			x	
	5 - Number of through lanes, direction of party 1	# Lanes		x	x		x	x		x	x
	6 - Number of through lanes, reverse direction of party 1	# Lanes		x	x		x	x		x	x
	7 - One-way street at intersection	Primary Approach/ Secondary Approach/ Both, One-Way	x			x			x		

Table 4-1: Roadway Characteristic Variables

	Attributes	Variables	A) Vehicular-Only			B) Pedestrian-Involved			C) Bicycle-Involved		
			Intersection Footprint	Intersection Influence Area	Mid-Block	Intersection Footprint	Intersection Influence Area	Mid-Block	Intersection Footprint	Intersection Influence Area	Mid-Block
Median	8 - Presence/Type of Median	Raised, Striped, Center Left Turn, Undivided		x	x		x	x		x	x
Speed	9 - Posted Speed Limit Primary Road	MPH	x	x	x	x	x	x	x	x	x
	10 - Posted Speed Limit Secondary Road	MPH	x			x			x		
Parking	11 - Presence/Type of On-Street Parking Primary Road	Angled, Parallel, Unknown, None				x	x	x	x	x	x
	12 - Presence of On-Street Parking Secondary Road	Angled, Parallel, Unknown, None				x			x		
Traffic control	13 - Presence/Type of Intersection Control	Traffic Signal, All-Way Stop, Side-Street Stop	x	x		x	x		x	x	
Dedicated ways	14 - Presence of Bike Lane	Yes, Lane Drop/Mixing, No								x	x
	15 - Presence of Sidewalk	Yes, No					x	x			
	16 - Presence/Type of Crosswalk	High Visibility, Basic, None				x	x	x			
Traffic Counts	17 - Traffic volumes along primary road	ADT	x	x	x	x	x	x	x	x	x
	18 - Traffic volumes along secondary road	ADT	x			x			x		

Unless otherwise specified, the collection of the variables detailed below are valid for every mode.

Number and type of lanes

The definitions of the variables to be collected regarding the number and type of lanes has been refined over time, leading to the creation of the "1A", "2A", etc., categories.

1 The number of lanes of the primary road was initially deemed important for all modes and all crash locations.

1A It was then decided to refine the definition of that variable, with the precision that the count of through lanes was to be done in both directions. The reason for this clarification is that collision data did not allow us to establish with certainty the direction of travel of the vehicles involved in the collision, which made the specification of the number of lanes in a certain direction useless. Additionally, the collection of this variable was restricted to intersection footprint collisions.

2 The number of lanes of the secondary road was initially deemed unnecessary outside of the intersection footprint. By definition of the intersection influence area, in the mid-block, the characteristics of the secondary road are not influencing the vehicle anymore. As for when a crash occurs in the intersection influence area itself, the secondary road environment seems to have little influence with the exception of the turning movements from the secondary road. Nevertheless, these turning vehicles to/from the secondary road are accounted for within the volume of the primary road.

2A The definition of that variable was refined similarly to primary roads, still under the assumption that the secondary road environment plays a limited role in crashes outside of the intersection footprint.

3 The number and type of turning lanes on the primary road was initially deemed important for all modes and crashes within the intersection influence area, but not mid-block. This nuance was justified by the consideration that outside of the intersection influence area, the fact that the vehicle involved in the crash was turning or not does not count anymore.

3A Instead of distinguishing between primary and secondary roads for the number and type of lanes, it was decided to create separate variables for each potential type of turning lane (either left or right-turn). The collection of this variable was restricted to intersection influence area collisions, as turning pockets can be found only in this area, by definition.

4 As for the secondary road, the number and type of turning lanes was deemed unnecessary outside of the intersection footprint (see variables 2 and 2A).

4A Similarly, the collection of this variable was restricted to intersection influence area collisions, as turning pockets can be found only in this area, by definition.

5 Additionally, it was decided to consider the direction of travel of the main party involved in the collision: the number of through lanes in the direction of party 1 is to be collected. However, at the current time, this variable is not collected at the intersection footprint level.

6 Similarly, the number of through lanes in the reverse direction of party 1 is not collected at the intersection footprint level at the current time.

7 It was decided to create a variable to identify one-way streets at the intersection, and, if applicable, whether the one-way street was on the primary, the secondary road, or both. Regarding one-way segments outside the intersection footprint, a different variable was used (collected for intersection influence area and mid-block collisions).

Median

8 The presence of a median and its type were deemed important for all crashes, outside of the intersection footprint. This is justified by the fact that within the footprint of an intersection, there can be no median.

Speed

9 The speed limit on primary roads was deemed important for all modes and all crash locations.

10 The speed limit on secondary roads was deemed unnecessary outside of the intersection footprint, for the same reason leading to the exclusion of information beyond the intersection footprint on secondary roads for other variables.

Parking

11 The presence and type of on-street parking on primary roads was deemed important for all crash locations, but not considered for vehicle-only crashes. This is attributable to the fact that the existence of on-street parking and the potential presence of a parked vehicle between the traffic flow and the pedestrian/bicycle flow is seen as a potential protection from vehicles driving by or a potential visual obstacle preventing drivers from seeing vulnerable street users.

12 The presence and type of on-street parking on secondary roads was not considered for vehicle-only crashes (similarly) and deemed important only for crashes within the intersection footprint. The latter point was presumably chosen for the same reason leading to the exclusion of information beyond the intersection footprint on secondary roads for other variables.

Traffic control

13 The presence and type of intersection control was deemed important for all crashes within the intersection influence area. Indeed, outside of it, the characteristics of the intersection (including the existence of intersection controls) do not influence the driver.

Dedicated way

14 The presence of a bike lane was deemed important for bike crashes only because it is only relevant to crashes involving bicycles. Additionally, it was not considered within the intersection footprint, as bike lanes are not marked through the intersection in San Diego. Another reason is that the to/from direction of a cyclist in the intersection footprint cannot be confirmed through the available data, nor whether those intersection legs have a marked bike lane.

15 The presence of a sidewalk, similarly, was deemed important for pedestrian crashes only (as it is only relevant to crashes involving pedestrians), and not within the intersection footprint (because the sidewalk ends there).
16 The presence and type of crosswalk was deemed important for pedestrian crashes only, and all locations.

Volume counts

Statistically speaking, a highly frequented roadway is more likely to have higher crash counts. It was thus decided to consider volume counts, with various volume category breaks. Moreover, these categories integrated the classification of the roadway (as a local road or not) for low-volume facilities: roadways with an ADT below 7,000 were divided into CHS-classified “local” roadways and “non-local” roadways. Since the ADT was retrieved from multiple sources, a data hierarchy was established regarding volume counts: first, the location points coming from the machine counts database were extrapolated along the City of San Diego’s speed survey segment extents; then, recent Community Plan Update volumes were used to fill the gaps, followed by *HwyCov* unadjusted volumes; finally, non-*HwyCov* locations were assumed to have an ADT below 7,000 and identified as either local or non-local using CHS. Additionally, when multiple recent volume counts exist for a single segment, the average was used.

17 Traffic volumes along the primary road were deemed important for all modes and locations.
18 Traffic volumes along the secondary road, on the other hand, matter for all modes, but within the intersection footprint only – presumably for the same reason leading to the exclusion of information beyond the intersection footprint on secondary roads for other variables.

Final Variable Selection by Mode for Roadway Characteristics

This section includes a series of tables identifying the roadway characteristic variables collected for each mode and each location and states whether or not the variable was retained in the final matrix structure.

Pedestrian

Table 4-2 presents pedestrian intersection footprint variables, Table 4-3 the intersection influence area and Table 4-4 the mid-block.

Bicycle

Table 4-5 presents bicycle intersection footprint variables, Table 4-6 the mid-block variables (combined intersection influence area and mid-block).

Vehicular

Table 4-7 presents vehicular intersection footprint variables, Table 4-8 the intersection influence area and Table 4-9 the mid-block.

Table 4-2: Pedestrian Intersection Footprint Matrix Variables

Variable category	ID	Variable	Selected?	Rationale
Number and Type of Lanes	1	number of lanes of the primary road	No	The set of variables regarding the number of lanes on the primary and secondary roads were redefined to allow a more compact structure for the matrix columns. It was decided to combine them into a single variable that would illustrate the number of lanes of both roads at once, in a format [number of lanes of road A] + [number of lanes of road B]. It is worthwhile noting that this variable is symmetric, as the collision data showed that there were no meaningful differences in the types of crashes that occurred on one branch of the intersection or the other.
	1A	number of lanes of the primary road in both directions	Yes	
	2	number of lanes of the secondary road	No	
	2A	number of lanes of the secondary road in both directions	Yes	
	3	number and type of turning lanes on the primary road	No	No information on turning lanes was added on top of the total number of lanes as they only spread out the columns without breaking down collisions in a meaningful way.
	4	number and type of turning lanes of the secondary road	No	
	7	one-way streets at the intersection	No	The presence of one-way streets is fairly concentrated within the Downtown and Uptown communities and did not reflect the greater City environments, while greatly expanding the number of matrix columns. This variable was not selected for the structure. However, the field remains attributed to each individual record.
Speed	9	speed limit of the primary road	No	Vehicle speed in an intersection is very much dependent on intersection control, especially for approaches with stop sign control or red indication at traffic signals.
	10	speed limit of the secondary road	No	
Parking	11	presence and type of on-street parking on primary road	No	Parking spaces may create a physical protection between vehicular traffic and pedestrian flow, but it could also be seen as a potential visual obstacle for drivers, preventing them from seeing the presence of a pedestrian (e.g. when turning). However, the data showed that the presence of parking was not a meaningful characterizer.
	12	presence and type of on-street parking on secondary road	No	
Traffic Control	13	presence and type of intersection control	Yes	The presence and type of traffic control was used as the very first layer of roadway characteristics for the intersection footprint, as it determines fundamentally the behavior of vehicles driving and pedestrian crossing in the intersection. Based on observed similarities in the collision data, some groupings were made, and eventually this variable distinguished between intersections with traffic signals, all-way stops, two-way stops, and others (including unsignalized intersections, roundabouts, etc.).
Dedicated Way	16	presence and type of crosswalk	No	Though the presence of dedicated ways like crosswalks may seem crucial at first when analyzing pedestrian crashes, considering that the presence (and usage) of crosswalks was already captured in the matrix rows through the pedestrian movement variable, adding the presence of a crosswalk in the columns would have been repetitive.
Volume Counts	17	traffic volumes along the primary road	Yes	For pedestrian crashes, the exposure of pedestrians to potential hazards can be related to the traffic volumes on the road network: crossing at a highly-frequented intersection presents more risks of getting hit by a vehicle than at an empty intersection. Traffic volumes were broken down between local roads and non-local ones with thresholds set at 7,000 – 15,000 – 25,000 ADT.
	18	traffic volumes along the secondary road	No	Since the overall number of pedestrian crashes is relatively low due to the limited timeframe of the collision data, breaking down the columns further would have watered down too much potential systemic hotspots and complicated their identification.

Table 4-3: Pedestrian Intersection Influence Area Matrix Variables

Variable category	ID	Variable	Selected?	Rationale
Number and type of lanes	1	number of lanes of the primary road	No	The number of lanes of the primary road was slightly redefined to better illustrate the structure of the road: it was decided to present the number of lanes in both directions at once, in a symmetrical format [number of lanes in direction 1] + [number of lanes in direction 2]. This indicator is symmetrical; in other words, it is not tied to the direction of travel of the vehicle involved in the collision. It only reflects the geometry of the road.
	3	number and type of turning lanes on the primary road	No	For compacity purposes, no information on turning lanes was added on top of the total number of lanes as they only spread out the columns without breaking down collisions in a meaningful way.
	3A	number of left-turn lanes	No	
	4A	number of right-turn lanes	No	
	5	number of through lanes in the direction of party 1	Yes	For vehicular collisions, only a small number of crashes have a different number of lanes depending on the direction of travel. Therefore, it was not worth it to integrate these variables separately in the matrix. The combined information is encompassed with the paired number of through lanes in each direction that was eventually retained for the final matrix structure (see above).
	6	number of through lanes in the reverse direction of party 1	Yes	
Median	8	presence and type of median	No	For pedestrian crashes, information on the potential presence of a median would be useful only to signal whether there is a physical barrier in the middle of the roadway that might deter pedestrians from crossing outside of the crosswalk. Considering that the information available about medians does not differentiate between raised or striped ones, including this variable would be useless.
Speed	9	speed limit of the primary road	No	Vehicle speed in an intersection influence area is very much dependent on intersection control, especially for approaches with stop sign control or red indication at traffic signals.
Parking	11	presence and type of on-street parking on primary road	No	Parking spaces may create a physical protection between vehicular traffic and pedestrian flow, but it could also be seen as a potential visual obstacle for drivers, preventing them from seeing the presence of a pedestrian (e.g. when turning). However, the data showed that the presence of parking was not a meaningful characterizer of pedestrian crashes.
Traffic control	13	presence and type of intersection control	Yes	The presence and type of traffic control was used as the very first layer of roadway characteristics for the intersection influence area, as it determines fundamentally the behavior of vehicles approaching the intersection, and pedestrians' anticipation of vehicles' behavior. Based on observed similarities collision data, some groupings were made, and eventually this variable distinguished between intersections with traffic signals, all-way stops, two-way stops, and others (including unsignalized intersections, roundabouts, etc.).
Dedicated way	15	presence of sidewalk	No	Though the presence of dedicated ways like sidewalks may seem crucial at first when analyzing pedestrian crashes, this variable was left out. It was relevant to only a fraction of crashes with a violation related to pedestrians outside of dedicated areas and would have greatly expanded the dimensions of the matrix, thus diluting systemic hotspots, which already total a relatively low number of crashes.
	16	presence and type of crosswalk	No	Though the presence of dedicated ways like crosswalks may seem crucial at first when analyzing pedestrian crashes, considering that the presence (and usage) of crosswalks was already captured in the matrix rows through the pedestrian movement variable, adding the presence of a crosswalk in the columns would have been repetitive.
Volume counts	17	traffic volumes along the primary road	Yes	For pedestrian crashes, the exposure of pedestrians to potential hazards can be translated into the traffic volumes on the road network: crossing at a highly-frequented intersection presents more risks of getting hit by a vehicle than being at an empty intersection. Traffic volumes were broken down between local roads and non-local ones with thresholds set at 7,000 – 15,000 – 25,000 ADT.

Table 4-4: Pedestrian Mid-Block Matrix Variables

Variable category	ID	Variable	Selected ?	Rationale
Number and type of lanes	1	number of lanes of the primary road	No	The number of lanes of the primary road was slightly redefined to allow better illustrate the structure of the road: it was decided to present the number of lanes in both directions at once, in a symmetrical format [number of lanes in direction 1] + [number of lanes in direction 2]. This indicator is symmetrical; in other words, it is not tied to the direction of travel of the vehicle involved in the collision. It only reflects the geometry of the road.
	5	number of through lanes in the direction of party 1	Yes	For vehicular collisions, only a small number of crashes have a different number of lanes depending on the direction of travel. Therefore, it was not worth it to integrate these variables separately in the matrix. The combined information is encompassed with the paired number of through lanes in each direction that was eventually retained for the final matrix structure (see above).
	6	number of through lanes in the reverse direction of party 1	Yes	
Median	8	presence and type of median	No	For pedestrian crashes, information on the potential presence of a median would be useful only to signal whether there is a physical barrier in the middle of the roadway that might deter pedestrians from crossing outside of the crosswalk. Considering that the information available about medians does not differentiate between raised or striped ones, including this variable would be useless.
Speed	9	speed limit of the primary road	Yes	Speed limits are a key determinant of the severity of pedestrian crashes, as a difference in 5 miles per hour may greatly affect the chances of survival of the victim of a collision. In the mid-block area, vehicles travel closer to these posted speed limits, which is why capturing them in the infrastructure profile is important to understand which driving behavior is enabled by the roadway characteristics, and act upon them if they prove problematic.
Parking	11	presence and type of on-street parking on primary road	No	Parking spaces may create a physical protection between vehicular traffic and pedestrian flow, but it could also be seen as a potential visual obstacle for drivers, preventing them from seeing the presence of a pedestrian (e.g. when turning). However, the data showed that the presence of parking was not a meaningful characterizer of pedestrian crashes.
Dedicated way	15	presence of sidewalk	No	Though the presence of dedicated ways like sidewalks may seem crucial at first when analyzing pedestrian crashes, this variable was left out. It was relevant to only a fraction of crashes with a violation related to pedestrians outside of dedicated areas and would have greatly expanded the dimensions of the matrix, thus diluting systemic hotspots, which already total a relatively low number of crashes.
	16	presence and type of crosswalk	No	Though the presence of dedicated ways like crosswalks may seem crucial at first when analyzing pedestrian crashes, considering that the presence (and usage) of crosswalks was already captured in the matrix rows through the pedestrian movement variable, adding the presence of a crosswalk in the columns would have been repetitive.
Volume counts	17	traffic volumes along the primary road	Yes	For pedestrian crashes, the exposure of pedestrians to potential hazards can be translated into the traffic volumes on the road network: crossing at a highly-frequented intersection presents more risks of getting hit by a vehicle than being at an empty intersection. Traffic volumes were broken down between local roads and non-local ones with thresholds set at 7,000 – 15,000 – 25,000 ADT.

Table 4-5: Bicycle Intersection Footprint Matrix Variables

Variable category	ID	Variable	Selected?	Rationale
Number and type of lanes	1	number of lanes of the primary road	No	The set of variables regarding the number of lanes on the primary and secondary roads were redefined to allow a more compact structure for the matrix columns. It was decided to combine them into a single variable that would illustrate the number of lanes of both roads at once, in a format [number of lanes of road A] + [number of lanes of road B]. It is worthwhile noting that this variable is symmetric, as the collision data showed that there were no meaningful differences in the types of crashes that occurred on one branch of the intersection or the other.
	1A	number of lanes of the primary road in both directions	Yes	
	2	number of lanes of the secondary road	No	
	2A	number of lanes of the secondary road in both directions	Yes	
	3	number and type of turning lanes on the primary road	No	For compacity purposes, no information on turning lanes was added on top of the total number of lanes as they only spread out the columns without breaking down collisions in a meaningful way.
	4	number and type of turning lanes of the secondary road	No	
	7	one-way streets at the intersection	No	The presence of one-way streets is fairly concentrated within the Downtown and Uptown communities and did not reflect the greater City environments, while greatly expanding the number of matrix columns. This variable was not selected for the structure, however, the field remains attributed to each individual record.
Speed	9	speed limit of the primary road	No	Vehicle speed in an intersection influence area is very much dependent on intersection control, especially for approaches with stop sign control or red indication at traffic signals.
	10	speed limit of the secondary road	No	
Parking	11	presence and type of on-street parking on primary road	No	Parking spaces may create a physical protection between vehicular traffic and bicycle flow, but it could also be seen as a potential visual obstacle for drivers, preventing them from seeing the presence of a bicyclist (e.g. when turning). However, the data showed that the presence of parking was not a meaningful characterizer of bike crashes.
	12	presence and type of on-street parking on secondary road	No	
Traffic control	13	presence and type of intersection control	Yes	The presence and type of traffic control was used as the very first layer of roadway characteristics for the intersection footprint, as it determines fundamentally the behavior of vehicles interacting in the intersection. Based on observed similarities collision data, some groupings were made, and eventually this variable distinguished between intersections with traffic signals, all-way stops, two-way stops, and others (including unsignalized intersections, roundabouts, etc.).
Volume counts	17	traffic volumes along the primary road	No	Since the overall number of bike crashes in that location is relatively low due to the limited timeframe of the collision data, breaking down more the columns would have watered down too much potential systemic hotspots and complicated their identification.
	18	traffic volumes along the secondary road	No	

Table 4-6: Bicycle Mid-Block Matrix Variables

Variable category	ID	Variable	Selected?	Rationale
Number and type of lanes	1	number of lanes of the primary road	No	The number of lanes of the primary road was slightly redefined to allow better illustrate the structure of the road: it was decided to present the number of lanes in both directions at once, in a symmetrical format [number of lanes in direction 1] + [number of lanes in direction 2]. This indicator is symmetrical; in other words, it is not tied to the direction of travel of the vehicle involved in the collision. It only reflects the geometry of the road.
	3	number and type of turning lanes on the primary road	No	For compacity purposes, no information on turning lanes was added as they only spread out the columns without breaking down collisions in a meaningful way.
	3A	number of left-turn lanes	No	
	4A	number of right-turn lanes	No	
	5	number of through lanes in the direction of party 1	No	For bicycle collisions, only a small number of crashes have a different number of lanes depending on the direction of travel. Therefore, it was not worth it to integrate these variables separately in the matrix. The combined information is encompassed with the paired number of through lanes in each direction that was eventually retained for the final matrix structure (see above). However, in the end, this variable was left out as it did not add any insights to the ones provided by the top layers of roadway characteristics regarding the distribution of crashes across infrastructure types. Furthermore, the use of speed limits in the columns can be seen as an indirect measure of the width of the road (in urban settings, it would be rare to have narrow high-speed streets) and its number of lanes.
	6	number of through lanes in the reverse direction of party 1	No	
Median	8	presence and type of median	No	For bicycle crashes, information on the potential presence of a median would be useful only to signal whether there is a physical barrier in the middle of the roadway that might deter bicyclist from crossing or making a U-turn outside of an intersection. Considering that the information available about medians does not differentiate between raised or striped ones, including this variable would be useless.
Speed	9	speed limit of the primary road	Yes	Similar to pedestrian crashes, speed limits are a key determinant of the severity of bicycle crashes, as a difference in 5 miles per hour may greatly affect the chances of survival of the victim of a collision. Outside of the intersection footprint, vehicles travel closer to these posted speed limits, which is why capturing them in the infrastructure profile is important to understand which driving behavior is enabled by the roadway characteristics, and act upon them if they prove problematic.
Parking	11	presence and type of on-street parking on primary road	Yes	For bicycles, similar to pedestrians, depending on the arrangement of the street, parking may represent a safety challenge (by reducing the amount of space available for bike circulation next to vehicles; encouraging vehicles to cut through bike lanes when entering/exiting a parking spot; presenting a risk of opening door unsafely; etc.), or a protection (in case parking spots are in between vehicular traffic and bike traffic). This justifies including parking in the matrix. Breaking down parking types is not relevant considering the low overall number of crashes.
Traffic control	13	presence and type of intersection control	No	Considering characteristics of the intersection beyond the intersection influence area does not make sense.
Dedicated way	14	presence of bike lane	Yes	The presence of bike lanes is a major indicator of the feeling of (real and perceived) security that bicyclists may get while biking on the road network, which influences their behavior as well as drivers' behavior by separating vehicle and bike traffic. It was therefore used as the primary layer of roadway characteristics. It also constitutes a straightforward indication of whether bike lanes are efficient in increasing (real) safety for bicyclists.
Volume counts	17	traffic volumes along the primary road	No	Since the overall number of bike crashes in that location is relatively low due to the limited timeframe of the collision data, breaking down more the columns would have watered down too much potential systemic hotspots and complicated their identification.

Table 4-7: Vehicle-Only Intersection Footprint Matrix Variables

Variable category	ID	Variable	Selected?	Rationale
Number and type of lanes	1	number of lanes of the primary road	No	The set of variables regarding the number of lanes on the primary and secondary roads were redefined to allow a more compact structure for the matrix columns. It was decided to combine them into a single variable that would illustrate the number of lanes of both roads at once, in the format: [number of lanes of road A] + [number of lanes of road B]. It is worthwhile noting that this variable is symmetric, as the collision data showed that there were no meaningful differences in the types of crashes that occurred on one branch of the intersection or the other.
	1A	number of lanes of the primary road in both directions	Yes	
	2	number of lanes of the secondary road	No	
	2A	number of lanes of the secondary road in both directions	Yes	
	3	number and type of turning lanes on the primary road	No	For compacity purposes, no information on turning lanes was added on top of the total number of lanes as they only spread out the columns without breaking down collisions in a meaningful way.
	4	number and type of turning lanes of the secondary road	No	
	7	one-way streets at the intersection	No	The presence of one-way streets is fairly concentrated within the Downtown and Uptown communities and did not reflect the greater City environments, while greatly expanding the number of matrix columns. This variable was not selected for the structure, however, the field remains attributed to each individual record.
Speed	9	speed limit of the primary road	No	Vehicle speed in an intersection is very much dependent on intersection control, especially for approaches with stop sign control or red indication at traffic signals.
	10	speed limit of the secondary road	No	
Traffic control	13	presence and type of intersection control	Yes	The presence and type of traffic control was used as the very first layer of roadway characteristics for the intersection footprint, as it determines fundamentally the behavior of vehicles interacting in the intersection. Based on observed similarities collision data, some groupings were made, and eventually this variable distinguished between intersections with traffic signals, all-way stops, two-way stops, and others (including unsignalized intersections, roundabouts, etc.).
Volume counts	17	traffic volumes along the primary road	Yes	The exposure of vehicles to potential hazards can be translated into the traffic volumes on the road network: driving on a highly-frequented road presents more risks of crashing into a vehicle than driving on an empty road. Vehicular collision data showed that distinguishing between "high-volume" and "low-volume" primary roads was sufficient, and the cut-off was taken at 15,000 ADT.
	18	traffic volumes along the secondary road	Yes	Similarly, for secondary roads traffic volumes were grouped into two categories, only with a different threshold: the final variable differentiated between "low-volume or local" roads (i.e. local roads, or roads with an ADT under 7,000) and "higher-volume" roads (any ADT above 7,000). Again, these groupings were motivated by the data distribution and how they allowed to single out infrastructure profiles associated with higher numbers of collisions.

Table 4-8: Vehicle Only Intersection Influence Area Matrix Variables

Variable category	ID	Variable	Selected?	Rationale
Number and type of lanes	1	number of lanes of the primary road	No	The number of lanes of the primary road was slightly redefined to better illustrate the structure of the road: it was decided to present the number of lanes in both directions at once, in a symmetrical format [number of lanes in direction 1] + [number of lanes in direction 2]. This indicator is symmetrical; in other words, it is not tied to the direction of travel of the vehicle involved in the collision. It only reflects the geometry of the road.
	3	number and type of turning lanes on the primary road	No	For compacity purposes, no information on turning lanes was added on top of the total number of lanes as they only spread out the columns without breaking down collisions in a meaningful way.
	3A	number of left-turn lanes	No	
	4A	number of right-turn lanes	No	
	5	number of through lanes in the direction of party 1	No	For vehicular collisions, only a small number of crashes have a different number of lanes depending on the direction of travel. Therefore, it was not worth it to integrate these variables separately in the matrix. The combined information is encompassed with the paired number of through lanes in each direction that was eventually retained for the final matrix structure (see above). However, in the end, this variable was left out as it did not add any insights to those provided by the top layers of roadway characteristics regarding the distribution of crashes across infrastructure types. Furthermore, the use of speed limits – which was retained for this matrix – can be seen as an indirect measure of the width of the road (in urban settings, it would be rare to have narrow high-speed streets) and its number of lanes.
	6	number of through lanes in the reverse direction of party 1	No	
Median	8	presence and type of median	Yes	The presence of a median is a major influencer of how vehicles navigate on a road segment, even when it is only striped, and not raised. It also influences how vehicles prepare to turn, or are finalizing their turn, to make sure they are well positioned in their new lane. It was therefore included in the retained roadway characteristics. The categorization compared the absence of median, against the presence of a central turning lane, and the presence of a raised or striped median.
Speed	9	speed limit of the primary road	Yes	Vehicle speed in an intersection influence area is very much dependent on intersection control, especially for approaches with stop sign control or red indication at traffic signals.
Traffic control	13	presence and type of intersection control	Yes	The presence and type of traffic control was used as the very first layer of roadway characteristics for the intersection footprint, as it determines fundamentally the behavior of vehicles interacting in the intersection. Based on observed similarities of the collision data, some groupings were made, and eventually this variable distinguished between intersections with traffic signals, all-way stops, two-way stops, and others (including unsignalized intersections, roundabouts, etc.).
Volume counts	17	traffic volumes along the primary road	No	Considering that including traffic counts in the columns would greatly expand the size of the matrix without successfully singling out meaningful systemic hotspots. Consequently, traffic volumes were left out.

Table 4-9: Vehicle Only Mid-Block Matrix Variables

Variable category	ID	Variable	Selected?	Rationale
Number and type of lanes	1	number of lanes of the primary road	No	Limited influence of the number of lanes on the matrix structure: information already indirectly captured by the speed and volume levels.
	5	number of through lanes in the direction of party 1	No	For vehicular collisions, only a small number of crashes have a different number of lanes depending on the direction of travel. Therefore, it is not worth it to integrate this variable in the matrix.
	6	number of through lanes in the reverse direction of party 1	No	
Median	8	presence and type of median	Yes	The presence of a median is a major influencer of how vehicles navigate on a road segment, even when it is only striped, and not raised. It also influences how vehicles prepare to turn, or are finalizing their turn, to make sure they are well positioned in their new lane. It was therefore included in the retained as the first layer in the columns. Because of data limitations, it was not possible to differentiate raised medians from striped ones. The categorization therefore compared the absence of median, against the presence of a central turning lane, and the presence of a raised or striped median.
Speed	9	speed limit of the primary road	Yes	The posted speed limit was used as the second layer of columns as the most straightforward way to capture the sources of the main violation type for vehicular collisions in the mid-block area, that is unsafe speed. It also allows to directly tackle the physical problems in the corresponding systemic hotspots by indicating whether the speed limit was appropriately set.
Traffic control	13	presence and type of intersection control	No	Considering characteristics of the intersection beyond the intersection influence area does not make sense.
Volume counts	17	traffic volumes along the primary road	Yes	Combined with information on posted speeds, volume counts speak to the exposure of vehicles to the risk of crashing into one another in the mid-block area. This is the reason why they were included, broken down between local roads and non-local ones with thresholds set at 7,000 – 15,000 – 25,000 ADT.

Pedestrian Involved Collisions - Intersection

Injury	(All)
CollLocati	Intersection Footprint
newPedCra	1

Count of Accidno	Column Labels																																																	
	Signalized																										All-Way Stop									2-way stop													Other	Grand Total
	Thru Lanes 2+2				4+0	4+2					4+4					6+2					6+4				6+6		Thru Lanes 2+2				4+2			4+4		Thru Lanes 2+2				4+2					4+4	6+2				
Row Labels	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	7,001-15,000	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	7,001-15,000	>25,000	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	<7,000 - local	<7,000 - non-local	7,001-15,000	<7,000 - local	<7,000 - non-local	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	<7,000 - local	7,001-15,000	15,001-25,000	>25,000		
Control Violation other movements		2	1	1			2	1	4	4	1		9	10	3			1	1					4	1	1		1								1				1										49
Control Violation through movement		1	3			1	2	7	11	4		1	7	3	2		2	1	1	4		1	2	3			2	2	3				1			1	1						2							68
Control Violation turning movement			1					3	3	1			1	2													1										1													13
Entering from minor facility								1	1				3						1										1							1	1		1				5							15
Failure to Yield																																																		
Crossing In Crosswalk At Intersection																																																		
Making Left Turn	1	5	12	5		6	8	17	29	14	7	3	30	14	1	1	1	1	6	4		1		1			8	8	4		3	2				5	2	1	4	1		2	3	2						212
Proceeding Straight				1			2	3	3	3	1	1	4	1	2			1	3				1				4	11	8		3	1	3			3	3	2	6	1		3	6		1					81
Making Right Turn			2			7	2	7	17	4	1	2	8	6	5	1		1	1	2		2	3	3			3	2	1		1		1			5		3				1	2	1					1	95
Other		1	1				3	4	6	4			4	1	2			1		1			2				5	3	5			2					1	3	1	4		2	2	2					1	61
Crossing In Crosswalk Not At Intersection	1								2					1													2		1				1						1	1	1		2					1	2	16
Crossing Not In Crosswalk	2		1			1		3	4	2		1		2	1							1		2		2	3	3	2		1	2	1			10	7	4	4	3	1	5	8	4						80
In Road			1			2			1				1																1							4	3		1										1	15
No Pedestrian Involved		3					2	3	1	1			1	1			1							1					1							1						1								17
Not In Road			1							2		1	2	1		1	1			1																6	1				1									18
Not Stated	1		1	3			1		2	1			1														1		2			1				1				1		2								18
Others	3	3	3	8		6	5	12	20	7	6		22	15	3		1		5	3		2	5	3	1	3	14	6	3		1	1	2	1		27	6	9	4	7	3	1	9	2				3	3	238
Pedestrian not in dedicated areas	1	2	4	3	1	2	2	6	11	6			7	4	7					2	1		1	3		1	4	5	2							13	6	3	3	3	1	4	9	3			2	1		123
Unsafe Speed				2		1	1	2	4	2			2	1			1		1								1	3	3	1					1	6	6						1				1		2	42
Unsafe Turning Left		1	5			4	2	5	10	1			5	1	2	1		1						1			3	1					1			3	3			1		1		1						53
Unsafe Turning other			1					1	2	1		1		2	3			1		1			1	1				2							1	6	1	2	1			1	2			1				32
Unsafe Turning Right							1	2	1	2				1	1									2				1								3		1		1										16
Grand Total	9	18	37	23	1	30	33	77	132	59	16	10	107	66	32	4	7	8	19	18	1	7	15	24	2	7	51	48	37	1	9	9	10	1	2	96	42	28	26	24	7	23	51	15	1	1	3	5	10	1262

Pedestrian Involved Collisions - Intersection Influence Area

Injury	(All)
CollLocati	Intersection Inf Area
newPedCra	1

Count of Accidno	Column Labels																																						
	Signalized																			All-Way Stop				2-Way Stop												Others			Grand
	Thru Lanes 1+1				2+0	2+1		2+2			3+0				3+2		3+3			4+4	1+0	Thru Lanes 1+1			Thru Lanes 1+1				2+1	2+2				3+0	3+3		Thru Lanes 1+1			
Row Labels	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	7,001-15,000	7,001-15,000	15,001-25,000	7,001-15,000	15,001-25,000	>25,000	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	15,001-25,000	>25,000	7,001-15,000	15,001-25,000	>25,000	>25,000	<7,000 - non-local	<7,000 - local	<7,000 - non-local	7,001-15,000	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	7,001-15,000	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	7,001-15,000	15,001-25,000	>25,000	<7,000 - local	<7,000 - non-local	7,001-15,000	
Control Violation other movements									1																															1
Control Violation through movement							1			1																														2
Entering from minor facility								1																																1
Failure to Yield	1	1	1	2	1	1	1	3	8	3	1					1	1	2	4			4	1	1	7	5		1	1			7	2							60
Following too closely			1																																					1
Others	1		2			1		1	3	5			1		1				3			1			3	1				3	1	2	2	2	1		1	1	1	37
Pedestrian not in dedicated areas	3		2	3	1	1		6	13	8	1	1	1	2	2			4	2	1	1	1		1	5	3	3	2		2	1	8	2			4				84
Unsafe Speed	1	1	3						1									1				2			1					1	1						1			13
Unsafe Turning Left								1																				1												2
Unsafe Turning other	3				1			1	2				1											1	6							1								16
Unsafe Turning Right									2																															2
Grand Total	**9**	**2**	**9**	**5**	**3**	**3**	**2**	**13**	**30**	**17**	**2**	**1**	**3**	**2**	**3**	**1**	**1**	**7**	**9**	**1**	**1**	**8**	**1**	**3**	**22**	**9**	**3**	**4**	**1**	**6**	**3**	**18**	**6**	**2**	**1**	**4**	**2**	**1**	**1**	**219**

Pedestrian Involved Collisions - Midblock

Injury	(All)
CollLocati	Midblock
newPedCra	1

Count of Accidno — Column Labels

Row Labels	25mph										
	Thru Lanes 1+1				2+0		2+2			3+0	3+2
	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	<7,000 - non-local	7,001-15,000	<7,000 - local	<7,000 - non-local	7,001-15,000	7,001-15,000	7,001-15,000
Control Violation other movements											
Crossing In Crosswalk At Intersection											
Control Violation through movement											
Crossing In Crosswalk At Intersection											
Entering from minor facility											
Crossing Not In Crosswalk	1										
Not In Road											
Not Stated											
Failure to Yield											
Crossing In Crosswalk At Intersection	1									1	
Crossing In Crosswalk Not At Intersection											
Crossing Not In Crosswalk	11	1		1	1		1				
In Road	8		1								
Not In Road			1								
Not Stated	1										
Others											
Crossing In Crosswalk At Intersection											1
Crossing In Crosswalk Not At Intersection	1										
Crossing Not In Crosswalk	3	1									
In Road	4	1									
No Pedestrian Involved											
Not In Road		2						1			
Not Stated	2										
(blank)	1										
Pedestrian not in dedicated areas											
Crossing Not In Crosswalk	3	6		2					1		
In Road	5	1	1			1					
No Pedestrian Involved	1										
Unsafe Speed											
Crossing Not In Crosswalk	2										
In Road	3	1	1								
Not In Road											
Unsafe Turning Left											
In Road	1										
Not In Road	1										
Unsafe Turning other											
In Road	3	2									
No Pedestrian Involved											
Not In Road									1		
Not Stated											
Unsafe Turning Right											
Not In Road											
Grand Total	52	15	4	3	1	1	1	1	2	1	1

Row Labels	30 & 35mph														
	Thru Lanes 1+1				2+1		2+2					3+0	3+2	3+3	
	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	<7,000 - non-local	7,001-15,000	<7,000 - local	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	7,001-15,000	>25,000	15,001-25,000	>25,000
Control Violation other movements															
Crossing In Crosswalk At Intersection															
Control Violation through movement															
Crossing In Crosswalk At Intersection										1					
Entering from minor facility															
Crossing Not In Crosswalk															
Not In Road								1							
Not Stated		1													
Failure to Yield															
Crossing In Crosswalk At Intersection															
Crossing In Crosswalk Not At Intersection		1													
Crossing Not In Crosswalk			1				1	1	4	1	1				
In Road									1					1	
Not In Road	1	1	2			1		1			1	1			
Not Stated											1				
Others															
Crossing In Crosswalk At Intersection															
Crossing In Crosswalk Not At Intersection											1				
Crossing Not In Crosswalk			1						1						
In Road										1					
No Pedestrian Involved															
Not In Road		1			1				1	1					
Not Stated		1													1
(blank)															
Pedestrian not in dedicated areas															
Crossing Not In Crosswalk			1		1	1		1	4	3	2	2			1
In Road		1								1		1			
No Pedestrian Involved															
Unsafe Speed															
Crossing Not In Crosswalk									1						
In Road										1					
Not In Road															
Unsafe Turning Left															
In Road															
Not In Road										1					1
Unsafe Turning other															
In Road		2	1							1	1				
No Pedestrian Involved													1		
Not In Road				2						1	1				
Not Stated										1					
Unsafe Turning Right															
Not In Road				1											
Grand Total	1	8	6	3	2	2	1	4	12	13	8	4	1	1	3

Row Labels	40 & 45mph								
	Thru Lanes 1+1		2+1	2+2			3+2		3+3
	<7,000 - local	>25,000	7,001-15,000	7,001-15,000	15,001-25,000	>25,000	15,001-25,000	>25,000	>25,000
Control Violation other movements									
Crossing In Crosswalk At Intersection		1		1					
Control Violation through movement									
Crossing In Crosswalk At Intersection									
Entering from minor facility									
Crossing Not In Crosswalk									
Not In Road									
Not Stated									
Failure to Yield									
Crossing In Crosswalk At Intersection									
Crossing In Crosswalk Not At Intersection									1
Crossing Not In Crosswalk						1			
In Road									
Not In Road									2
Not Stated									
Others									
Crossing In Crosswalk At Intersection									
Crossing In Crosswalk Not At Intersection			1						
Crossing Not In Crosswalk					1	1			
In Road							1		
No Pedestrian Involved	1								
Not In Road									
Not Stated									
(blank)				1		2			
Pedestrian not in dedicated areas									
Crossing Not In Crosswalk				2		4		1	
In Road				1	2	1			1
No Pedestrian Involved									
Unsafe Speed									
Crossing Not In Crosswalk									
In Road				1			1		
Not In Road									
Unsafe Turning Left									
In Road									
Not In Road									
Unsafe Turning other									
In Road									
No Pedestrian Involved						1			
Not In Road									
Not Stated									
Unsafe Turning Right									
Not In Road									
Grand Total	1	1	1	6	3	10	2	1	4

Row Labels	50mph				Grand Total
	2+0	2+2		3+3	
	<7,000 - non-local	15,001-25,000	>25,000	>25,000	
Control Violation other movements					
Crossing In Crosswalk At Intersection					2
Control Violation through movement					
Crossing In Crosswalk At Intersection					1
Entering from minor facility					
Crossing Not In Crosswalk					1
Not In Road					1
Not Stated					1
Failure to Yield					
Crossing In Crosswalk At Intersection					2
Crossing In Crosswalk Not At Intersection					2
Crossing Not In Crosswalk					25
In Road					11
Not In Road					11
Not Stated					2
Others					
Crossing In Crosswalk At Intersection					1
Crossing In Crosswalk Not At Intersection					3
Crossing Not In Crosswalk				1	9
In Road				1	8
No Pedestrian Involved					1
Not In Road					7
Not Stated					4
(blank)					4
Pedestrian not in dedicated areas					
Crossing Not In Crosswalk	1		1	2	39
In Road					16
No Pedestrian Involved					1
Unsafe Speed					
Crossing Not In Crosswalk					3
In Road					8
Not In Road		1			1
Unsafe Turning Left					
In Road					1
Not In Road					3
Unsafe Turning other					
In Road		1			11
No Pedestrian Involved					2
Not In Road				1	6
Not Stated					1
Unsafe Turning Right					
Not In Road					1
Grand Total	1	2	1	5	189

Bicyclist Involved Collisions - Intersection

Injury	(All)
CollLocati	Intersection Footprint
newBikeCra	1

Count of Accidno	Column Labels																
	Signalized						All-Way Stop			2-way stop				Others			Grand Total
Row Labels	Thru La	4+2	4+4	6+2	6+4	6+6	Thru La	4+2	4+4	Thru La	4+2	4+4	6+2	Thru La	4+2	6+2	
Bicyclist																	
Control Violation other movements	1	1		2					1	2							7
Control Violation through movement	5	18	15	4	8	3	3	1		15	3				1		76
Control Violation turning movement		1		1	1		1			3							7
Entering from minor facility	1	2	4	2	2		1			3	1						16
Failure to yield		4					1	1		7	1	1					15
Following too closely										1	2						3
Others	1	9	7	2	3	1	2	1		7	3		2	1			39
Unsafe Operation of Bicycle		6	1		3	1	1			4	3						19
Unsafe Overtaking			1											1			2
Unsafe Speed	4	14	8	3	5		5	1		13	6	1		2		1	63
Unsafe Turning Left	1	3			1					3	1						9
Unsafe Turning other	2	14	7	4	6	1	4	1		6	3		1	3			52
Unsafe Turning Right	1	1	1							3							6
Wrong lane		13	10	4	6	2	3			5	5						48
Pedestrian not in dedicated areas					1												1
Equipment of vehicles		2		1													3
Driver																	
Control Violation other movements		1		1													2
Control Violation through movement		8	4		2		1			2							17
Control Violation turning movement		5	4	1						2							12
Entering from minor facility		1			1					1	1						4
Failure to yield	2	10	3	2	3	2	8	2		8	6		1	1			48
Following too closely		1					1										2
Others	1	7	1	1	2					4	1		1				18
Unsafe Door Opening	1						1			1							3
Unsafe Overtaking										1	1						2
Unsafe Speed		2	1								1						4
Unsafe Turning Left	6	10	1		1		4			14	7		1				44
Unsafe Turning other	1	8	5	1	2		1	3		5	4		1	1			32
Unsafe Turning Right	1	9	7	3	3		1			5	6		2				37
Wrong lane		1															1
Other																	
Control Violation other movements			1	1	1		1						1				5
Control Violation through movement		5	4	5	1		4	1		3							23
Control Violation turning movement		1	1	1	1						1						5
Entering from minor facility						1				3							4
Failure to yield		1		2	1		2	1		5	2		1	3			18
Following too closely		2	2		2												6
Others	9	28	24	6	6	1	9			35	17	1		5			141
Unsafe Door Opening	1		2														3
Unsafe Operation of Bicycle	1	4	1	1	1					2							10
Unsafe Overtaking											1						1
Unsafe Speed		5		4			2			11	1	1		2			26
Unsafe Turning Left	1	7	2							6	3						19
Unsafe Turning other	1	3	4	1		1	1			3	5		1				20
Unsafe Turning Right		2	3				1			3	1						10
Wrong lane		2	3	2			1			2	4		3				17
Parked Vehicle																	
Unsafe Door Opening	1		1				1			1							4
Pedestrian																	
Failure to yield	2																2
Pedestrian not in dedicated areas		1								1							2
Grand Total	**44**	**212**	**128**	**55**	**63**	**13**	**60**	**12**	**1**	**190**	**90**	**4**	**15**	**19**	**1**	**1**	**908**

Bicyclist Involved Collisions - Midblock

Injury	(All)
CollLocati	(Multiple Items)
newBikeCra	1

Count of Accidno	Column Labels																	
	No bikelane								Bikelane								Shoulder	Grand Total
	25mph			30 & 35mph		40 & 45mph		50mph	25mph	30 & 35mph		40 & 45mph				50mph	50mph	
Row Labels	Parking	No Parking	N/A	Parking	No Parking	Parking	No Parking	No Parking	No Parking	Parking	No Parking	Parking	No Parking	N/A	999	No Parking	No Parking	
Bicyclist																		
Control Violation through movement					2		1											3
Control Violation turning movement	2						1					1						4
Entering from minor facility	4	1		2	2		3				1							13
Failure to yield	3																	3
Following too closely										1			1			1		3
Others	7			2	2	1	2						1					15
Unsafe Operation of Bicycle	3	1		2	2		1											9
Unsafe Overtaking	1				2						1							4
Unsafe Speed	11	5		11	5		4			1	3	1	10			4		55
Unsafe Turning Left	2			3							1							6
Unsafe Turning other	14	1	2	7	4		4	1	1	1		1	3	1		1	1	42
Unsafe Turning Right		1		1	1								1					4
Wrong lane	2	2		2	4		3						1			1	1	16
Driver																		
Control Violation other movements	1												2					3
Entering from minor facility	3	1		2	4							1	1					12
Failure to yield	4			2	2		1					1	2					12
Following too closely				1			1	1										3
Others	3			1	3	1												8
Unsafe Door Opening	1	1		4		1					1					1		9
Unsafe Operation of Bicycle										1								1
Unsafe Overtaking	1			1	2					1								5
Unsafe Speed	1	1		1	3								1			3	1	11
Unsafe Turning Left	2	1			1	1	1											6
Unsafe Turning other	6			8	3	1	2											20
Unsafe Turning Right	4			3	1		1	1		1	4	1						16
Wrong lane																1		1
Other																		
Control Violation through movement																1		1
Entering from minor facility	3			1									1					5
Failure to yield	1					1												2
Following too closely													1					1
Others	12	3	1	9	8	1	8			1		2	2			5	1	53
Unsafe Door Opening	5			2			1											8
Unsafe Operation of Bicycle	1	1			1					1								4
Unsafe Overtaking						1												1
Unsafe Speed	8		2	3	1	1	1						1			2		19
Unsafe Turning Left				2									1					3
Unsafe Turning other	2	1	1	10			1	2				1	3		2			23
Unsafe Turning Right	3	1			2						1	1	1					9
Wrong lane	1	1			2		1				1							6
Parked Vehicle																		
Unsafe Door Opening	2			3														5
Pedestrian																		
Failure to yield	1																	1
Grand Total	114	22	6	83	57	9	37	5	1	8	13	10	33	1	2	20	4	425

Vehice Only Involved Collisions - Intersection

CollLocati	Intersection Footprint
newPedCra	0
newBikeCra	0
PDO	0

Count of Accidno — Column Labels

Signalized

Row Labels	Thru Lanes 2+2 <15k ADT <7K	2+2 <15k ADT >7K	2+2 >15k ADT <7K	2+2 >15k ADT >7K	4+0 <15k ADT <7K	4+0 <15k ADT >7K	4+2 <15k ADT <7K	4+2 <15k ADT >7K	4+2 >15k ADT <7K	4+2 >15k ADT >7K	4+4 <15k ADT <7K	4+4 <15k ADT >7K	4+4 >15k ADT <7K	4+4 >15k ADT >7K	6+2 <15k ADT <7K	6+2 <15k ADT >7K	6+2 >15k ADT <7K	6+2 >15k ADT >7K	6+4 <15k ADT <7K	6+4 <15k ADT >7K	6+4 >15k ADT <7K	6+4 >15k ADT >7K	6+6 <15k ADT >7K	6+6 >15k ADT >7K
Broadside																								
Control Violation other movements	1					1	2	5	7	3			1	6		1	2	2			1	10		2
Control Violation through movement	8	7	8				37	50	106	38	10	112	19	95	5	8	60	39	2	15	9	102	1	14
Control Violation turning movement		3					4	8	15	10		5	1	18		1	4	9		3	1	37		8
Entering from minor facility	3			1			1	3	8	1	1	6	1	6		3	5	1		2	1	14		6
Following too closely									1															1
Unsafe Speed			1				2	3	5	5	1	3		6		1		3				5		1
Unsafe Turning Left	6	7	1	1			17	15	35	9	2	9	3	11		2	4	1		3		9		2
Unsafe Turning other	2	1	3				5	5	11	4	2	8	2	4	1	1	3					5		2
Unsafe Turning Right		3								4				2		1	2			2		4		
Others	1	3	2				16	10	46	11	5	31	6	25		5	18	12		6	2	35		7
Failure to Yield	1	1	1				2	5	5	5		2		1								6		
Head-On																								
Control Violation other movements			1				1	1		1				1			1	1						1
Control Violation through movement							6	2	12	1		4		7	1		10	1		2		17		2
Control Violation turning movement							3	2	8	1	1	4		6			2	3		1		13		4
Entering from minor facility								1	1							1	1					2		1
Following too closely									1			1												
Unsafe Speed		1	1	2				3	2		1	2				1	1	1		2		3		
Unsafe Turning Left	4	3	5				16	13	17	7		13	2	5		4	1			2		2		1
Unsafe Turning other			2				1	4	10	2		1		5		1	3			1		2		
Unsafe Turning Right								5	1	1				1								2		
Others	2	3	1				3	7	16	6	2	5	1	11	1		5	1		2		2		3
Failure to Yield								3	1			2		1			1	1				1		
Hit Object																								
Control Violation through movement																						1		1
Entering from minor facility																					1			
Unsafe Speed							3	7	18	4	2	3	2	6			1			2		7		3
Unsafe Turning Left		1							2				1							1				1
Unsafe Turning other		1	4				6	3	14	9	1	2	2	3	4		4	4		3		7		
Unsafe Turning Right							2	1		1				2								1		
Others		1					2	5	2	1	1	1		3				2		2	1	3		1
Failure to Yield												1									1			
Not Stated																								
Control Violation other movements			1											1			1					1		
Control Violation through movement		2	1				4	2	7	3	1	8	1	6	1	1	3	3			1	4		3
Control Violation turning movement		1	2									1	1								1	3		1
Entering from minor facility										1							1							
Following too closely								1	4		1			4			1	1				2		1
Unsafe Speed	1		1				3	2	6	2		3	1	5	1	1	1				1	3		3
Unsafe Turning Left	1	3	1				1	2	5	1		1				1				1		2		
Unsafe Turning other	1						3	1	1	1		1	1	2		1	2	1				3		1
Unsafe Turning Right																		1				1		
Others	1	1	2				4	4	12	10	1	9	1	7			5	4			1	8		
Failure to Yield							1			1		1		1										
Other																								
Control Violation other movements									1			1												
Control Violation through movement							1		1	1		1		2			2	1			1	1		
Control Violation turning movement							1		1					1										
Entering from minor facility		1										1												
Following too closely																								
Unsafe Speed		1					1	1	8	3			1	3			2	1			1	2		
Unsafe Turning Left									1	2		2		1								1		
Unsafe Turning other				1				1	1	1		1		2			1							
Unsafe Turning Right		1												1										
Others	2	2		1			1	3	3	2	2	1		4		1	2					3		
Failure to Yield		1							1		1			1				1		1		1		
Overturned																								
Control Violation other movements																								
Control Violation through movement							1	1	1	1		3		2				1				3		
Control Violation turning movement								1						1										
Following too closely							1		1															
Unsafe Speed							1	5	2	4	1			3				1				1		2
Unsafe Turning Left							1			1														
Unsafe Turning other	3		2	1			2		3	3	1		1	1							1	1		1
Unsafe Turning Right								1					1				1							1
Others	1									1	1	2		2								4		1
Failure to Yield												1		1										
Rear-End																								
Control Violation other movements																				1				
Control Violation through movement								1	7	3		1	2	7			3					5		2
Control Violation turning movement									1													2		
Entering from minor facility																						1		
Following too closely	4	2	5	2	1		16	22	56	21	2	22	3	35	1	2	26	15		6	4	56		14
Unsafe Speed	8	10	14	2			21	26	95	50	2	27	11	90	1	3	42	26		9	14	85	2	32
Unsafe Turning Left									2					1			1					1		
Unsafe Turning other	1	3	2	1			3	6	13	6		8		6		1		4		2		2		4
Unsafe Turning Right	1													1				1						
Others	2	1	4	1	1		6	9	28	8	1	7	7	25		2	11	1		3	2	23		6
Failure to Yield	1	2	2				3	7	12	5		6	1	10			6	2		2		14		1
Sideswipe																								
Control Violation other movements							1			1							1					2		1
Control Violation through movement	1		1	1			3	1	4	3		4		7	1	1	5	4				5		2
Control Violation turning movement							1	1	3			2		3		1	5	2				5		1
Entering from minor facility							1	1	1			3		2							1	1		
Following too closely		1							2	1				1				1						
Unsafe Speed	1	1					1	1	4	2		3		2				3			1	3		
Unsafe Turning Left	4	2					5	7	8	3	4	6	2	9		2	1					1		3
Unsafe Turning other	2	2	1				11	10	27	11	3	10	2	13	1	1	4	4		1		16		4
Unsafe Turning Right							2	1	1	2		5		1			1				1	7		3
Others	1	1	1				4	13	13	2	1	6	1	11			5	3		4	3	6		
Failure to Yield								1	1			1		1		1						1		
Vehicle - Pedestrian	1	3					1	3	9	1	2	10	2	1		1	1	2		2		1		
Grand Total	65	76	70	14	2	1	234	296	690	281	53	373	80	502	18	50	262	164	2	81	50	571	3	148

All-Way Stop

Row Labels	Thru Lanes 2+2 <15k ADT <7K	2+2 <15k ADT >7K	2+2 >15k ADT <7K	4+2 <15k ADT <7K	4+2 <15k ADT >7K	4+2 >15k ADT <7K	4+2 >15k ADT >7K	4+4 <15k ADT <7K	4+4 <15k ADT >7K	4+4 >15k ADT <7K
Broadside										
Control Violation other movements										
Control Violation through movement	19	8		5	3			1		
Control Violation turning movement	1	1								
Entering from minor facility	6			1						
Following too closely				1						
Unsafe Speed	3									
Unsafe Turning Left	1		1		1		2			
Unsafe Turning other	3			2	1	1				1
Unsafe Turning Right	1									
Others	10	1		1				1		
Failure to Yield	22	5	2	4	1			1		
Head-On										
Control Violation other movements										
Control Violation through movement	4						1			
Control Violation turning movement										
Entering from minor facility										
Following too closely										
Unsafe Speed										
Unsafe Turning Left	2	2								
Unsafe Turning other	6	1		1						
Unsafe Turning Right										
Others	2	1		1	2					
Failure to Yield	1									
Hit Object										
Control Violation through movement										
Entering from minor facility										
Unsafe Speed	9	1		1						
Unsafe Turning Left	1									
Unsafe Turning other	5			1						
Unsafe Turning Right										
Others	4			1						
Failure to Yield										
Not Stated										
Control Violation other movements										
Control Violation through movement	1									
Control Violation turning movement										
Entering from minor facility										
Following too closely										
Unsafe Speed				1						
Unsafe Turning Left										
Unsafe Turning other										
Unsafe Turning Right										
Others	4			1						
Failure to Yield	2									
Other										
Control Violation other movements										
Control Violation through movement	1									
Control Violation turning movement										
Entering from minor facility										
Following too closely				1						
Unsafe Speed	4									
Unsafe Turning Left										
Unsafe Turning other	1									
Unsafe Turning Right										
Others	4	1		1						
Failure to Yield										
Overturned										
Control Violation other movements										
Control Violation through movement										
Control Violation turning movement										
Following too closely										
Unsafe Speed	2	1				1				1
Unsafe Turning Left										
Unsafe Turning other										
Unsafe Turning Right										
Others										
Failure to Yield										
Rear-End										
Control Violation other movements										
Control Violation through movement	1			1						
Control Violation turning movement										
Entering from minor facility	2									
Following too closely	9	3	1	2		1				
Unsafe Speed	14	2	2	2	2		1	1	1	
Unsafe Turning Left	2									
Unsafe Turning other	4	1		1						
Unsafe Turning Right										
Others	9	1		1				1		
Failure to Yield	4									
Sideswipe										
Control Violation other movements										
Control Violation through movement	4	1								
Control Violation turning movement										
Entering from minor facility	1									
Following too closely										
Unsafe Speed	2									
Unsafe Turning Left	1	1		1						
Unsafe Turning other	12	3		2						
Unsafe Turning Right	2									
Others	6	1								
Failure to Yield	4									
Vehicle - Pedestrian	2									
Grand Total	198	35	6	33	10	3	4	5	1	2

2-way stop

Row Labels	Thru Lanes 2+2 <15k ADT <7K	2+2 <15k ADT >7K	2+2 >15k ADT <7K	2+2 >15k ADT >7K	4+2 <15k ADT <7K	4+2 <15k ADT >7K	4+2 >15k ADT <7K	4+2 >15k ADT >7K	4+4 <15k ADT <7K	4+4 <15k ADT >7K	4+4 >15k ADT <7K	4+4 >15k ADT >7K	6+2 <15k ADT <7K	6+2 <15k ADT >7K	6+2 >15k ADT <7K	6+2 >15k ADT >7K	6+4 <15k ADT <7K	6+4 >15k ADT <7K	Other	Grand Total
Broadside																				
Control Violation other movements	2						1													47
Control Violation through movement	40	5	3		5	5	4	1			1	1							1	847
Control Violation turning movement	4				3	1	2								1					140
Entering from minor facility	21		3	1	14	4	16								3					132
Following too closely	1		1																	5
Unsafe Speed	9	1	2	1	1	1	6								1				1	62
Unsafe Turning Left	46	2	6		24	4	65	8	1				1	1	9	6	1		1	317
Unsafe Turning other	15	1	3		9	5	11	2				1		1	3					118
Unsafe Turning Right	5				1		2													27
Others	29	4	2		13	4	21		1			1			4		1		2	336
Failure to Yield	114	9	6		45	28	61	1	2	3	2			1	8				5	349
Head-On																				
Control Violation other movements							1													9
Control Violation through movement	2																			72
Control Violation turning movement							2								1					51
Entering from minor facility	2				1		1													11
Following too closely																				2
Unsafe Speed	9		1		2	1	2												1	36
Unsafe Turning Left	26	3	4		5		17	1				1				2				158
Unsafe Turning other	24	1	1	1	4	1	7												4	83
Unsafe Turning Right	3					1	1													15
Others	17	4	5		5		5								3				1	117
Failure to Yield	9	2	1		4	1											1			29
Hit Object																				
Control Violation through movement		1																		3
Entering from minor facility																				1
Unsafe Speed	18		1		4	3	4					1			1				9	110
Unsafe Turning Left	3				2		1								1				1	15
Unsafe Turning other	30	1	1		3	2	15		1						4				5	135
Unsafe Turning Right	2	1				1	1													12
Others	7		1		3		4								3				2	50
Failure to Yield	1		1																1	5
Not Stated																				
Control Violation other movements																				4
Control Violation through movement	1				1					1									1	56
Control Violation turning movement																				10
Entering from minor facility		1					1													4
Following too closely	1		2		2		1								1					22
Unsafe Speed	6	1				1	2								1				1	47
Unsafe Turning Left	2	1			1		1	2												26
Unsafe Turning other	7	1	2		1	1	3	1							1					36
Unsafe Turning Right																				2
Others	13				1	1	4	1		1					2					98
Failure to Yield	5				2	2	4												1	20
Other																				
Control Violation other movements																				2
Control Violation through movement	1																			13
Control Violation turning movement																				3
Entering from minor facility																				2
Following too closely	1						1													3
Unsafe Speed	11	1			2	1	3												1	47
Unsafe Turning Left	1		1		1		2									1				13
Unsafe Turning other	4																		2	17
Unsafe Turning Right																				2
Others	12	1	1		1		2		1				1	1					1	54
Failure to Yield	4				3	2													1	17
Overturned																				
Control Violation other movements															1					1
Control Violation through movement																				13
Control Violation turning movement																				2
Following too closely																1				3
Unsafe Speed	10	2	1		4		5									1		1	2	51
Unsafe Turning Left																				2
Unsafe Turning other	8	1	1		1		3							1					1	36
Unsafe Turning Right											1				1					6
Others	2	1	2		2									1	1					21
Failure to Yield	1	1					1												1	6
Rear-End																				
Control Violation other movements					1															2
Control Violation through movement	1						1								1					36
Control Violation turning movement																1				4
Entering from minor facility					1															4
Following too closely	23	4	8	1	7	7	27	2						2	5	1			1	419
Unsafe Speed	29	3	17		14	5	51	3		1		1			8	2			8	737
Unsafe Turning Left	4																			11
Unsafe Turning other	31	1	3				15								2					120
Unsafe Turning Right																				3
Others	8	1	3		6	1	15	1		2					3				2	202
Failure to Yield	5				3	3	3							1		1			3	97
Sideswipe																				
Control Violation other movements	1																			7
Control Violation through movement	3						1												1	53
Control Violation turning movement	1		1																	26
Entering from minor facility	1		1				4													17
Following too closely	1				1			1												9
Unsafe Speed	6	1			2		1												1	35
Unsafe Turning Left	10	1	3		6	2	8								1	1	1		2	95
Unsafe Turning other	44	2	6		12	4	15	1							7				4	235
Unsafe Turning Right	2				1	1						1			2				1	34
Others	17		3		9	2	5								1	1			3	123
Failure to Yield	12		3		1	3	3								2	1				35
Vehicle - Pedestrian	3	2			1	1	3	1								1			2	56
Grand Total	731	61	100	4	235	99	437	26	6	8	4	7	2	9	82	20	4	1	74	6293

Vehice Only Involved Collisions - Intersection Influence Area

CollLocati	Intersection Inf Area
newPedCra	0
newBikeCra	0
PDO	0

Count of Accidno	Column Labels																														
	Signalized												All-Way Stop						2-way stop											Others	Grand Total
	25mph			25-35mph			35-45mph			50mph		Ramp	25mph			25-35mph			25mph			25-35mph			35-45mph			50mph			
Row Labels	No Median	CLTL	Median	No Median	CLTL	Median	No Median	CLTL	Median	No Median	Median	Median	No Median	CLTL	Median	No Median	CLTL	Median	No Median	CLTL	Median	No Median	CLTL	Median	No Median	CLTL	Median	No Median	Median		
Broadside																															
Control Violation other movements											1																			1	2
Control Violation through movement	1			4		7	2	4	11	1	2													1							33
Control Violation turning movement				1			1		2																						4
Entering from minor facility	3	2		6	7	2	4	2	4		2					1	1		2	3		3	5	1	2		2				52
Failure to Yield				1	1	3												1	2	1		3		1			1			1	15
Unsafe Speed	1			1		1		1		1									4			2	1				1				13
Unsafe Turning Left	4			7	1	2	1		6		1		1						1			3	3	2	1	2	4		1	3	43
Unsafe Turning other	1			4	1	3	2	2	4		1								1		1	5	3			1	1				30
Unsafe Turning Right		1		1					2										1			1									6
Others	1			7	1	3	4	3	5		1		1									3					1				30
Head-On																															
Control Violation other movements				1						1																					2
Control Violation through movement						1	1		1										1											1	5
Control Violation turning movement									1																						1
Entering from minor facility						1							1																		2
Failure to Yield	1								1																						2
Following too closely																						1									1
Unsafe Speed				1		1			1	1						1			3			1									9
Unsafe Turning Left				2			1		1	1						1			2			3			1		1		1		14
Unsafe Turning other					1				1		1								7	1		2					1		1	1	16
Unsafe Turning Right	1																														1
Others	1			4	2	1	2	1	1				2			1	1		4			1			1			2			24
Hit Object																															
Control Violation through movement					1																										1
Entering from minor facility													1																		1
Following too closely																														1	1
Unsafe Speed				3	1	1	2		7	1	1					1			3					1						4	25
Unsafe Turning Left																			1												1
Unsafe Turning other	3		1	5	1	2	2	1	18	2	3		2						6	2		5			5	1	1		2	1	63
Unsafe Turning Right								1	1				1																		3
Others		1	2			2			7				2						3	1		1					1				20
Not Stated																															
Control Violation other movements									1																						1
Control Violation through movement									1		1											1									3
Entering from minor facility				1		1																				1					3
Failure to Yield						1																		1							2
Following too closely									3	1												1				1					6
Unsafe Speed						3	2		1		1											1					1			1	10
Unsafe Turning Left								1																1							2
Unsafe Turning other				1	1	1			1							1			2			1	1	2		1	1			1	14
Unsafe Turning Right				1	2																										3
Others			1	4			3		1		1								3			1	1								15
Other																															
Control Violation other movements									1																						1
Control Violation turning movement				1																											1
Entering from minor facility	1		1	2	1														1												6
Failure to Yield	1	1					1											1	1			1									6
Unsafe Speed	1			2		1	1	1	1		2					1			1			1		1							13
Unsafe Turning Left				1		1				1																					3
Unsafe Turning other									1													1			1		1				4
Others					1	2	2												4			1		2	1		1			1	15
Overturned																															
Control Violation through movement							1																								1
Entering from minor facility							1													1											2
Unsafe Speed				1		1	1		3		1								3	1		1			1		1		1	3	18
Unsafe Turning Left																			1												1
Unsafe Turning other			1	2				2	1		1		1						1	1		2		2	1					1	16
Unsafe Turning Right																			1												1
Others						1	1		1				1						1			1						1			7
Rear-End																															
Control Violation through movement	1																										1				2
Control Violation turning movement									1																						1
Entering from minor facility		1												1																	2
Failure to Yield	2		1	4	1	1	3	1	8				1			1			2		1	1		1		1					29
Following too closely	9	1	4	38	10	14	7	7	24	1	8				1	1			4	4	1	6	4	10		2	9			3	168
Unsafe Speed	10	4	4	31	13	55	21	8	83	9	27		3						6	1	1	16	4	15	4	4	5			7	331
Unsafe Turning Left									1				1																		2
Unsafe Turning other	4	1		7	1	7	4	2	12		1			1					11	1		10	4	2	2	2	3		1	2	78
Unsafe Turning Right					1																										1
Others	2			8		8	4	2	15	1	4					1		1	1			7	3		1	1	2			5	66
Sideswipe																															
Control Violation through movement				1			1																					1			3
Control Violation turning movement	1						1																								2
Entering from minor facility				2	1														1			2	1	1			1				9
Failure to Yield	2					1							1								1		1							1	7
Following too closely						1									1															1	3
Unsafe Speed			1	2	2	3			2	1			1						3			4		3						1	23
Unsafe Turning Left				1					1										1			3								1	7
Unsafe Turning other	9			10	2	9	2	2	9		1	1	3						19	2	1	12	3	8			1			1	95
Unsafe Turning Right	1		1			1	1															2				1					7
Others	1			10	3	7	3	2	5	1	3		1						1		2	3	1	1	1	1	2	1		1	50
Vehicle - Pedestrian																															
Control Violation other movements																						1									1
Entering from minor facility																			1						1						2
Failure to Yield				1					3										1			2									7
Unsafe Speed							1																							1	2
Others	1																		1												2
Pedestrian not in dedicated areas																			1												1
Grand Total	63	12	17	179	56	149	83	43	254	23	64	1	24	2	2	10	2	3	113	19	8	116	35	56	23	19	43	5	7	44	1475

Vehice Only Involved Collisions - Midblock

CollLocati	Midblock
newPedCra	0
newBikeCra	0
PDO	0

Count of Accidno	Column Labels																																																			Gr
	No Median																				Median																Center Left Turn Lane											N/A				
	25mph					30-35mph					40-45mph					>50mph				Ramp	25mph			30-35mph				40-45mph					>50mph				25mph			30-35mph				40-45mph			>50mp	30-35m	40-45mph			
Row Labels	<7,000 - Local	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	<7,000 - Local	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	<7,000 - Local	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	<7,000 - Local	7,001-15,000	15,001-25,000	>25,000	<7,000 - Local	<7,000 - non-local	7,001-15,000	15,001-25,000	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	<7,000 - Local	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	<7,000 - Local	7,001-15,000	15,001-25,000	>25,000	<7,000 - non-local	7,001-15,000	15,001-25,000	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	7,001-15,000	15,001-25,000	>25,000	>25,000	<7,000 - non-local	7,001-15,000	15,001-25,000	>25,000	
Broadside																																																				
Control Violation other movements							1	1																																				1								3
Control Violation through movement								2	1			1		3	1		1	3														2			1	1																16
Control Violation turning movement								1							2																	1																				4
Entering from minor facility	14	5	2	2			4	4	1	2			4	1									1			2				2	2					5	3	2	1	1	5	5		1	1	3						73
Failure to Yield	4					3	1		1				1													1	1			1	1	1				1																16
Unsafe Speed			1				1		1					1															1		1	2				1																9
Unsafe Turning Left	3	4	1					5	3	3		1	1	1	1			1								1				1	2	3			1	2		1		1	4	2	4	1								47
Unsafe Turning other	9	3	2	1			3	7	2				1	2	1			2	1				1		1	2				2	1	2									4	2	1		1			1				52
Unsafe Turning Right										1																					1																					2
Others	6	3		1		1	3	4	1	3	1			3	1		1					1	1		1	1	1			1		3				3		1			1	1			1							44
Head-On																																																				
Control Violation other movements			1																													1																				2
Control Violation through movement							1	2	1																1							1				1																7
Entering from minor facility		1		1				1	1				1																												1				1							7
Failure to Yield			1					1																																												2
Following too closely	1																																																			1
Unsafe Speed	2	1		1			1	1					1														1		1	1												1										11
Unsafe Turning Left	2	2					1		1																					1											1	2	1									11
Unsafe Turning other	15	6	1			2	5	4					1													1	1				1				1								1	1							1	41
Unsafe Turning Right	1																																																			1
Others	10	2	1			1	1	2										1	2						1										1																	22
Hit Object																																																				
Control Violation through movement												1																																								1
Failure to Yield	1						1																																													2
Unsafe Speed	5	1	2					3	1			1		3	2		3		1			1			1		1			1	2	2			3	9					2		1									45
Unsafe Turning Left												1					1												1																							3
Unsafe Turning other	9	3		1			4	6	1			1	1	2	3	1	4	3	2						1	5	2			8	5	5			2	7		1	1		2	1	1	1								83
Unsafe Turning Right																			1																	1																2
Others	3	3				1	1								1				1											1		5			1							1	1			2						21
Not Stated																																																				
Control Violation through movement												1		1	1																																					3
Control Violation turning movement																																1																				1
Entering from minor facility	1																																												2							3
Failure to Yield																									1																											1
Following too closely			1					1																		1																			1							4
Unsafe Speed						1			1						1																	4				2						1										10
Unsafe Turning Left						1	1																													1																3
Unsafe Turning other	5						3	2		1																2	1							1						1			1									17
Others	2						2	1	1																	1						2			1										1							11
Other																																																				
Entering from minor facility	1																																																			1
Failure to Yield			1																						1																											2
Unsafe Speed	2					1		1							2				1												1	1			1											1			1			12
Unsafe Turning other	4	1		1			1	2			1				1																	2				1						1										15
Unsafe Turning Right									1																																											1
Others	3		2			1		1							1															1						2							1									12
Overturned																																																				
Control Violation turning movement																																1																				1
Failure to Yield	1																																																			1
Unsafe Speed	4							1				2	1	1					2									1		1	1	2			1	2					1											20
Unsafe Turning Left								1										1																																		2
Unsafe Turning other	5	2					1	1	1					1		1	2									1	1			3	1	2																				22
Unsafe Turning Right																																1																				1
Others	2					1			1																						1											1										6
Rear-End																																																				
Control Violation other movements																																				1																1
Control Violation through movement																			1																																	1
Entering from minor facility																										1					1																					2
Failure to Yield	1	1	1					1							1								1									1				2									1	1						11
Following too closely	1	1	2	1		1		6	6	2			5	3	9				4	1			1		3	4	7	1		1	4	12	1			8			2		4	3	2		2	1						98
Unsafe Speed	2	4	7	2			2	8	5	10		2	7	6	13		2		8				4		3	8	15			2	7	28		1	2	27			2		4	4	2		1	7				1		196
Unsafe Turning Left	1																																																			1
Unsafe Turning other	23	9	6	3	1	4	5	14	2	2				2	3				1					1	5	9	5			1	1	7				1	2			1	3	5	2		1	1						120
Unsafe Turning Right									1																																											1
Others	5	1					1	2	1	1			1	2	5			1	2				2			2	3			1	2	5			1	6			1		4	1	1			1						52
Sideswipe																																																				
Control Violation other movements							1																																	1												2
Control Violation through movement													1	2			1															1																				5
Control Violation turning movement								1																																												1
Entering from minor facility		1						1				1	1								1											1					1					1	2									10
Failure to Yield		2						1																		1												1		1												6
Unsafe Speed	1	1	1				1			1				1			1													1		4		1		1						2										16
Unsafe Turning Left	1	1					1	2	1																						1									1												8
Unsafe Turning other	28	9	7	2		3	13	7	6	4			1	2	1				1				1		2	4	6	1		3	7	4			1	4		1		1	5	1	2									127
Unsafe Turning Right																										1										1						1										3
Others	9		1				1	2	1	2				1	1				1							4	2					5			1	5	1								1		1					39
Pedestrian not in dedicated areas																																										1										1
Vehicle - Pedestrian																																																				
Failure to Yield	1						1																																													2
Unsafe Turning other	1																																								1											2
Others	3	1																								1										1				1												7
Pedestrian not in dedicated areas	1	1					1																																		1				1							5
Grand Total	193	69	41	16	1	21	63	100	43	32	2	12	28	38	51	2	16	12	29	1	1	2	12	1	21	53	47	3	3	33	43	112	1	3	18	96	7	7	7	9	43	37	23	5	15	17	1	1	1	1	1	1394

Appendix C

Identification of Systemic Hotspots

Identification of Systemic Hotspots

Systemic hotspots are identified using the framework of the systemic collision matrices. The highest priority systemic concerns are identified using a statistically significant percentile value. For the vehicle matrices, the 99.5th percentile was set as the threshold criterion for identifying systemic hotspots. For the pedestrian and bicycle matrices, the 99th percentile was used as the threshold criterion for identifying systemic hotspots. The difference in percentile thresholds are a result of the relative size of the statistical population (i.e. the number of records in the ped/bike matrices is smaller relative to the number of vehicle records). For both criteria, the percentile is rounded down to prevent situations where a systemic hotspot was missed due to a fraction of a crash and to maintain a conservative approach. The methodology to select the threshold is described in Appendix A.

Further scrutiny was taken for each collision matrix and each individual scenario to determine whether countermeasures could be made on a systemic basis based on the geometrics and features of each collision identified in the hotspots. Roadway characteristics (i.e. intersection control, number of lanes) were examined for each collision to ensure that none of the collisions were mis-geocoded or erroneously assigned the incorrect environment attributes. Collisions that did not correctly match the hotspot environment were removed. Additionally, engineering judgment was employed to discern which hotspots could reasonably maintain a systemic approach to implementing city-wide countermeasures. A summary for all hotspots removed after the primary statistical analysis are described below each table.

Table 1A: Pedestrian Injury Collisions - Intersection Footprint
(99% percentile = 15.14 collisions; the criterion is 15)

Number of Collisions	Crash Scenario	Roadway Environment
27	Failure to Yield – Crossing in Crosswalk at Intersection – Making Left Turn	Signalized, Primary Road ADT 7,001-15,000 3-Lane (1-Way) Intersects 3-Lane (1-Way) or 3-Lane (1-Way) Intersects 4-Lane (2-Way)
27	Failure to Yield – Crossing in Crosswalk at Intersection – Making Left Turn	Signalized, Primary Road ADT 7,001-25,000 4-Lane (2-Way) Intersects 2-Lane (2-Way)
17	Failure to Yield – Crossing in Crosswalk at Intersection – Making Right Turn	Signalized, Primary Road ADT 15,001-25,000 2-Lane (2-Way) Intersects 4-Lane (2-Way)

Hotspots #2 and #4 were combined as they were similar in both intersection control and roadway cross-section, the hotspots only varied in terms of the Primary Roadway ADT.

~~Table 1B: Pedestrian Injury Collisions - Intersection Influence Area~~
~~(99% percentile = 9.15 collisions; the criterion is 9)~~

~~Number of Collisions~~	~~Crash Scenario~~	~~Roadway Environment~~
~~13~~	~~Pedestrian Not in Dedicated Areas~~	~~Signalized, 2 Lanes in Each Direction, ADT 15,001-25,000~~

This hotspot was removed as very few collisions occurred under these conditions as compared to the number of intersections this hotspot represents.

~~Table 1C: Pedestrian Injury Collisions - Midblock~~
~~(99% percentile = 8.12 collisions; the criterion is 8)~~

~~Number of Collisions~~	~~Crash Scenario~~	~~Roadway Environment~~
~~11~~	~~Failure to Yield - Crossing Not in Crosswalk~~	~~≤25 MPH, 1 Lane in Each Direction, ADT ≤7,000 (Local)~~
~~8~~	~~Failure to Yield – In road~~	~~≤25 MPH, 1 Lane in Each Direction, ADT ≤7,000 (Local)~~

These hotspots were removed as very few collisions occurred under these conditions as compared to the number of roadway miles this hotspot represents. This roadway environment makes up a majority of City of San Diego streets, making systemic countermeasures very difficult to implement.

Table 2A: Bicycle Injury Collisions - Intersection Footprint
(99% percentile = 14.65 collisions; the criterion is 14)

Number of Collisions	Crash Scenario	Roadway Environment	Tie-Breakers
18	Bicyclist at Fault - Control Violation Through Movement	Signalized, 4-Lane Intersects 2-Lane	N/A
15	Bicyclist at Fault - Control Violation Through Movement	Signalized, 4-Lane Intersects 4-Lane	(15/128)
15	Bicyclist at Fault - Control Violation Through Movement	Side-Street Stop, 2-Lane Intersects 2-Lane	(15/190)
~~14~~	~~Driver at Fault - Unsafe Turning Left~~	~~Side-Street Stop, 2-Lane Intersects 2-Lane~~	~~(14/190)~~
~~14~~	~~Bicyclist at Fault - Unsafe Speed~~	~~Signalized, 4-Lane Intersects 2-Lane~~	~~(14/212), 63~~
~~14~~	~~Bicyclist at Fault - Unsafe Turning Other~~	~~Signalized, 4-Lane Intersects 2-Lane~~	~~(14/212), 52~~

Three of these hotspots were removed. The driver at fault hotspot was removed as very few collisions occurred under these conditions as compared to the number of intersections this hotspot represents. The two bicyclist at fault hotspots were removed as the collisions were largely attributed to careless behavior and did not have any operational characteristics that were common amongst the collision records.

Table 3A: Vehicular Injury Collisions - Intersection Footprint
(99.5% percentile = 89.47 collisions; the criterion is 89)

Number of Collisions	Crash Scenario	Roadway Environment
~~111~~	~~Broadside - Failure to Yield~~	~~Side-Street Stop,~~ ~~Primary Road ADT ≤15,000, Secondary Road ADT ≤7,000,~~ ~~2-Lane (2-Way) Intersects 2-Lane (2-Way)~~
104	Broadside - Control Violation Through Movement	Signalized, Primary Road ADT >15,000, Secondary Road ADT ≤7,000, 4-Lane (2-Way) Intersects 2-Lane (2-Way)
88	Broadside - Control Violation Through Movement	Signalized, Primary Road ADT >15,000, Secondary Road ADT >7,000, 6-Lane (2-Way) Intersects 4-Lane (2-Way)
~~89~~	~~Rear-End - Unsafe Speed~~	~~Signalized,~~ ~~Primary Road ADT >15,000, Secondary Road ADT ≤7,000,~~ ~~4-Lane (2-Way) Intersects 2-Lane (2-Way)~~
86	Broadside - Control Violation Through Movement	Signalized, Secondary Road ADT >7,000, 4-Lane (2-Way) Intersects 4-Lane (2-Way)
~~76~~	~~Rear-End - Unsafe Speed~~	~~Signalized,~~ ~~Primary Road ADT >15,000, Secondary Road ADT >7,000,~~ ~~4-Lane (2-Way) Intersects 4-Lane (2-Way)~~
55	Broadside - Control Violation Through Movement	Signalized, Primary Road ADT ≤15,000, Secondary Road ADT >7,000, 3-Lane (One-Way) Intersects 3-Lane (One-Way)

Three of these hotspots were removed. The side-street stop hotspot was removed as the number of this type of intersection makes systemic countermeasures very difficult to implement. The two rear-end hotspots were removed. However, the rear-end crash intersections will receive the countermeasures identified for the broadside hotspots due to matching environments.

Table 3B: Vehicular Injury Collisions - Intersection Influence Area
(99.5% percentile = 34.01 collisions; the criterion is 34)

Number of Collisions	Crash Scenario	Roadway Environment
83	Rear-End - Unsafe Speed	Signalized, 35-45 MPH, Median
55	Rear-End - Unsafe Speed	Signalized, 25-35 MPH, Median
38	Rear-End - Following Too Closely	Signalized, 35-45 MPH, No Median

These hotspots were removed as few collisions occurred under these conditions as compared to the number of intersections these hotspots represent. This intersection environment makes up a majority of City of San Diego signalized intersections, making systemic countermeasures very difficult to implement.

Table 3C: Vehicular Injury Collisions - Midblock
(99.5% percentile = 23.10 collisions; the criterion is 23)

Number of Collisions	Crash Scenario	Roadway Environment	Tie-Breakers
28	Rear-End – Unsafe Speed	Median, 40 & 45 MPH, ADT >25,000	(28/112)
28	Sideswipe - Unsafe Turning Other	No Median, ≤25 MPH, ADT ≤7,000 (Local)	(28/193)
27	Rear-End - Unsafe Speed	Median, ≥50 MPH, ADT >25,000	N/A
23	Rear-End - Unsafe Turning Other	No Median, ≤25 MPH, ADT ≤7,000 (Local)	N/A

These hotspots were removed as very few collisions occurred under these conditions as compared to the number of roadway miles this hotspot represents. This roadway environment makes up a majority of City of San Diego streets, making systemic countermeasures very difficult to implement.

Pedestrian Matrix - Intersection Footprint #1

<u>Scenarios Description</u>

Hotspot Roadway Environment (columns):

- Intersection Control: Signalized
- One-way 3-lane roadway intersects with a 4-lane roadway; OR
  one-way 3-lane roadway intersects with a one-way 3-lane roadway
- Primary Roadway ADT: 7,001 – 15,000

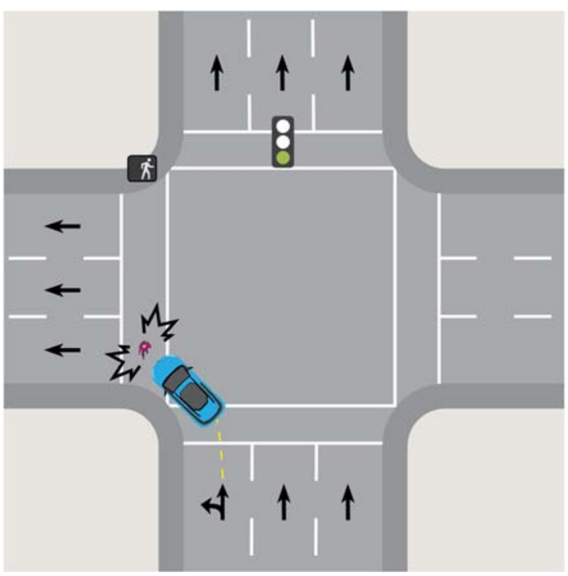
Behaviors Associated with this Hotspot Roadway Environment (rows):

- Violation Code: "Failure to Yield"
- Pedestrian Action: "Crossing in Crosswalk at Intersection"
- Driver Movement: "Making Left Turn"

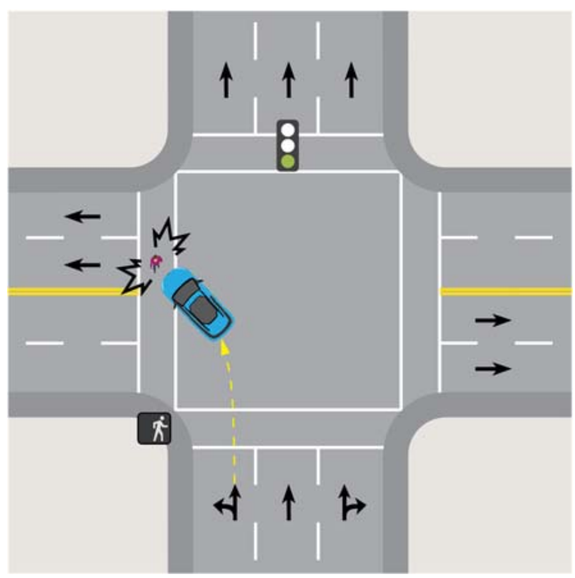
Safety Issue: Conflict between a vehicle on a one-way street making a left turn and a pedestrian crossing in the crosswalk at a signalized intersection.

The majority of locations where a one-way street intersects a one-way street occur in Downtown San Diego where pedestrian volumes are significantly higher than other parts of the City.

Multi-lane one-way streets present a unique challenge for pedestrians wanting to cross the intersection leg that conflicts with left turning vehicles from a one-way street (see Case 1 and 2 below). Left turning vehicles do not have opposing traffic to yield to before executing their turns. Because of this, a driver might mistake their movement as being a protected movement. In cases where a one-way street intersects a one-way street, wide turning radii allow for higher speed turning movements.



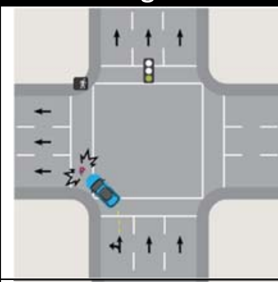
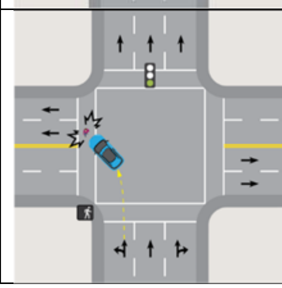
Case 1



Case 2

A total of 27 records were identified under these conditions. The driver was at-fault in all instances. The 27 collisions were experienced at 21 unique locations. One collision was a fatality at the intersection of 4th Avenue and B Street.

Vehicle-Pedestrian Intersection Hotspot #1 Scenarios

	Collision Scenario	Crashes	Diagram
Case 1	Vehicle turning left from a 3-lane (1-way) roadway onto a 3-lane (1-way) roadway	22	
Case 2	Vehicle turning left from a 3-lane (1-way) roadway onto a 4-lane (2-way) roadway	5	

Engineering Countermeasures

Short-Term Systemic Countermeasure Recommendations

The three countermeasures listed below are low cost, highly effective, and can be implemented systemically with relative ease. Individually, each of these countermeasures has been shown to enhance safety for people crossing at signalized intersections, with individual Crash Reduction Factors (CRFs) as high as 60%. Combined together, these countermeasures will likely lead to a significant reduction in collisions identified in this hotspot. They will provide people walking with high-visibility marked areas and exclusive lead time for crossing.

Vehicle-Pedestrian Intersection Hotspot #1 Short-Term Countermeasures

	Countermeasure	CRF[1]
1	Signal Phasing (Lead Pedestrian Interval (LPI))	60%
2	High Visibility Pedestrian Crossing (Marked Continental Crosswalks)	40%
3	Pedestrian Countdown Signal Heads	25%

[1] The CRFs shown represent the anticipated percentage drop in collisions after a given countermeasure is implemented. These values are taken from the LRSM and the FHWA CMF Clearinghouse. Note: A recent New York City before and after study of 104 intersections with LPIs showed left turn pedestrian and bicycles injuries declined by 14% and left turn pedestrian and bicycle severe injuries and fatalities declined by 56%.

Lead Pedestrian Interval (LPI) Signal Phasing - CRF: 60% (Case 1 and 2)

A leading pedestrian interval (LPI) gives pedestrians the opportunity to enter an intersection crosswalk before vehicles are given a green indication. With this head start, pedestrians can establish their presence in the crosswalk before vehicles have the opportunity to turn left. By the time the left turning vehicle has a green indication allowing for permissive left turns, the pedestrian is in a much more conspicuous position in the crosswalk. Implementation of LPIs will result in a little less green time for vehicles each signal cycle for fixed time traffic signals.

LPIs provide:

- increased visibility of crossing pedestrians
- reduced conflicts between pedestrians and vehicles
- increased likelihood of motorists yielding to pedestrians
- established opportunity for pedestrians who may be slower to start crossing

An LPI gives pedestrians a walk indication while vehicles traveling in the same direction still have a red indication. In these situations, it is important to consider protecting the crossing pedestrians from vehicles turning left on red from a one-way street to a one-way street (Case 1). Drivers wanting to turn left on red look to their right for a gap in the traffic and begin their turn when the gap appears. This could lead to collisions during the LPI when pedestrians have started their crossing. “No Left Turn on Red” signs can eliminate this conflict. However, static “No Left Turn on Red” signs can, at some locations, significantly increase vehicle delay. One strategy to minimize vehicle delay is the inclusion of activated “No Left Turn” blank out signs rather than static “No Left Turn on Red” signs. The activated signs only restrict left-turning vehicles when the blank out sign is activated compared to static turn restriction signs that would restrict left turns for the entire red portion of the signal cycle.

For Case 1, activated “No Left Turn” blank out signs should be considered to compliment the recommended LPI. The blank out sign will restrict left turns on red during the LPI only, allowing for full protection for pedestrians during the LPI. The blank out signs should be programmed to turn on in advance of the LPI and turn off at the end of the LPI.

For Case 2, activated “No Right Turn” blank out signs should be considered to compliment the recommended LPI. This is because the LPI will be for both crossings of the intersection and, for Case 2, right turns on red are generally permitted.

High Visibility Crosswalks – CRF: 40% (Case 1 and 2)

High visibility crosswalks increase awareness of pedestrian crossing locations at intersections by using highly visible marking patterns. High visibility (continental) crosswalks are the current standard for all crosswalks in the City of San Diego. The implementation of high-visibility crosswalks will alert left turning vehicles to the presence of a dedicated pedestrian crossing area that conflicts with their intended movement.

Pedestrian Countdown Signal Heads – **CRF: 25% (Case 1 and 2)**
Pedestrian countdown signals heads provide crossing pedestrians with a countdown timer display to inform them of the number of seconds left to finish crossing a signalized pedestrian crossing. Countdown signals provide information for pedestrians so they can assess the risk associated with leaving the curb during the flashing "DON'T WALK" interval. Countdown signals begin counting down when the flashing "DON'T WALK" interval appears and stop at the beginning of the steady "DON'T WALK" interval. These signals have also been successful in encouraging more pedestrians to use the pushbutton rather than not using the crosswalk to cross or crossing against a red light.

Longer-Term Countermeasures
The two countermeasures listed below have moderate cost, and are moderately challenging to implement systemically.

Left Turn Lane and Protected Left Turn Phase – **CRF: 55% (Case 1 and 2)**
Multi-lane one-way streets typically do not have left turn lanes or a protected left turn phase. This is because left turning vehicles do not have opposing traffic to yield to before executing their turns. However, they do have to yield to pedestrians. Installation of a left turn lane with a protected left turn phase will significantly reduce collisions between left-turning vehicles and pedestrians. In these cases, providing a protected only phase for left turning vehicles will directly result in a fully protected phase for the pedestrians that would otherwise be in conflict with the left turning vehicle.

Implementation of this countermeasure should coincide with removal of LPI and activated "No Left Turn" blank out signs for Case 1. The fully protected left turn phase would mean these countermeasures would no longer be required. The LPI and activated "No Right Turn" blank out signs should remain for Case 2.

Flashing Yellow Arrows – **CRF: 36.5% (Case 1 and 2)**
Flashing yellow arrows can be used to warn vehicles turning left to proceed with caution. For vehicles turning left from a one-way street, the only conflict they encounter when making the turning movement is pedestrians crossing the street. Flashing yellow arrows could be implemented to turn on at the end of the LPI to provide an enhanced warning to vehicles. One advantage of Flashing Yellow Arrows is that their permitted left turn can become a red arrow while a pedestrian is being served. Traditional signal indications must either permit left turns during the pedestrian phase or not at all. This countermeasure can be implemented in conjunction with the LPI and activated "No Left Turn" blank out signs.

Educational Countermeasures

Intersection Control Awareness Campaign – (Case 1 and 2)
Develop and distribute information related to collision statistics, including how the three pedestrian intersection hotspots relate as a percentage to all pedestrian injury crashes at signalized intersections, and safe behaviors for vehicles making left turns from one-way streets at signalized intersections and for pedestrians crossing in crosswalks at signalized intersections along one-way streets. Safe behaviors for vehicles making left turns from one-way streets at signalized intersections should focus on watching for and yielding to pedestrians. It is recommended that this material include information related to the proposed LPIs and blank out signs. Information should be distributed immediately following the installation of the initial phase of LPIs and blank out signs for maximum effect. A variety of media should be considered in order to reach as much of the population as possible including, but not limited to, social media, radio, and print. The Think Blue San Diego campaign should be considered as a model for a successful awareness campaign.

Enforcement Countermeasures

Pedestrian Safety Zones – CRF: 8.5% - 13.3% (Case 1 and 2)
Target enforcement of left turning vehicles at one-way street signalized intersections. Enforcement would be most effective immediately following the installation of the initial phase of LPIs and blank out signs.

Pedestrian Matrix - Intersection Footprint #2

Scenarios Description

Hotspot Roadway Environment (columns):

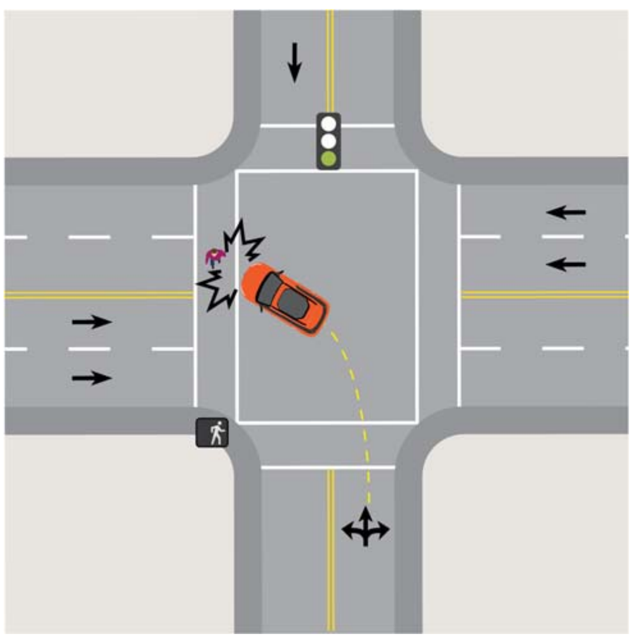
- Intersection Control: Signalized
- Two-way, 4-lane roadway intersects with a two-way, 2-lane roadway
- Primary Roadway ADT: 7,001 – 25,000

Behaviors Associated with this Hotspot Roadway Environment (rows):

- Violation Code: “Failure to Yield”
- Pedestrian Action: “Crossing in Crosswalk at Intersection”
- Driver Movement: “Making Left Turn”

Safety Issue: Conflict between a vehicle making a left turn and a pedestrian crossing in the crosswalk at a signalized intersection.

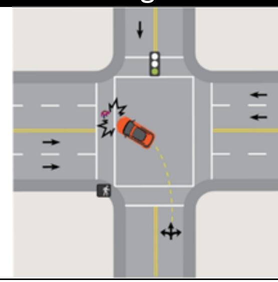
Intersections with permissive left turn signal phasing present a unique challenge for pedestrians wanting to cross the intersection leg that conflicts the left turning vehicles. Permissive left turn signal phasing at locations where a two-way, 4-lane roadway intersects a two-way, 2-lane roadway (see Case 1 below) may result in a scenario where the vehicle intending to turn left is focused on vehicles heading towards them (through the intersection) to determine when it is clear to make the left turn. This focus on oncoming vehicles may distract the driver from seeing pedestrians – who have the right-of-way – that are crossing the leg of the intersection where the vehicle intends to make the left turn.



Case 1

A total of 27 records were identified under these conditions. The driver was at-fault in all instances. The 27 collisions were experienced at 21 unique locations.

Vehicle-Pedestrian Intersection Hotspot #2 Scenario

Collision Scenario	Crashes	Diagram
Vehicle turning left from a 2-lane (2-way) roadway onto a 4-lane (2-way) roadway	27	

Engineering Countermeasures

If locations are prioritized, intersections with primary roadway ADT greater than 15,000 vpd should be prioritized for countermeasures.

Short-Term Systemic Countermeasure Recommendations

The three countermeasures listed below are low cost, highly effective, and can be implemented systemically with relative ease. Individually, each of these countermeasures has been shown to enhance safety for people crossing at signalized intersections, with individual Crash Reduction Factors (CRFs) as high as 60%. Combined together, these countermeasures will likely lead to a significant reduction in collisions identified in this hotspot. They will provide people walking with high-visibility marked areas and exclusive lead time for crossing.

Vehicle-Pedestrian Intersection Hotspot #2 Short-Term Countermeasures

	Countermeasure	CRF[1]
1	Signal Phasing (Lead Pedestrian Interval (LPI))	60%
2	High Visibility Pedestrian Crossing (Marked Continental Crosswalks)	40%
3	Pedestrian Countdown Signal Heads	25%

[1] The CRFs shown represent the anticipated percentage drop in collisions after a given countermeasure is implemented. These values are taken from the LRSM and the FHWA CMF Clearinghouse. Note: A recent New York City before and after study of 104 intersections with LPIs showed left turn pedestrian and bicycles injuries declined by 14% and left turn pedestrian and bicycle severe injuries and fatalities declined by 56%.

Lead Pedestrian Interval (LPI) Signal Phasing - **CRF: 60%**
A leading pedestrian interval (LPI) gives pedestrians the opportunity to enter an intersection crosswalk before vehicles are given a green indication. With this head start, pedestrians can establish their presence in the crosswalk before vehicles have the opportunity to turn left. By the time the left turning vehicle has a green indication allowing for permissive left turns, the pedestrian is in a much more conspicuous position in the crosswalk. Implementation of LPIs will result in a little less green time for vehicles each signal cycle for fixed time traffic signals.

LPIs provide:

- increased visibility of crossing pedestrians
- reduced conflicts between pedestrians and vehicles
- increased likelihood of motorists yielding to pedestrians
- established opportunity for pedestrians who may be slower to start crossing

An LPI gives pedestrians a walk indication while vehicles traveling in the same direction still have a red indication. In these situations, it is important to consider protecting the crossing pedestrians from vehicles turning right on red. Drivers wanting to turn right on red look to their left for a gap in the traffic and begin their turn when the gap appears. This could lead to collisions during the LPI when pedestrians have started their crossing. "No Right Turn on Red" signs can eliminate this conflict. However, static "No Right Turn on Red" signs can, at some locations, significantly increase vehicle delay. One strategy to minimize vehicle delay is the inclusion of activated "No Right Turn" blank out signs rather than static "No Right Turn on Red" signs. The activated signs only restrict right-turning vehicles when the blank out sign is activated compared to static turn restriction signs that would restrict right turns for the entire red portion of the signal cycle.

For both Case 1 and 2, activated "No Right Turn" blank out signs should be considered to compliment the recommended LPI. This is because the LPI will be for both crossings of the intersection and, for both Case 1 and 2, right turns on red are generally permitted.

High Visibility Crosswalks – **CRF: 40%**
High visibility crosswalks increase awareness of pedestrian crossing locations at intersections by using highly visible marking patterns. High visibility (continental) crosswalks are the current standard for all crosswalks in the City of San Diego. The implementation of high-visibility crosswalks will alert left turning vehicles to the presence of a dedicated pedestrian crossing area that conflicts with their intended movement.

Pedestrian Countdown Signal Heads – **CRF: 25%**
Pedestrian countdown signals heads provide crossing pedestrians with a countdown timer display to inform them of the number of seconds left to finish crossing a signalized pedestrian crossing. Countdown signals provide information for pedestrians so they can assess the risk associated with leaving the curb during the flashing "DON'T WALK" interval. Countdown signals begin counting down when the flashing "DON'T WALK" interval appears and stop at the beginning of the steady "DON'T WALK" interval. These signals have also been successful in

encouraging more pedestrians to use the pushbutton rather than not using the crosswalk to cross or crossing against a red light.

Longer-Term Countermeasures

The two countermeasures listed below have moderate cost, and are moderately challenging to implement systemically.

Left Turn Lane and Protected Left Turn Phase – **CRF: 55%**

Of the 21 unique locations where these collisions occurred, only 4 have an existing left turn lane and none of the locations have a protected left turn phase. Installation of a left turn lane with a protected left turn phase will significantly reduce collisions between left-turning vehicles and pedestrians. A dedicated left turn lane helps to clearly signify the vehicles intention (to either turn or not) to oncoming traffic, while eliminating the pressure to turn from vehicles waiting behind them. In these cases, providing a protected only phase for left turning vehicles will directly result in a protected phase for the pedestrians that would otherwise be in conflict with the left turning vehicle. This countermeasure can be implemented in conjunction with the LPI and activated "No Right Turn" blank out signs.

Flashing Yellow Arrows – **CRF: 36.5%**

Flashing yellow arrows can be used to warn vehicles turning left to proceed with caution. For vehicles turning left from a two-way street, the driver focuses on vehicles heading towards them (through the intersection) to determine when it is clear to make the left turn and may not anticipate a pedestrian crossing the street. Flashing yellow arrows could be implemented to turn on at the end of the LPI to provide an enhanced warning to vehicles. One advantage of Flashing Yellow Arrows is that their permitted left turn can become a red arrow while a pedestrian is being served. Traditional signal indications must either permit left turns during the pedestrian phase or not at all. This countermeasure can be implemented in conjunction with the LPI and activated "No Right Turn" blank out signs.

Educational Countermeasures

Intersection Control Awareness Campaign –

Develop and distribute information related to collision statistics, including how the three pedestrian intersection hotspots relate as a percentage to all pedestrian injury crashes at signalized intersections; and safe behaviors for vehicles making permissive left turns at signalized intersections and for pedestrians crossing in crosswalks at signalized intersections with permissive left turn phasing. Safe behaviors for vehicles making permissive left turns at signalized intersections should focus on watching for and yielding to pedestrians. It is recommended that this material include information related to the proposed LPIs and blank out signs. Information should be distributed immediately following the installation of the initial phase of LPIs and blank out signs for maximum effect. A variety of media should be considered in order to reach as much of the population as possible including, but not limited to, social media, radio, and print. The Think Blue San Diego campaign should be considered as a model for a successful awareness campaign.

Enforcement Countermeasures

Pedestrian Safety Zones – CRF: 8.5% - 13.3%

Target enforcement of left turning vehicles at signalized intersections where a two-way, 4-lane roadway intersects a two-way, 2-lane roadway. Enforcement would be most effective immediately following the installation of the initial phase of LPIs and blank out signs.

Pedestrian Matrix - Intersection Footprint #3

Scenarios Description

Hotspot Roadway Environment (columns):

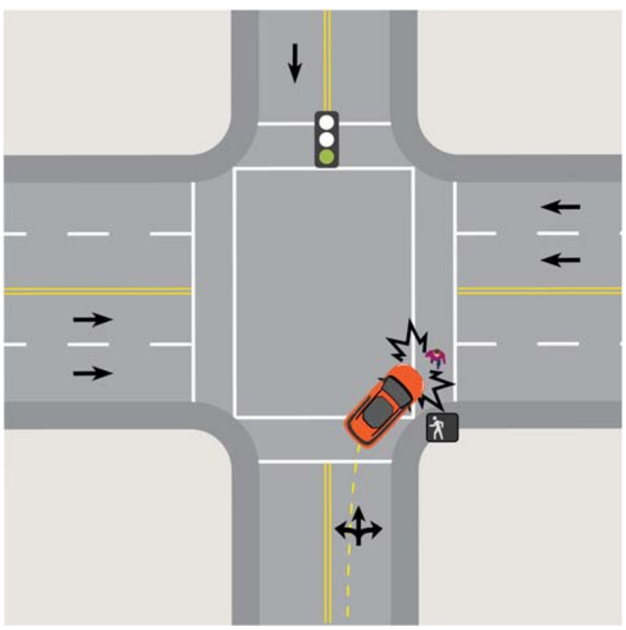
- Intersection Control: Signalized
- Two-way 4-lane roadway intersects with a two-way 2-lane roadway
- Primary Roadway ADT: 15,001 – 25,000

Behaviors Associated with this Hotspot Roadway Environment (rows):

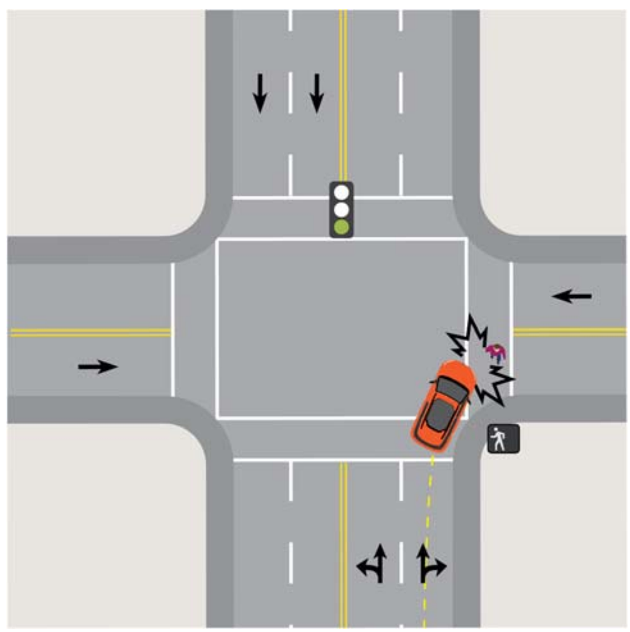
- Violation Code: “Failure to Yield”
- Pedestrian Action: “Crossing in Crosswalk at Intersection”
- Driver Movement: “Making Right Turn”

Safety Issue: Conflict between a vehicle making a right turn and a pedestrian crossing in the crosswalk at a signalized intersection.

Intersections that allow right turns on red present a challenge for pedestrians wanting to cross the intersection leg that conflicts with right turning vehicles. Drivers wanting to turn right on red look to their left for a gap in the traffic and begin their turn when the gap appears. In these situations, the driver may not be aware of a pedestrian to their right. When the gap in traffic comes at the same time the WALK and GREEN indications come on, the driver may continue with their turn at the same time a pedestrian has started to cross in the crosswalk.



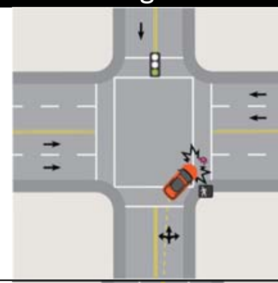
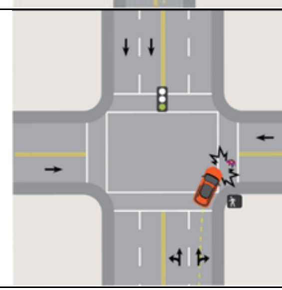
Case 1



Case 2

A total of 17 records were identified under these conditions. The driver was the party at-fault in all instances. The 17 collisions were experienced at 16 unique locations. Two collisions occurred at the intersection of West Bernardo Drive and Poblado Road.

Vehicle-Pedestrian Intersection Hotspot #3 Scenarios

Collision Scenario	Crashes	Diagram
Vehicle turning right from a 2-lane (2-way) roadway onto a 4-lane (2-way) roadway	9	
Vehicle turning right from a 4-lane (2-way) roadway onto a 2-lane (2-way) roadway	8	

Engineering Countermeasures

Short-Term Systemic Countermeasure Recommendations

The three countermeasures listed below are low cost, highly effective, and can be implemented systemically with relative ease. Individually, each of these countermeasures has been shown to enhance safety for people crossing at signalized intersections, with individual Crash Reduction Factors (CRFs) as high as 60%. Combined together, these countermeasures will likely lead to a significant reduction in collisions identified in this hotspot. They will provide people walking with high-visibility marked areas and exclusive lead time for crossing.

Vehicle-Pedestrian Intersection Hotspot #3 Short-Term Countermeasures

	Countermeasure	CRF[1]
1	Signal Phasing (Lead Pedestrian Interval (LPI))	60%
2	High Visibility Pedestrian Crossing (Marked Continental Crosswalks)	40%
3	Pedestrian Countdown Signal Heads	25%

[1] The CRFs shown represent the anticipated percentage drop in collisions after a given countermeasure is implemented. These values are taken from the LRSM and the FHWA CMF Clearinghouse. Note: A recent New York City before and after study of 104 intersections with LPIs showed left turn pedestrian and bicycles injuries declined by 10% and left turn pedestrian and bicycle severe injuries and fatalities declined by 74%.

Lead Pedestrian Interval (LPI) Signal Phasing - **CRF: 60% (Case 1 and 2)**
A leading pedestrian interval (LPI) gives pedestrians the opportunity to enter an intersection crosswalk before vehicles are given a green indication. With this head start, pedestrians can establish their presence in the crosswalk before vehicles have the opportunity to turn right. By the time the right turning vehicle has a green indication allowing for permissive right turns, the pedestrian is in a much more conspicuous position in the crosswalk. Implementation of LPIs will result in a little less green time for vehicles each signal cycle for fixed time traffic signals.

LPIs provide:

- increased visibility of crossing pedestrians
- reduced conflicts between pedestrians and vehicles
- increased likelihood of motorists yielding to pedestrians
- established opportunity for pedestrians who may be slower to start crossing

An LPI gives pedestrians a walk indication while vehicles traveling in the same direction still have a red indication. Drivers wanting to turn right on red look to their left for a gap in the traffic and begin their turn when the gap appears. This could lead to collisions during the LPI when pedestrians have started their crossing. "No Right Turn on Red" signs can eliminate this conflict. However, static no right turn on red signs can, at some locations, significantly increase vehicle delay. One strategy to minimize vehicle delay is the inclusion of activated "No Right Turn" blank out signs rather than static "No Right Turn on Red" signs. The activated signs only restrict right-turning vehicles when the blank out sign is activated compared to static turn restriction signs that would restrict right turns for the entire red portion of the signal cycle.

For both Case 1 and 2, activated "No Right Turn" blank out signs should be considered to compliment the recommended LPI. The blank out sign will restrict right turns on red during the LPI only, allowing for full protection for pedestrians during the LPI. The blank out signs should be programmed to turn on in advance of the LPI and turn off at the end of the LPI.

High Visibility Crosswalks – **CRF: 40% (Case 1 and 2)**
High visibility crosswalks increase awareness of pedestrian crossing locations at intersections by using highly visible marking patterns. High visibility (continental) crosswalks are the current standard for all crosswalks in the City of San Diego. The implementation of high-visibility crosswalks will alert right turning vehicles to the presence of a dedicated pedestrian crossing area that conflicts with their intended movement.

Pedestrian Countdown Signal Heads – **CRF: 25% (Case 1 and 2)**
Pedestrian countdown signals heads provide crossing pedestrians with a countdown timer display to inform them of the number of seconds left to finish crossing a signalized pedestrian crossing. Countdown signals provide information for pedestrians so they can assess the risk associated with leaving the curb during the flashing "DON'T WALK" interval. Countdown signals begin counting down when the flashing "DON'T WALK" interval appears and stop at the beginning of the steady "DON'T WALK" interval. These signals have also been successful in

encouraging more pedestrians to use the pushbutton rather than not using the crosswalk to cross or crossing against a red light.

Educational Countermeasures

Intersection Control Awareness Campaign – (Case 1 and 2)
Develop and distribute information related to collision statistics, including how the three pedestrian intersection hotspots relate as a percentage to all pedestrian injury crashes at signalized intersections; and safe behaviors for vehicles making permissive right turns at signalized intersections and for pedestrians crossing in crosswalks at signalized intersections with permissive right turn phasing. Safe behaviors for vehicles making permissive right turns at signalized intersections should focus on watching for and yielding to pedestrians. It is recommended that this material include information related to the proposed LPIs and blank out signs. Information should be distributed immediately following the installation of the initial phase of LPIs and blank out signs for maximum effect. A variety of media should be considered in order to reach as much of the population as possible including, but not limited to, social media, radio, and print. The Think Blue San Diego campaign should be considered as a model for a successful awareness campaign.

Enforcement Countermeasures

Pedestrian Safety Zones – CRF: 8.5% - 13.3% (Case 1 and 2)
Target enforcement of right turning vehicles at signalized intersections where a two-way, 4-lane roadway intersects a two-way, 2-lane roadway (Case 1 and 2). Enforcement would be most effective immediately following the installation of the initial phase of LPIs and blank out signs.

Bicycle Matrix - Intersection Footprint #1

<u>Scenario Description</u>

Hotspot Roadway Environment (columns):

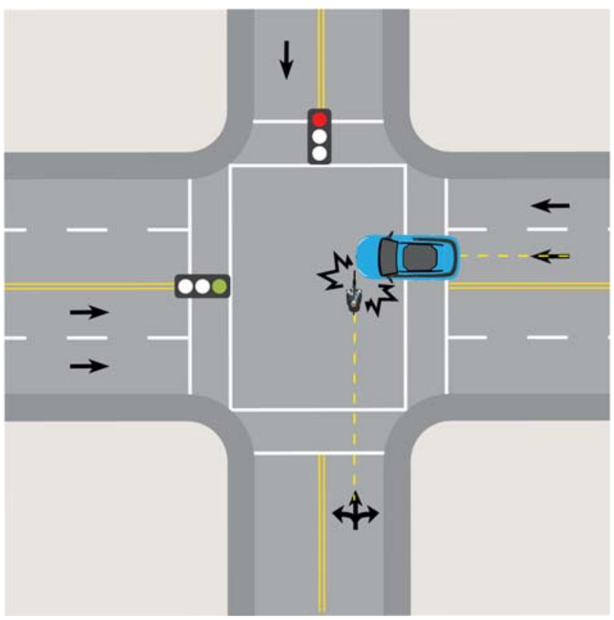
- Intersection Control: Signalized
- 4-lane roadway intersects with a 2-lane roadway; OR
  4-lane roadway intersects with a 4-lane roadway

Behaviors Associated with this Hotspot Roadway Environment (rows):

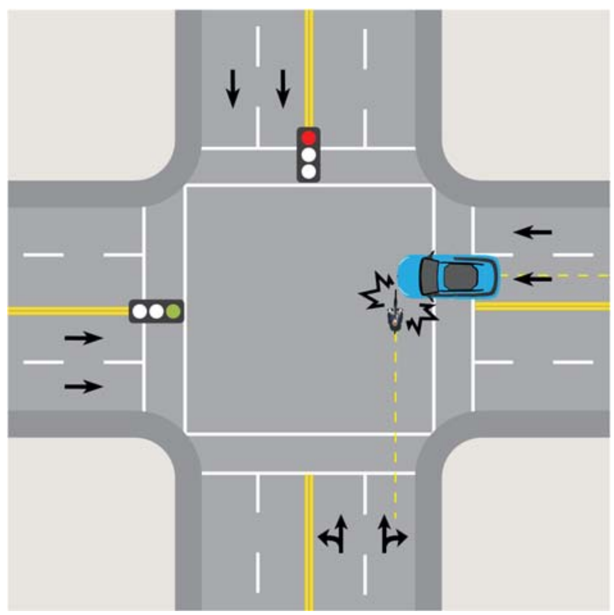
- Bicyclist at-Fault
- Violation Code: "Control Violation Through Movement"

Safety Issue: Bicyclists approaching an intersection and proceeding through against a red light.

Signalized intersections may result in a scenario where a bicyclist approaching a red light continues through the intersection rather than coming to a complete stop and waiting for a GREEN indication. Bicyclists may be inclined to risk passing through crossing traffic in order to avoid stopping and then having to regain momentum when the signal turns green.



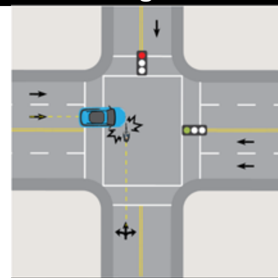
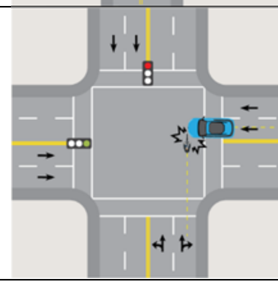
Case 1



Case 2

A total of 33 records were identified under these conditions. The bicyclist was the party at-fault in all instances. The 33 collisions were experienced at 30 unique locations. Four collisions occurred at the intersection of Fairmount Avenue and Home Avenue. Three collisions resulted in a severe injury at the intersections of Fairmount Avenue & Home Avenue, 47th Avenue & Market Street, and Friars Road & Sea World Drive.

Vehicle-Bicycle Intersection Hotspot #1 Scenarios

Collision Scenario	Instances	Diagram
4-lane (2-way) roadway intersects with a 2-lane (2-way) roadway	18	
4-lane (2-way) roadway intersects with a 4-lane (2-way) roadway	15	

Engineering Countermeasures

Short-Term Systemic Countermeasure Recommendations

The countermeasure listed below is low cost, highly effective, and can be implemented systemically with relative ease. This countermeasure has been shown to enhance safety for all users at signalized intersections. It will decrease the amount of time people have to wait for a green signal indication, enhancing compliance and safety.

Loop Detectors – **(Case 1 and 2)**
Loop detectors for vehicles and bikes help to enhance compliance at signalized intersections. When a signalized intersection does not have loop detectors or the loops require maintenance, the signal is placed into recall mode for vehicles and bikes. In these cases, users on the main street may get used to a traffic signal serving the side street or left turns when there is no traffic present. This situation can lead to non-compliance, which can lead to injury collisions. Robust loop detectors enhance signal operations and decrease driver and cyclist frustration. The implementation of robust loop detectors and a program to quickly and efficiently fix broken systems will reduce delay at signalized intersections, enhancing compliance and safety.

Educational Countermeasures

Public Safety Messaging Campaign – **(Case 1 and 2)**
Develop and distribute information related to collision statistics and safe behaviors ("Don't Ride the Red") for bicyclists at intersections. Focus should be on how bicyclists should behave at signalized intersections and how vehicles should behave when bikes are present. A variety of media should be considered in order to reach as much of the population as possible including, but not limited to, social media, radio, and print. The Think Blue San Diego campaign and San

Francisco's "Coexist" campaign should be considered as models for a successful awareness campaign.

Enforcement Countermeasures

Bicycle Red Light Running Enforcement – **(Case 1 and 2)**
Bicyclists running red lights are more likely to experience broadside collisions from crossing traffic. Target enforcement of bicyclists running red lights at signalized intersections where a two-way, 4-lane roadway intersects a two-way, 2-lane roadway (Case 1) and where a two-way, 4-lane roadway intersects a two-way, 4-lane roadway (Case 2). Targeted enforcement of higher volume bicycle areas will most effectively reduce this traffic violation.

Bicycle Matrix - Intersection Footprint #2

Scenario Description

Hotspot Roadway Environment (columns):

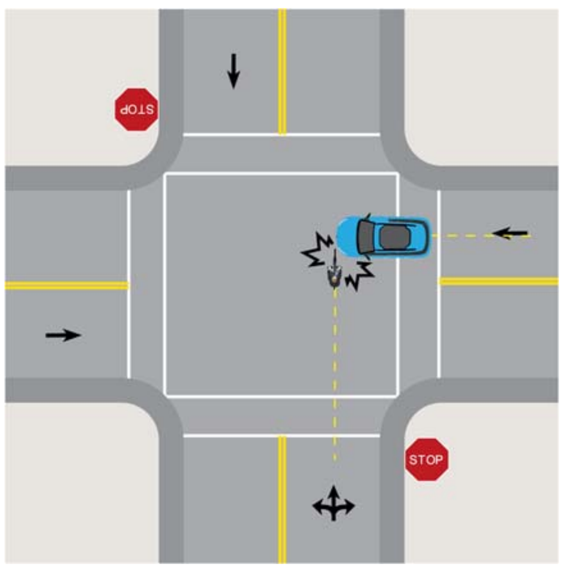
- Intersection Control: Side-Street Stop
- 2-lane roadway intersects with a 2-lane roadway

Behaviors Associated with this Hotspot Roadway Environment (rows):

- Bicyclist at-Fault
- Violation Code: "Control Violation Through Movement"

Safety Issue: Bicyclists approaching a stop sign at a side-street stop-controlled intersection and proceeding through without stopping at the stop sign.

Side-street stop-controlled intersections may result in a scenario where a bicyclist approaching a stop sign continues through the intersection rather than coming to a complete stop at the stop sign. Bicyclists may be inclined to risk passing through crossing traffic in order to avoid stopping and then having to regain momentum.



Case 1

A total of 15 records were identified under these conditions. The bicyclist was the party at-fault in all instances. The 15 collisions were experienced at 14 unique locations. Two collisions occurred at the intersection of Bacon Street and Niagara Avenue. One collision resulted in a severe injury at the intersection of University Avenue & 47th Street.

Educational Countermeasures

Public Safety Messaging Campaign – (Case 1 and 2)
Develop and distribute information related to collision statistics and safe behaviors ("Don't Roll the Stop") for bicyclists at intersections. Focus should be on how bicyclists should behave at side-street stop-controlled intersections and how vehicles should behave when bikes are present. A variety of media should be considered in order to reach as much of the population as possible including, but not limited to, social media, radio, and print. The Think Blue San Diego campaign and San Francisco's "Coexist" campaign should be considered as models for a successful awareness campaign.

Enforcement Countermeasures

Bicycle Stop Sign Running Enforcement – (Case 1 and 2)
Bicyclists running stop signs are more likely to experience broadside collisions from crossing traffic. Target enforcement of bicyclists running stop signs at side-street stop-controlled intersections where a two-way, 2-lane roadway intersects a two-way, 2-lane roadway. Targeted enforcement of higher volume bicycle areas will most effectively reduce this traffic violation.

Vehicle Intersection Footprint #1

Scenario Description

Hotspot Roadway Environment (columns):

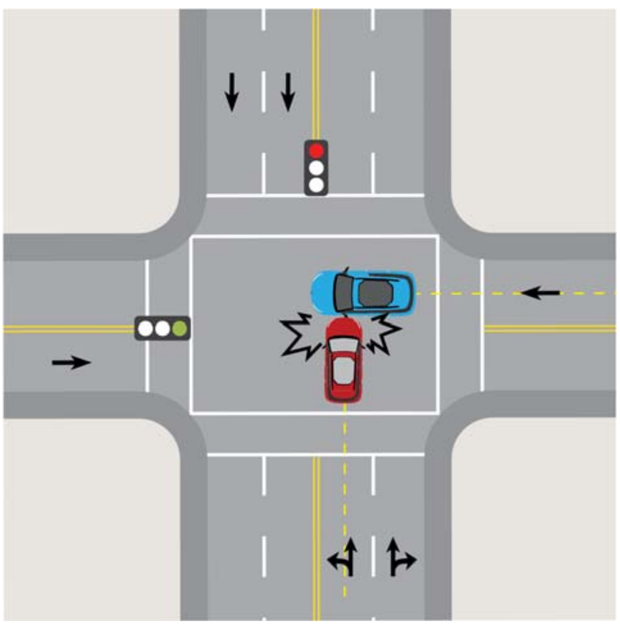
- Intersection Control: Signalized
- 4-lane roadway intersects with a 2-lane roadway
- Primary Roadway ADT: >15,000
- Secondary Roadway ADT: ≤7,000

Behaviors Associated with this Hotspot Roadway Environment (rows):

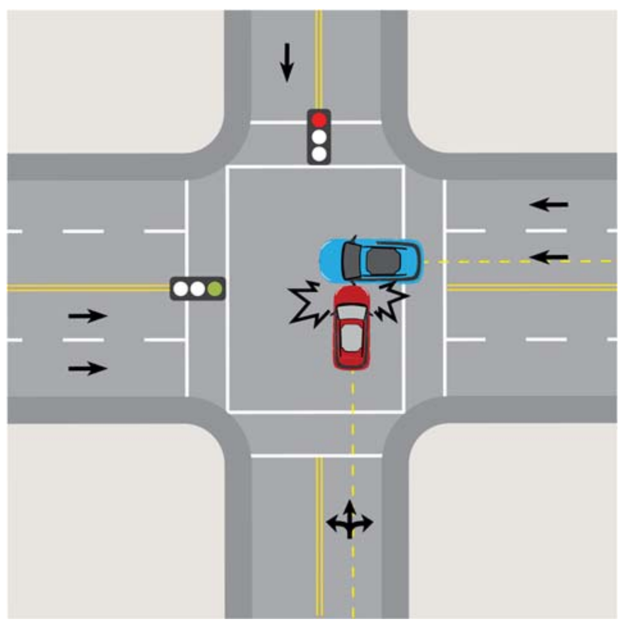
- Violation Code: "Control Violation Through Movement"
- Collision Type: Broadside

Safety Issue: Vehicles violating red-light stop control while making a through movement.

Signalized intersections (See Case 1 & 2 below) have been found to experience a higher prevalence of crashes compared to other types of intersection control. These intersection types may result in a scenario where the vehicle approaching a red signal indication continues through the intersection without stopping. This can result in a broadside injury collision. These collision types typically result in more severe injuries than other collisions types.



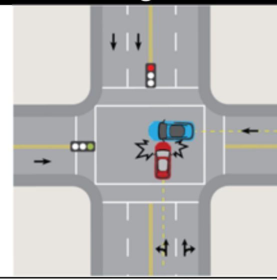
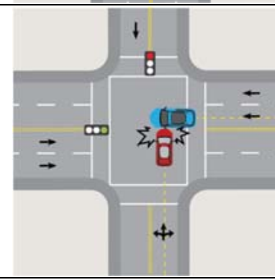
Case 1



Case 2

A total of 104 records were identified under these conditions. The 104 collisions were experienced at 83 unique locations. Two collisions were fatal at the intersections of El Cajon Boulevard & Chamoune Avenue and Navajo Road & Boulder Lake Avenue. A total of 5 additional collisions resulted in a severe injury.

Vehicle-Vehicle Intersection Hotspot #1 Scenarios

	Collision Scenario	Crashes	Diagram
Case 1	Vehicle traveling straight through a red signal indication while traveling on a 4-lane (2-way) roadway at the intersection with a 2-lane (2-way) roadway	90	
Case 2	Vehicle traveling straight through a red signal indication while traveling on a 2-lane (2-way) roadway at the intersection with a 4-lane (2-way) roadway	14	

Engineering Countermeasures

The countermeasure listed below is low cost, effective, and can be implemented systemically with relative ease. This countermeasure has been shown to enhance safety at signalized intersections, especially related to broadside collisions. It will improve the visibility and conspicuity of the traffic signal indications, enhancing compliance and safety.

Vehicle-Vehicle Intersection Hotspot #1 Short-Term Countermeasures

	Countermeasure	CRF[1]
1	Signal Hardware Upgrade – Backplates with Retroreflective Borders	15%

[1] The CRF shown represents the anticipated percentage drop in collisions after the countermeasure is implemented. These values are taken from the LRSM. Note: A Kentucky Transportation Cabinet (KYTC) before and after study of 30 intersections with backplates with retroreflective material showed broadside crashes declined by 44-percent.

Signal Hardware Upgrade – Backplates with Retroreflective Borders - **CRF: 15% (Case 1 & 2)**
Backplates with retroreflective borders enhance visibility of traffic signal indications and ultimately lead to fewer crashes. They can be particularly beneficial for aging drivers and color vision impaired drivers. Studies have shown this countermeasure to be particularly effective at reducing broadside collisions. Drivers will sometimes run a red light at a signalized intersection because they are unable to see traffic signals sufficiently in advance to safely negotiate the intersection being approached. This can result in a broadside collision (one of the most dangerous collision types). The enhanced visibility and conspicuity provided by backplates with retroreflective borders can aid drivers' advance perception of the upcoming signalized intersection.

Longer-Term Countermeasure

The countermeasure listed below is high cost, and can be challenging to implement systemically. However, as existing signals reach the end of their useful life, an opportunity arises to consider conversion of the intersection to a roundabout.

Convert intersection to roundabout (from signal) – CRF: 35% - 67% (Case 1 and 2)
Well-designed roundabouts have been proven to lessen the severity of crashes within an intersection footprint. This is because the types of collisions that occur at roundabouts are different from those occurring at conventional intersections; namely, broadside and left turn conflicts are not present in a roundabout (i.e. it is not possible for a broadside collision to occur based on roundabout geometry). The geometry of a well-designed roundabout forces drivers to reduce speeds as they proceed through the intersection. This helps reduce the severity of crashes when they do occur.

Per the City of San Diego Street Design Manual (March 2017 Edition), when deciding what type of control an intersection should have, follow Caltrans Intersection Control Evaluation (Traffic Operations Policy Directive 13-02). When expansion or addition of one type of intersection traffic control is considered, this evaluation ensures a comparison with other types of traffic control and the no-build scenario on the basis of system impacts, safety and mobility benefits for all modes, and life-cycle costs.

Educational Countermeasures

Intersection Control Awareness Campaign – (Case 1 and 2)
Develop and distribute information related to collision statistics, including how the four vehicle intersection hotspots relate as a percentage to all vehicle injury crashes at signalized intersections; and safe behaviors for vehicles approaching signalized intersections. Safe behaviors for vehicles approaching signalized intersections should focus on signal indication awareness. It is recommended that this material include information related to the proposed backplates with retroreflective borders. Information should be distributed immediately following the installation of the initial phase of backplates with retroreflective borders for maximum effect. A variety of media should be considered in order to reach as much of the population as possible including, but not limited to, social media, radio, and print. The Think Blue San Diego campaign should be considered as a model for a successful awareness campaign.

Enforcement Countermeasures

Vehicle Red Light Running Enforcement – (Case 1 and 2)
Target enforcement of vehicles running red lights at signalized intersections where a two-way, 4-lane roadway intersects a two-way, 2-lane roadway (Case 1 and 2). Enforcement would be most effective immediately following the installation of the initial phase of backplates with retroreflective borders.

Vehicle Intersection Footprint #2

Scenario Description

Hotspot Roadway Environment (columns):

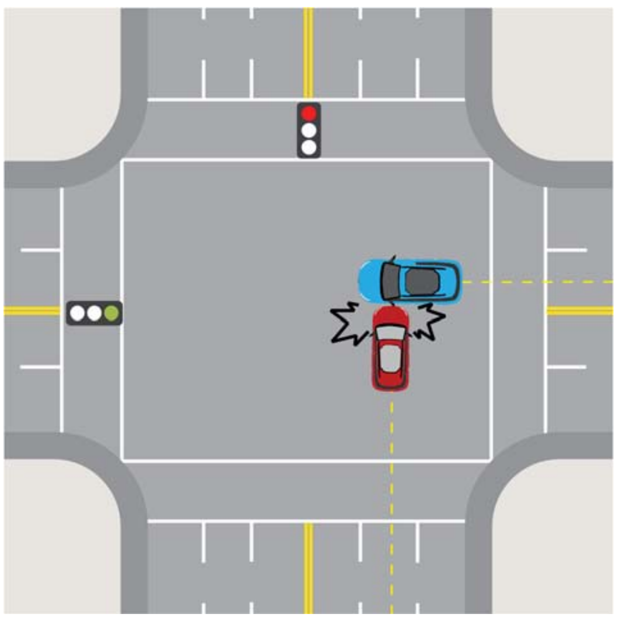
- Intersection Control: Signalized
- 6-lane roadway intersects with a 4-lane roadway
- Primary Roadway ADT: >15,000
- Secondary Roadway ADT: >7,000

Behaviors Associated with this Hotspot Roadway Environment (rows):

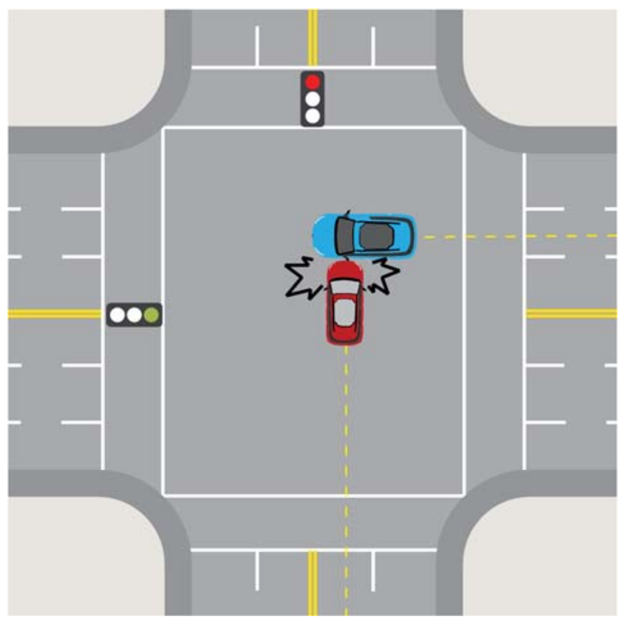
- Collision Type: Broadside
- Violation Code: "Control Violation Through Movement"

Safety Issue: Vehicles violating red-light control while making a through movement.

Signalized intersections (See Case 1 & 2 below) have been found to experience a higher prevalence of crashes compared to other types of intersection control. These intersection types may result in a scenario where the vehicle approaching a red signal indication continues through the intersection without stopping. This can result in a broadside injury collision. These collision types typically result in more severe injuries than other collisions types.



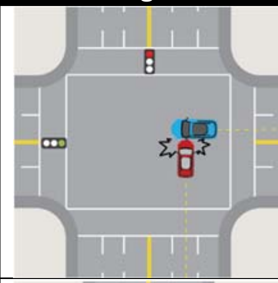
Case 1



Case 2

A total of 88 records were identified under these conditions. The 88 collisions were experienced at 49 unique locations. Mira Mesa Boulevard experienced 14 of the 88 total collisions.

Vehicle-Vehicle Intersection Hotspot #2 Scenarios

	Collision Scenario	Instances	Diagram
Case 1	Vehicle traveling straight through a red signal indication while traveling on a 6-lane (2-way) roadway at the intersection with a 4-lane (2-way) roadway	74	
Case 2	Vehicle traveling straight through a red signal indication while traveling on a 4-lane (2-way) roadway at the intersection with a 6-lane (2-way) roadway	14	

Engineering Countermeasures

The countermeasure listed below is low cost, effective, and can be implemented systemically with relative ease. This countermeasure has been shown to enhance safety at signalized intersections, especially related to broadside collisions. It will improve the visibility and conspicuity of the traffic signal indications, enhancing compliance and safety.

Vehicle-Vehicle Intersection Hotspot #1 Short-Term Countermeasures

	Countermeasure	CRF[1]
1	Signal Hardware Upgrade – Backplates with Retroreflective Borders	15%

[1] The CRF shown represents the anticipated percentage drop in collisions after the countermeasure is implemented. These values are taken from the LRSM. Note: A Kentucky Transportation Cabinet (KYTC) before and after study of 30 intersections with backplates with retroreflective material showed broadside crashes declined by 44-percent.

Signal Hardware Upgrade – Backplates with Retroreflective Borders - **CRF: 15% (Case 1 & 2)**
Backplates with retroreflective borders enhance visibility of traffic signal indications and ultimately lead to fewer crashes. They can be particularly beneficial for aging drivers and color vision impaired drivers. Studies have shown this countermeasure to be particularly effective at reducing broadside collisions. Drivers will sometimes run a red light at a signalized intersection because they are unable to see traffic signals sufficiently in advance to safely negotiate the intersection being approached. This can result in a broadside collision (one of the most dangerous collision types). The enhanced visibility and conspicuity provided by backplates with retroreflective borders can aid drivers' advance perception of the upcoming signalized intersection.

Longer-Term Countermeasure

The countermeasure listed below is high cost, and can be challenging to implement systemically. However, as existing signals reach the end of their useful life, an opportunity arises to consider conversion of the intersection to a roundabout.

Convert intersection to roundabout (from signal) – CRF: 35% - 67% (Case 1 and 2)
Well-designed roundabouts have been proven to lessen the severity of crashes within an intersection footprint. This is because the types of collisions that occur at roundabouts are different from those occurring at conventional intersections; namely, broadside and left turn conflicts are not present in a roundabout (i.e. it is not possible for a broadside collision to occur based on roundabout geometry). The geometry of a well-designed roundabout forces drivers to reduce speeds as they proceed through the intersection. This helps reduce the severity of crashes when they do occur.

Per the City of San Diego Street Design Manual (March 2017 Edition), when deciding what type of control an intersection should have, follow Caltrans Intersection Control Evaluation (Traffic Operations Policy Directive 13-02). When expansion or addition of one type of intersection traffic control is considered, this evaluation ensures a comparison with other types of traffic control and the no-build scenario on the basis of system impacts, safety and mobility benefits for all modes, and life-cycle costs.

Educational Countermeasures

Intersection Control Awareness Campaign – (Case 1 and 2)
Develop and distribute information related to collision statistics, including how the four vehicle intersection hotspots relate as a percentage to all vehicle injury crashes at signalized intersections; and safe behaviors for vehicles approaching signalized intersections. Safe behaviors for vehicles approaching signalized intersections should focus on signal indication awareness. It is recommended that this material include information related to the proposed backplates with retroreflective borders. Information should be distributed immediately following the installation of the initial phase of backplates with retroreflective borders for maximum effect. A variety of media should be considered in order to reach as much of the population as possible including, but not limited to, social media, radio, and print. The Think Blue San Diego campaign should be considered as a model for a successful awareness campaign.

Enforcement Countermeasures

Vehicle Red Light Running Enforcement – (Case 1 and 2)
Target enforcement of vehicles running red lights at signalized intersections where a two-way, 6-lane roadway intersects a two-way, 4-lane roadway (Case 1 and 2). Enforcement would be most effective immediately following the installation of the initial phase of backplates with retroreflective borders.

Vehicle Intersection Footprint #3

Scenario Description

Hotspot Roadway Environment (columns):

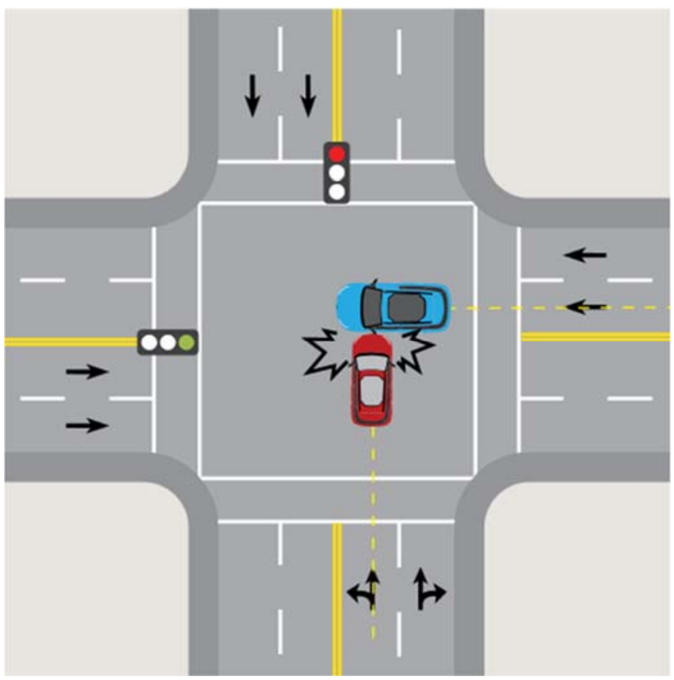
- Intersection Control: Signalized
- 4-lane roadway intersects with a 4-lane roadway
- Secondary Roadway ADT: >7,000

Behaviors Associated with this Hotspot Roadway Environment (rows):

- Collision Type: Broadside
- Violation Code: "Control Violation Through Movement"

Safety Issue: Vehicles violating red-light control while making a through movement.

Signalized intersections (See Case 1 below) have been found to experience a higher prevalence of crashes compared to other types of intersection control. These intersection types may result in a scenario where the vehicle approaching a red signal indication continues through the intersection without stopping. This can result in a broadside injury collision. These collision types typically result in more severe injuries than other collisions types.



Case 1

A total of 86 records were identified under these conditions. The 86 collisions were experienced at 55 unique locations. One collision was fatal at the intersection of Morena Boulevard & Avati Drive. Four collisions resulted in a severe injury at the intersection of Carmel Country Road & Del Mar Trails Road, Grand Avenue & Balboa Avenue, Imperial Avenue & 47th Street, and Morena Boulevard & Sherman Street.

Engineering Countermeasures

The countermeasure listed below is low cost, effective, and can be implemented systemically with relative ease. This countermeasure has been shown to enhance safety at signalized intersections, especially related to broadside collisions. It will improve the visibility and conspicuity of the traffic signal indications, enhancing compliance and safety.

Vehicle-Vehicle Intersection Hotspot #1 Short-Term Countermeasures

	Countermeasure	CRF[1]
1	Signal Hardware Upgrade – Backplates with Retroreflective Borders	15%

[1] The CRF shown represents the anticipated percentage drop in collisions after the countermeasure is implemented. These values are taken from the LRSM. Note: A Kentucky Transportation Cabinet (KYTC) before and after study of 30 intersections with backplates with retroreflective material showed broadside crashes declined by 44-percent.

Signal Hardware Upgrade – Backplates with Retroreflective Borders - **CRF: 15%**
Backplates with retroreflective borders enhance visibility of traffic signal indications and ultimately lead to fewer crashes. They can be particularly beneficial for aging drivers and color vision impaired drivers. Studies have shown this countermeasure to be particularly effective at reducing broadside collisions. Drivers will sometimes run a red light at a signalized intersection because they are unable to see traffic signals sufficiently in advance to safely negotiate the intersection being approached. This can result in a broadside collision (one of the most dangerous collision types). The enhanced visibility and conspicuity provided by backplates with retroreflective borders can aid drivers' advance perception of the upcoming signalized intersection.

Longer-Term Countermeasure

The countermeasure listed below is high cost, and can be challenging to implement systemically. However, as existing signals reach the end of their useful life, an opportunity arises to consider conversion of the intersection to a roundabout.

Convert intersection to roundabout (from signal) – **CRF: 35% - 67%**
Well-designed roundabouts have been proven to lessen the severity of crashes within an intersection footprint. This is because the types of collisions that occur at roundabouts are different from those occurring at conventional intersections; namely, broadside and left turn conflicts are not present in a roundabout (i.e. it is not possible for a broadside collision to occur based on roundabout geometry). The geometry of a well-designed roundabout forces drivers to reduce speeds as they proceed through the intersection. This helps reduce the severity of crashes when they do occur.

Per the City of San Diego Street Design Manual (March 2017 Edition), when deciding what type of control an intersection should have, follow Caltrans Intersection Control Evaluation (Traffic Operations Policy Directive 13-02). When expansion or addition of one type of intersection traffic control is considered, this evaluation ensures a comparison with other types of traffic control and the no-build scenario on the basis of system impacts, safety and mobility benefits for all modes, and life-cycle costs.

Educational Countermeasures

Intersection Control Awareness Campaign

Develop and distribute information related to collision statistics, including how the four vehicle intersection hotspots relate as a percentage to all vehicle injury crashes at signalized intersections; and safe behaviors for vehicles approaching signalized intersections. Safe behaviors for vehicles approaching signalized intersections should focus on signal indication awareness. It is recommended that this material include information related to the proposed backplates with retroreflective borders. Information should be distributed immediately following the installation of the initial phase of backplates with retroreflective borders for maximum effect. A variety of media should be considered in order to reach as much of the population as possible including, but not limited to, social media, radio, and print. The Think Blue San Diego campaign should be considered as a model for a successful awareness campaign.

Enforcement Countermeasures

Vehicle Red Light Running Enforcement

Target enforcement of vehicles running red lights at signalized intersections where a two-way, 4-lane roadway intersects a two-way, 4-lane roadway. Enforcement would be most effective immediately following the installation of the initial phase of backplates with retroreflective borders.

Vehicle Intersection Footprint #4

Scenario Description

Hotspot Roadway Environment (columns):

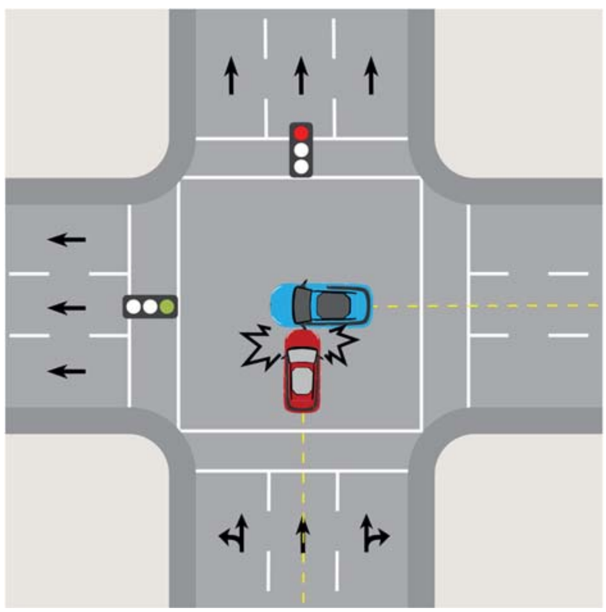
- Intersection Control: Signalized
- One-way 3-lane roadway intersects with a one-way 3-lane roadway
- Primary Roadway ADT: ≤15,000
- Secondary Roadway ADT: >7,000

Behaviors Associated with this Hotspot Roadway Environment (rows):

- Collision Type: Broadside
- Violation Code: "Control Violation Through Movement"

Safety Issue: Vehicles violating red-light control while making a through movement.

Signalized intersections (See Case 1 below) have been found to experience a higher prevalence of crashes compared to other types of intersection control. These intersection types may result in a scenario where the vehicle approaching a red signal indication continues through the intersection without stopping. This can result in a broadside injury collision. These collision types typically result in more severe injuries than other collisions types.



Case 1

A total of 55 records were identified under these conditions. The 55 collisions were experienced at 22 unique locations. One collision resulted in a severe injury at the intersection of Ash Street & 4th Avenue.

<u>Engineering Countermeasures</u>

The countermeasure listed below is low cost, effective, and can be implemented systemically with relative ease. This countermeasure has been shown to enhance safety at signalized intersections, especially related to broadside collisions. It will improve the visibility and conspicuity of the traffic signal indications, enhancing compliance and safety.

Vehicle-Vehicle Intersection Hotspot #1 Short-Term Countermeasures

	Countermeasure	CRF[1]
1	Signal Hardware Upgrade – Backplates with Retroreflective Borders	15%

[1] The CRF shown represents the anticipated percentage drop in collisions after the countermeasure is implemented. These values are taken from the LRSM. Note: A Kentucky Transportation Cabinet (KYTC) before and after study of 30 intersections with backplates with retroreflective material showed broadside crashes declined by 44-percent.

Signal Hardware Upgrade – Backplates with Retroreflective Borders - **CRF: 15% (Case 1 & 2)**
Backplates with retroreflective borders enhance visibility of traffic signal indications and ultimately lead to fewer crashes. They can be particularly beneficial for aging drivers and color vision impaired drivers. Studies have shown this countermeasure to be particularly effective at reducing broadside collisions. Drivers will sometimes run a red light at a signalized intersection because they are unable to see traffic signals sufficiently in advance to safely negotiate the intersection being approached. This can result in a broadside collision (one of the most dangerous collision types). The enhanced visibility and conspicuity provided by backplates with retroreflective borders can aid drivers' advance perception of the upcoming signalized intersection.

Longer-Term Countermeasure

The countermeasure listed below is high cost, and can be challenging to implement systemically. However, as existing signals reach the end of their useful life, an opportunity arises to consider conversion of the intersection to a roundabout.

Convert intersection to roundabout (from signal) – **CRF: 35% - 67% (Case 1 and 2)**
Well-designed roundabouts have been proven to lessen the severity of crashes within an intersection footprint. This is because the types of collisions that occur at roundabouts are different from those occurring at conventional intersections; namely, broadside and left turn conflicts are not present in a roundabout (i.e. it is not possible for a broadside collision to occur based on roundabout geometry). The geometry of a well-designed roundabout forces drivers to reduce speeds as they proceed through the intersection. This helps reduce the severity of crashes when they do occur.

Per the City of San Diego Street Design Manual (March 2017 Edition), when deciding what type of control an intersection should have, follow Caltrans Intersection Control Evaluation (Traffic Operations Policy Directive 13-02). When expansion or addition of one type of intersection traffic control is considered, this evaluation ensures a comparison with other types of traffic control and the no-build scenario on the basis of system impacts, safety and mobility benefits for all modes, and life-cycle costs.

Educational Countermeasures

Intersection Control Awareness Campaign – (Case 1 and 2)
Develop and distribute information related to collision statistics, including how the four vehicle intersection hotspots relate as a percentage to all vehicle injury crashes at signalized intersections; and safe behaviors for vehicles approaching signalized intersections. Safe behaviors for vehicles approaching signalized intersections should focus on signal indication awareness. It is recommended that this material include information related to the proposed backplates with retroreflective borders. Information should be distributed immediately following the installation of the initial phase of backplates with retroreflective borders for maximum effect. A variety of media should be considered in order to reach as much of the population as possible including, but not limited to, social media, radio, and print. The Think Blue San Diego campaign should be considered as a model for a successful awareness campaign.

Enforcement Countermeasures

Vehicle Red Light Running Enforcement – (Case 1 and 2)
Target enforcement of vehicles running red lights at signalized intersections where a one-way, 3-lane roadway intersects a one-way, 3-lane roadway. Enforcement would be most effective immediately following the installation of the initial phase of backplates with retroreflective borders.