Seattle Department of Transportation

CITY OF SEATTLE BICYCLE AND PEDESTRIAN SAFETY ANALYSIS

September 30, 2016

Seattle
Department of
Transportation


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LIST OF FIGURES

ACKNOWLEDGMENTS

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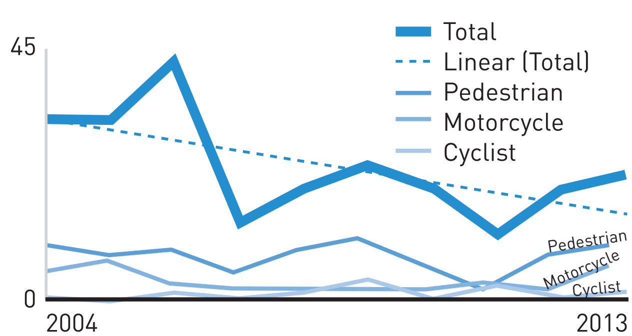
All photos provided by SDOT.

INTRODUCTION

Our Vision Zero Plan lays out an aggressive goal to eliminate deaths and serious injuries on our streets by 2030. We'll achieve this goal with education, enforcement and engineering strategies. Throughout, we'll use a data-driven approach to inform our work and evaluate our progress.

We know that the vast majority of crashes are preventable. The Bicycle and Pedestrian Safety Analysis project connects our vision of a safe and innovative city, using cutting edge methods to expand our knowledge of where, how, and why crashes happen. **The results of this analysis allows us to proactively identify locations and prioritize safety improvements with the goal of preventing future crashes.**

FIGURE 1: TRAFFIC FATALITY TRENDS



Traffic fatalities on Seattle streets have been declining; however, pedestrians and bicyclists make up a disproportionate percentage of all traffic fatalities.

BICYCLE AND PEDESTRIAN SAFETY ANALYSIS OVERVIEW

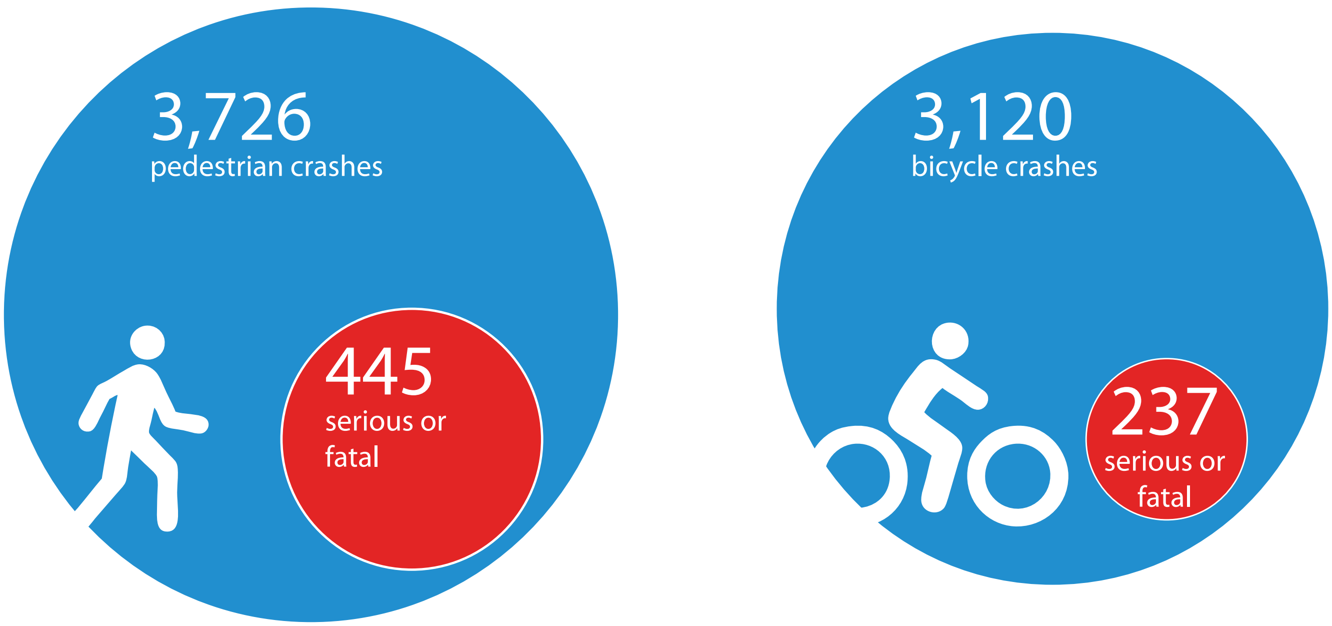
We analyzed bicycle and pedestrian crashes that occurred from 2007 to 2014 in our city so we can identify problems to address through better street design and traffic operations. We looked at many different data sources to explore the relationship between where, how, and to the extent possible, why crashes happen. We included information such as crash type, actions of people walking, biking, or driving, and roadway configuration where the crash happened. This analysis explored factors contributing to all pedestrian and bicycle crashes across the city and the most common factors associated with higher rates of severe crashes (i.e., fatal or serious injury). As a result, we have a better understanding of some of the most common issues, and where and how we need to focus our efforts for making our streets safer for all users.

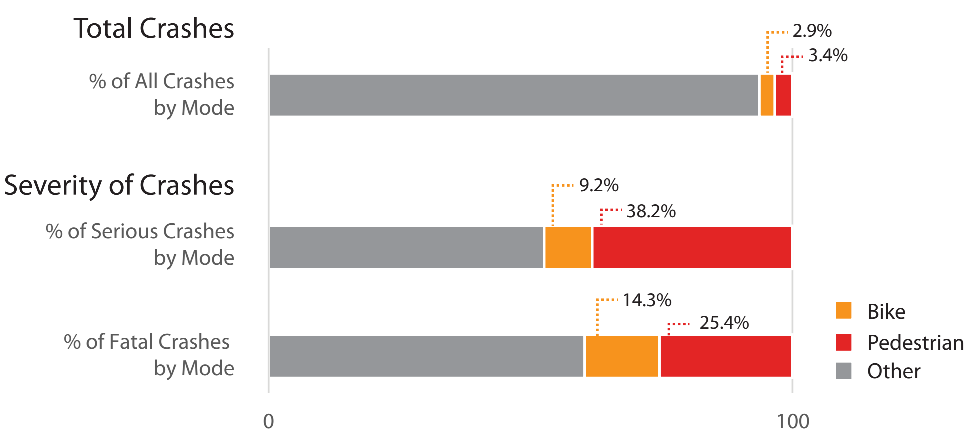
This document summarizes the main results of the Bicycle and Pedestrian Analysis. It's organized into several sections, including:

- **Exploratory Analysis** –characteristics and common patterns of how bicycle and pedestrian crashes happen.
- **Digging Deeper into the Data**- significant factors that may lead to crashes
- **How Are We Going to Use This Information?**

For a more detailed description of analysis process and results, refer to the **Bicycle and Pedestrian Safety Technical Memo**.

FIGURE 2: BICYCLE AND PEDESTRIAN CRASHES, 2007-2014





While Bicyclists and Pedestrians only make up 6.3% of all crashes, they represent a much larger percentage of Serious (47.4%) and Fatal (39.7%) crashes

WHAT DOES THE ANALYSIS TELL US?

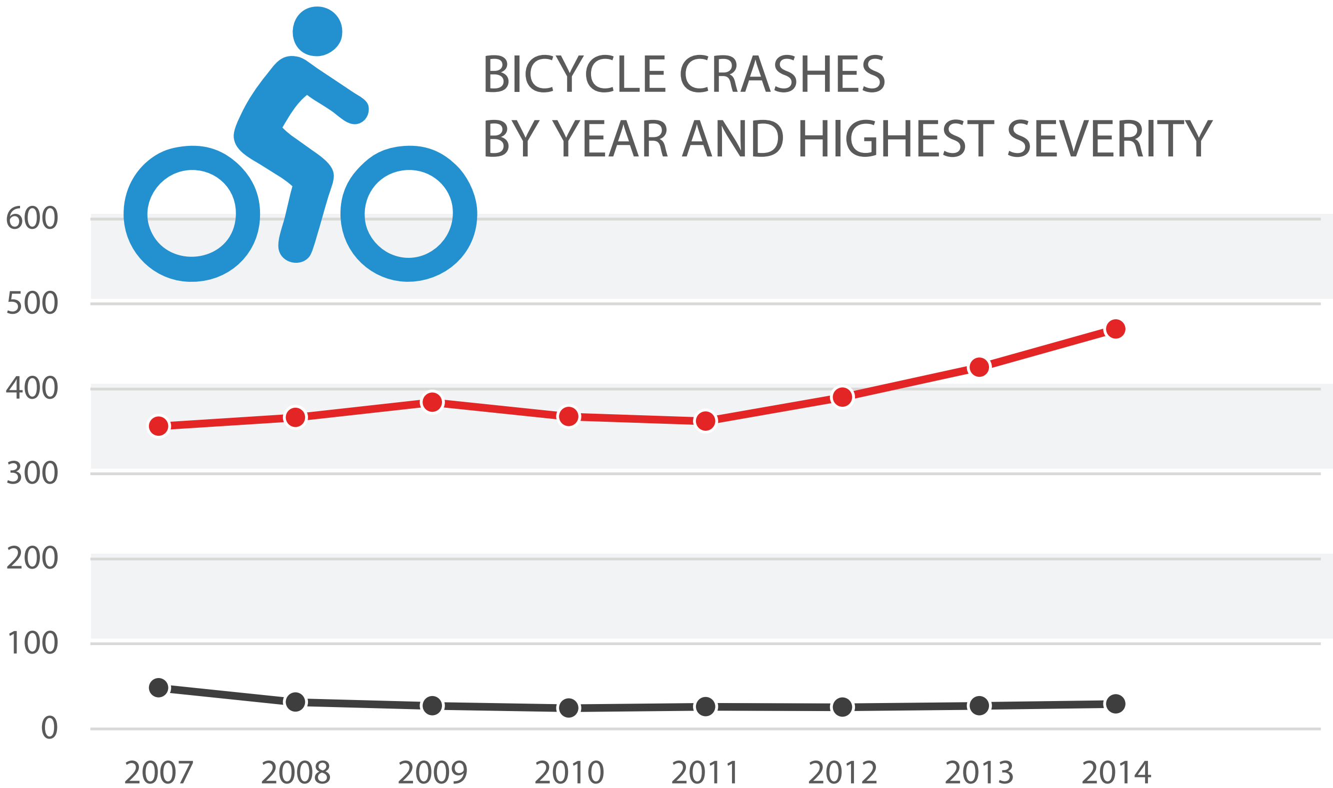
As our Vision Zero Plan notes, the citywide collision rate has been steadily falling over the last decade, which is great news. This means that even while the level of activity on our streets has been increasing, the number of pedestrian and bicycle crashes have been steady and even declined during the same period.

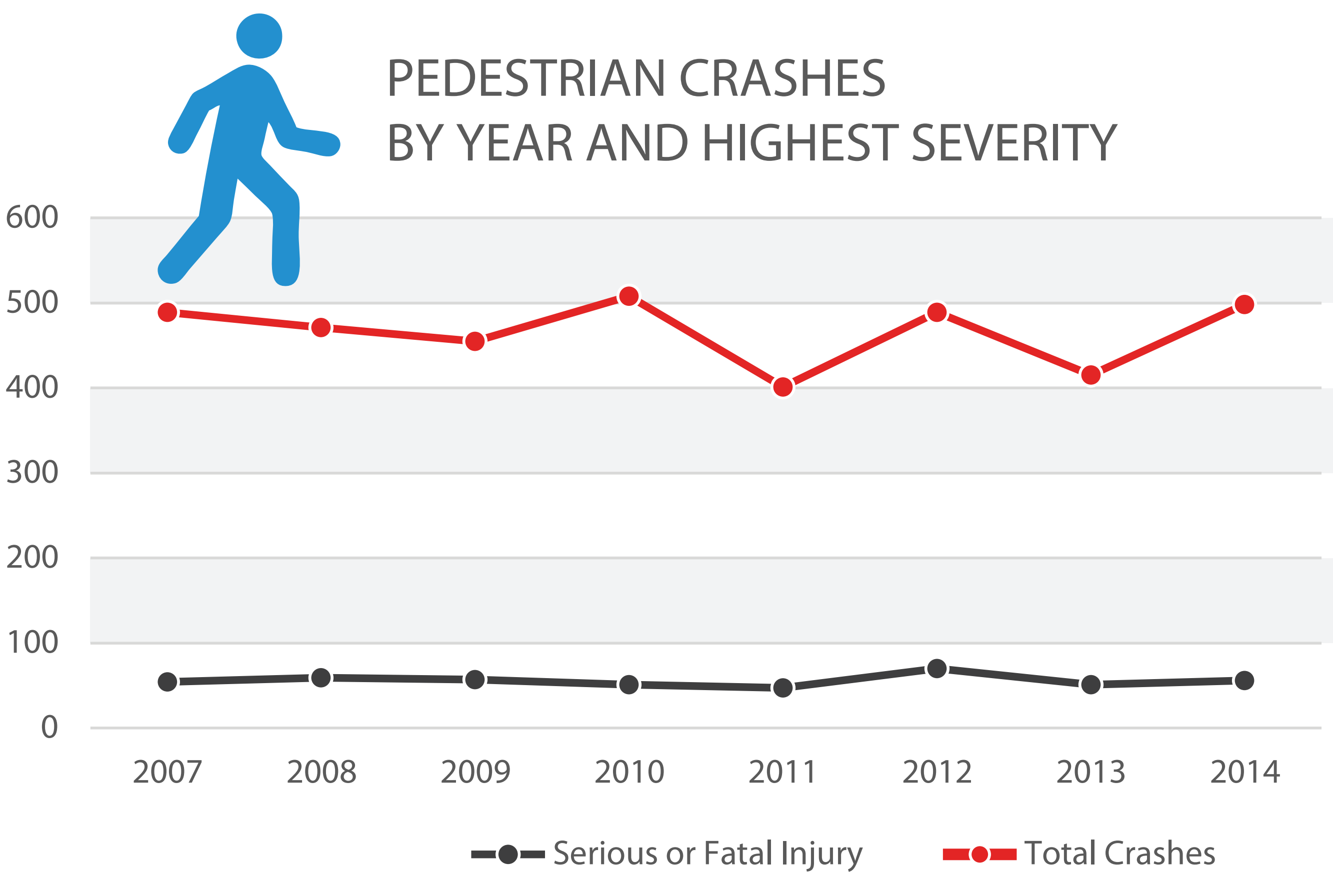
This trend supports the concept of "safety in numbers"—as more people walk and bike, safety improves. This is mostly because motorists become more aware and come to expect people walking and biking.

However, there are still too many collisions involving people walking and biking. Serious and fatal collisions disproportionately affect these vulnerable users.

Although the number of bicycle crashes per person bicycling has generally declined over the past decade, the total number of bicycle crashes has been on an upward trend from 2012-2014.

FIGURE 3: BICYCLE AND PEDESTRIAN SEVERE CRASHES, 2007-2014





EXPLORATORY ANALYSIS: KEY RESULTS

We started our analysis by exploring crash data and a wide variety of roadway, land use and environmental data. Our goal was to better understand the actions of those involved in the crash and characteristics of locations where crashes occurred.

The purpose of this initial analysis was to identify patterns and better identify some of the factors that could be contributing to crashes. We looked at many different combinations of **actions** and the **characteristics of where and how crashes happened.**

Actions include information such as what each of the individuals involved in the crash were doing when the crash occurred. For example, we wanted to see what combination of actions and roadway characteristics lead to the highest number of crashes and the highest number of severe crashes.

This analysis looked at one or two factors at a time and did not account for volumes of pedestrians, bicyclists or motor vehicles in a given location.

For more information on how we analyzed travel volumes, see **Digging Deeper into the Data.**

FIGURE 4: EXPLORATORY ANALYSIS DATA SOURCES

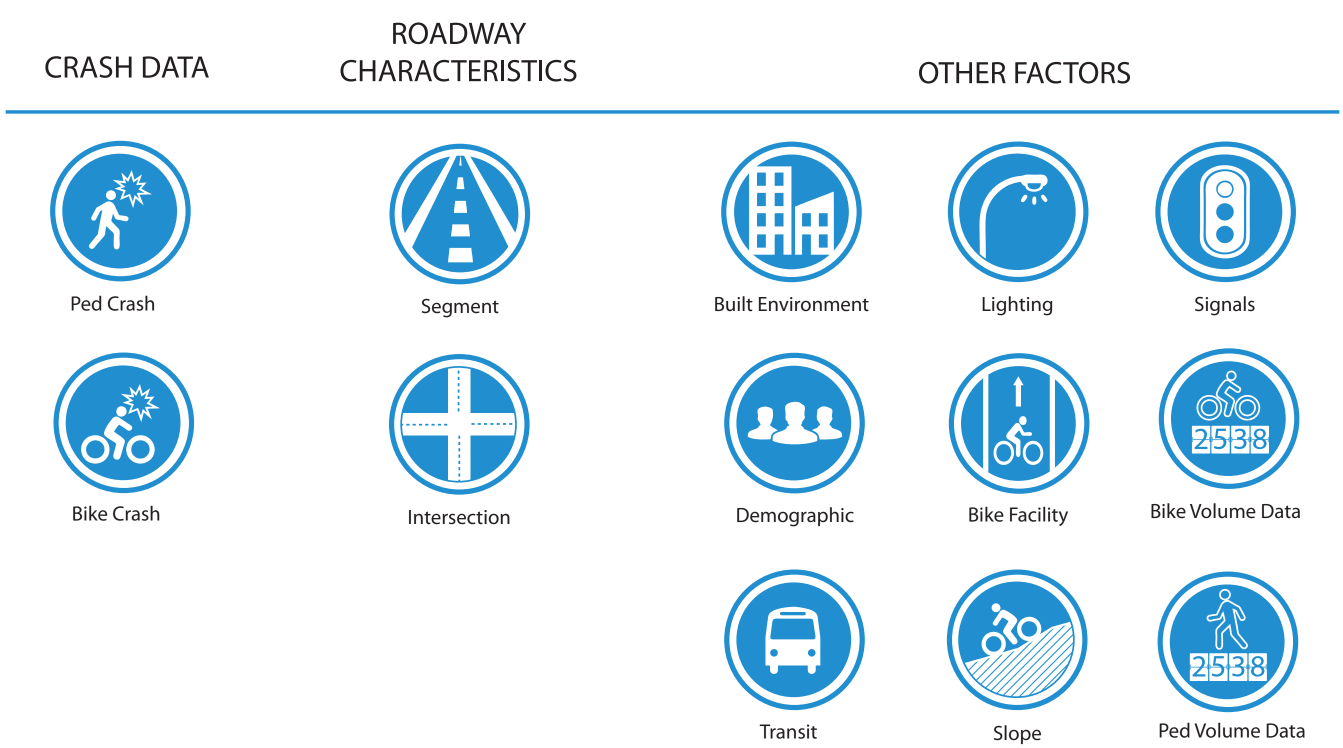
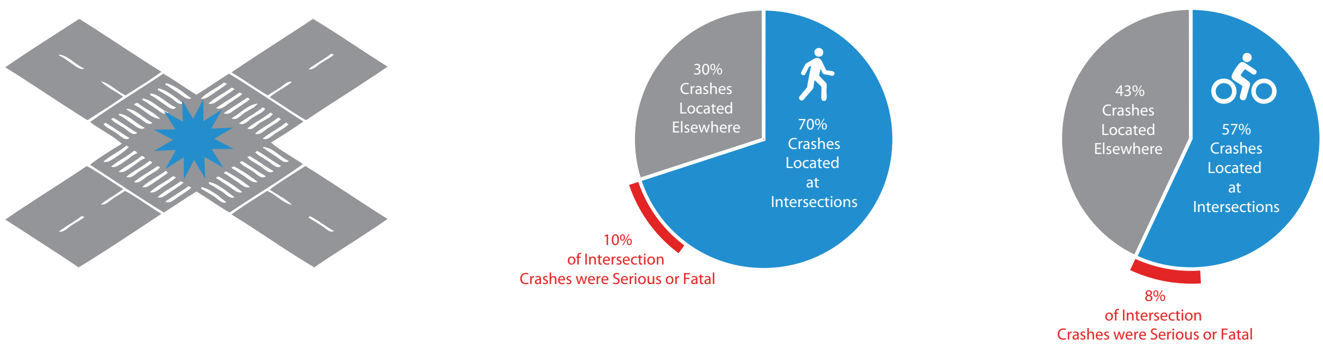


FIGURE 5: BICYCLE AND PEDESTRIAN INTERSECTION CRASHES

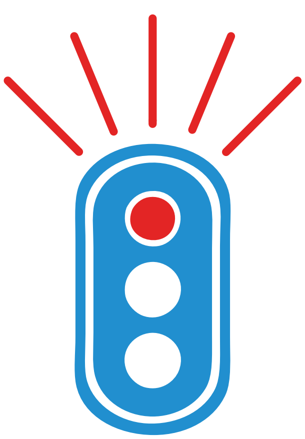
THE MAJORITY OF BICYCLE AND PEDESTRIAN CRASHES HAPPEN AT INTERSECTIONS



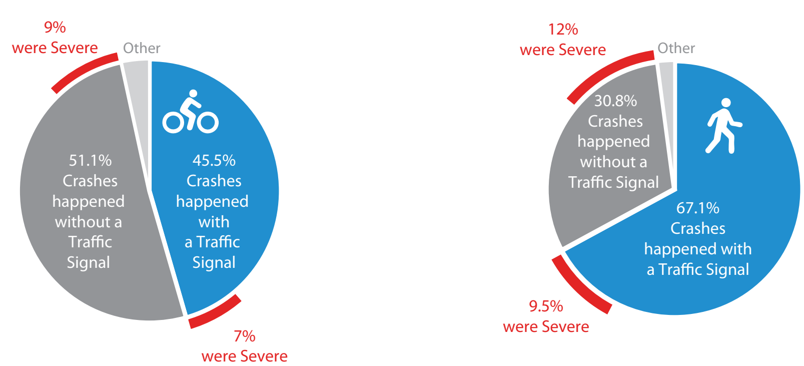
We found that the majority of bicycle and pedestrian crashes happen at intersections. This is not surprising, given intersections have the highest potential for conflicts—they have more users interacting and more movements.

Most pedestrian collisions at intersections were at signalized locations, while just over 51% of bicycle crashes at intersections were at unsignalized locations. However, for both pedestrians and bicyclists, crashes were more likely to be severe at locations without a traffic signal.

FIGURE 6: BICYCLE AND PEDESTRIAN CRASHES AT SIGNALIZED INTERSECTIONS



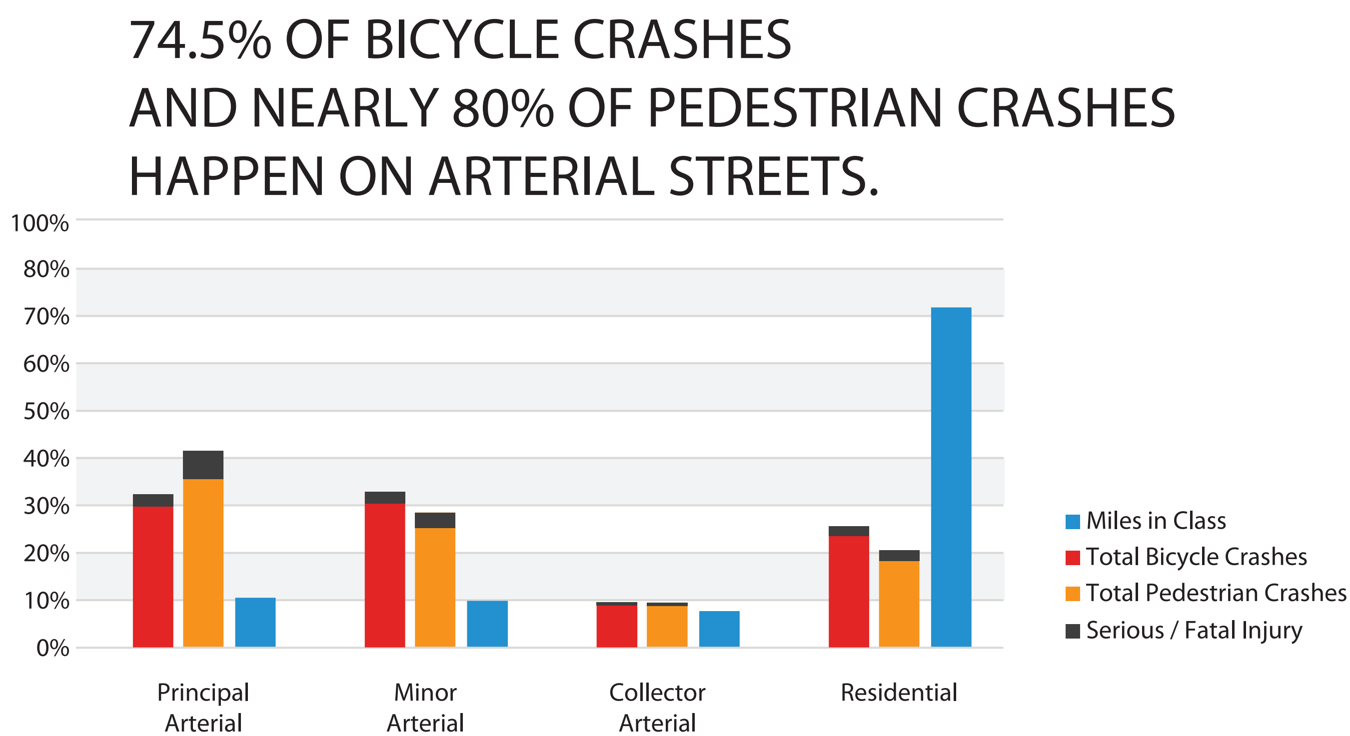
PEDESTRIAN INTERSECTION CRASHES MORE LIKELY TO HAPPEN AT LOCATIONS WITH TRAFFIC SIGNALS



Arterial streets –Seattle's primary transportation corridors – had more pedestrian and bicycle crashes, even though arterials make up a relatively small percentage of the total street network. Further, there are a higher number of serious or fatal pedestrian and bicycle crashes on arterial streets.

Although some crashes happened on residential streets, we found that pedestrian crashes on residential streets were likely to be near arterial streets. This reinforces what we already know—**streets that have higher traffic volumes and higher speeds need special attention** if we're going to meet our Vision Zero goal.

FIGURE 7: BICYCLE AND PEDESTRIAN CRASHES ON ARTERIAL STREETS



CRASH TYPES

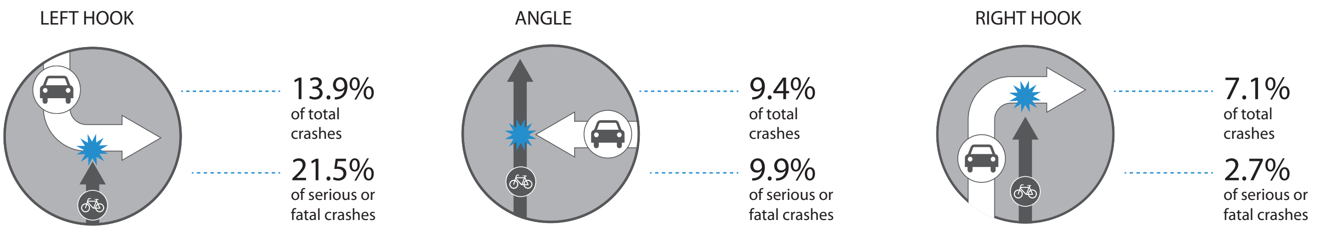
When a crash between a motorist and a pedestrian or bicyclist happens, the police officer on the scene fills out a crash report that includes many details such as time of day, weather and lighting conditions and the actions of those involved in the crash.

While we analyzed dozens of combinations of motorist, bicyclist, and pedestrian actions, we learned that many crashes, and most serious and fatal crashes, happen in similar ways.

Most Common Bicycle Crash Types

The top three bicycle crash types were "left hooks", "angle crashes", and "right hooks." Over 1 in 5 serious or fatal bicycle crashes happened when a left turning motorist struck a person bicycling straight (most often in the opposite direction).

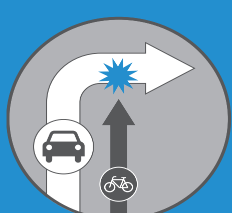
FIGURE 8: TOP THREE BICYCLE CRASH TYPES



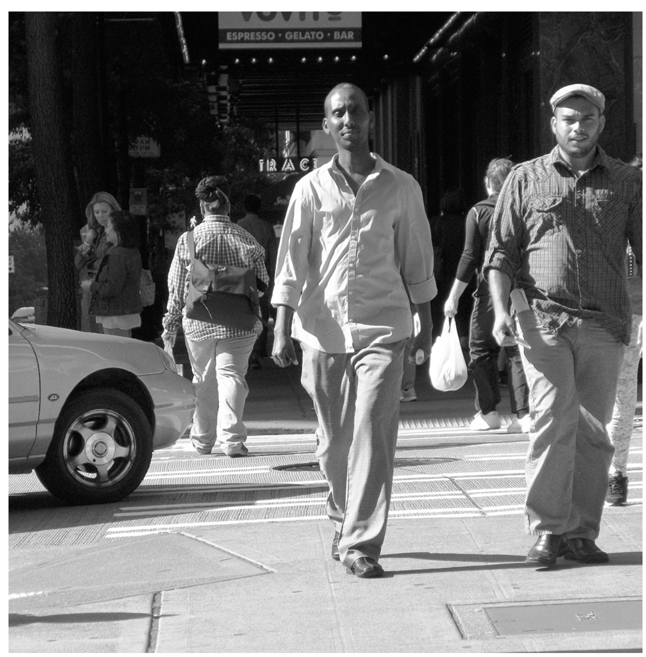
Crash reports for a portion of crashes didn't have information on the actions of the motorist, bicyclist or pedestrian, and could not be fully analyzed. It's critical to know these actions to understanding what factors may be contributing to crashes. That's why detailed crash reporting is so important.

Although these three crash types made up the highest percentage of bicycle crashes, there were also a number of crashes where actions were unknown, as well as smaller percentages of crashes that happened in other ways.

What's a crash type?



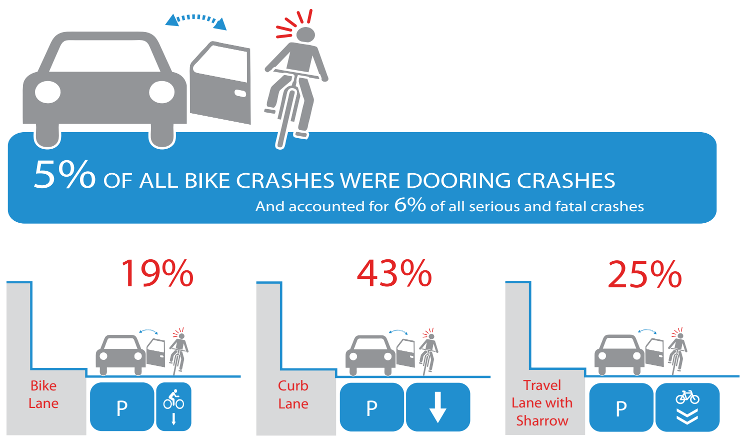
The majority of bicycle and pedestrian crashes happen in similar ways. We use 'crash types' to describe common scenarios of bicyclist, pedestrian and motorist movements that lead to crashes. An example of a crash type is motorist turning right hitting a bicyclist (or pedestrian) that is going straight in the same direction (also known as a "right-hook").



Crashes involving bicyclists and opened doors of parked vehicles ("dooring") are the fourth most common crash type, but the third highest number of serious and fatal crashes.

We found that the frequency of dooring crashes partly depends on the lane condition next to the parked vehicle, but there are likely other factors at play.

FIGURE 9: BICYCLE DOORING CRASHES

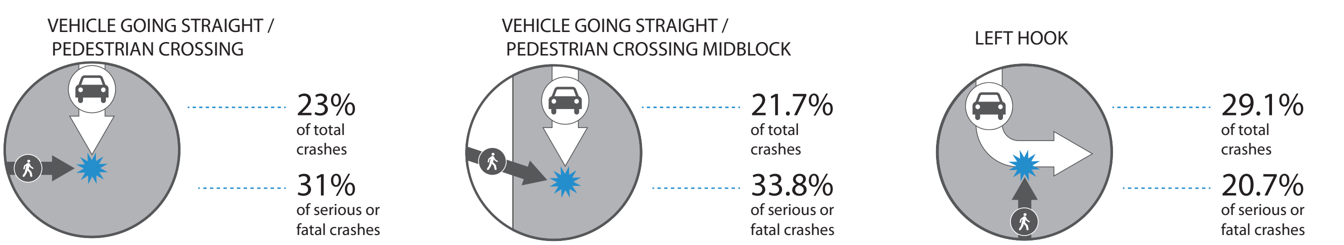


Most Common Pedestrian Crash Types

For pedestrian crashes, the top three crash types were pedestrian "angle crashes" at intersections, "angle crashes" at midblock, and "left hooks."

Combined, pedestrian "angle crashes" at midblock and at intersections were over 43% of all pedestrian crashes. These three crash types made up the highest percentage of total and severe crashes.

FIGURE 10: TOP THREE PEDESTRIAN CRASH TYPES



DIGGING DEEPER INTO THE DATA

Our exploratory analyses yielded useful information about where and how crashes happen. We conducted more advanced (multivariate) statistical analysis to better understand the significance of various factors that may contribute to crashes.
In this analysis, we accounted for the level of pedestrian and bicycle activity and different combinations of factors (see below).

Otherwise, we may misunderstand or misinterpret how various factors relate to pedestrian and bicycle safety. For example, locations where crashes occur that have more people walking and bicycling may actually be much safer because so many more people travel through that area.

What's exposure and why is it important?

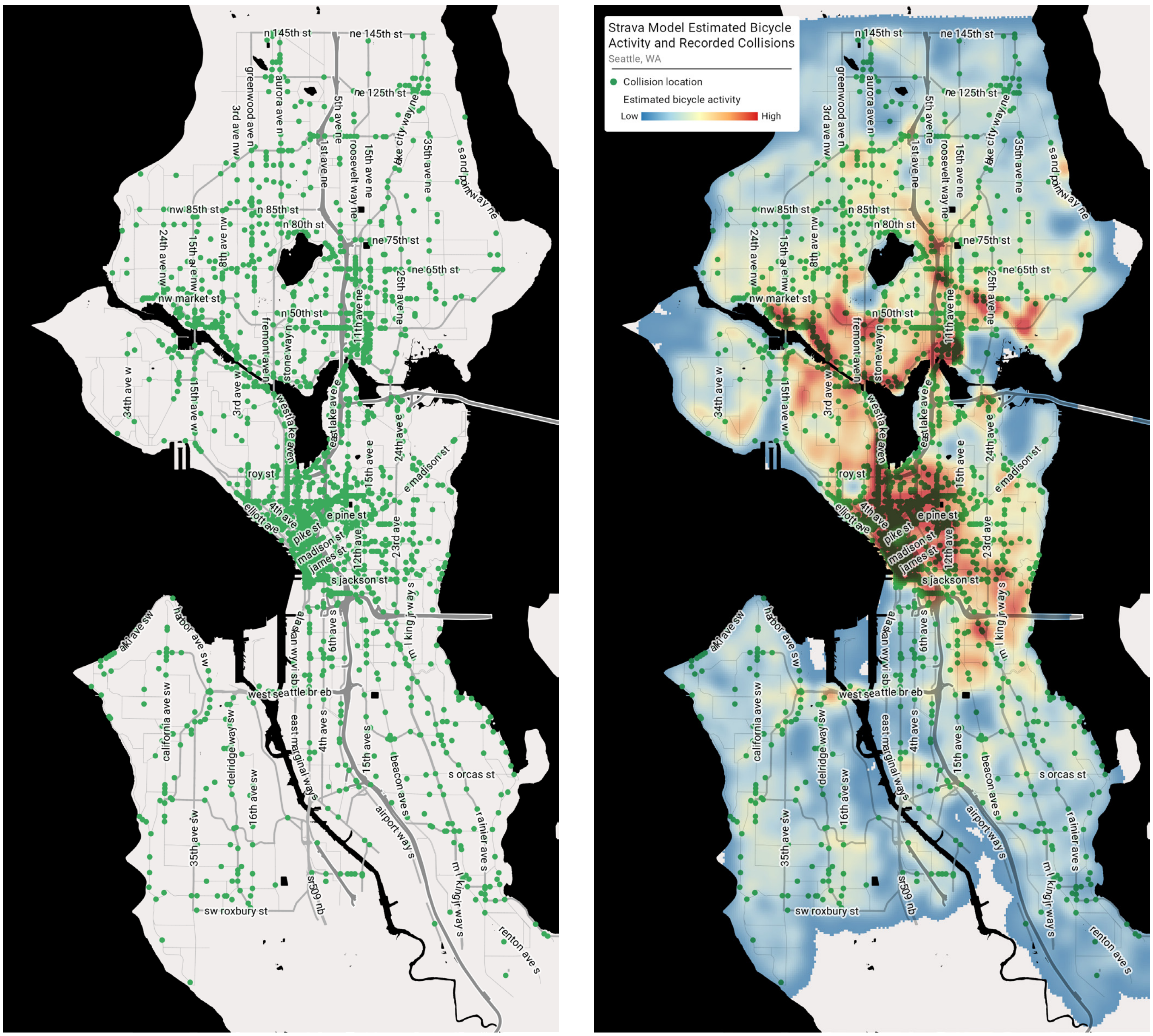
Exposure measures how many people walking or biking may be at risk for crashes in an area. We can use exposure to compare locations across the City with different levels of bicycle and pedestrian activity. If we don't account for exposure, we can't accurately assess the risk of a given location. For example, a location with three crashes, but few people walking may be higher risk than a location with an equal number of crashes, but many more people walking. We estimated "ballpark" bicycle and pedestrian exposure using available data and best practices, including count data, Strava app data, and information such as land use, transit, and pedestrian and bicycle facilities.

Prior research has found a strong relationship between traffic volume and pedestrian crashes. One of the main limitations of this analysis was the lack of motorized traffic volume data for all intersections and segments throughout the City. Traffic volume likely correlates to a number of significant factors, such as whether the crash occurred along an arterial or other multi-lane roadways, and whether it occurred at a signalized intersection. In the future, system-wide traffic volume data would help us to further understand key risk factors.

The following maps of bicycle crashes citywide show why we need to account for pedestrian and bicycle activity to understand risk. The first map shows all crashes citywide - note that many crashes happened near the downtown area.

However, when we overlay crashes with bicycle volume estimates, we see that crashes often happen in areas with more bicycling activity. That's why activity is important to consider when assessing risk—key examples include downtown and along the Burke Gilman Trail. That's not to say that safety shouldn't be improved in those areas, but accounting for exposure helps us assess actual risk.

FIGURE 11: BICYCLE CRASHES AND BICYCLE VOLUME ESTIMATES

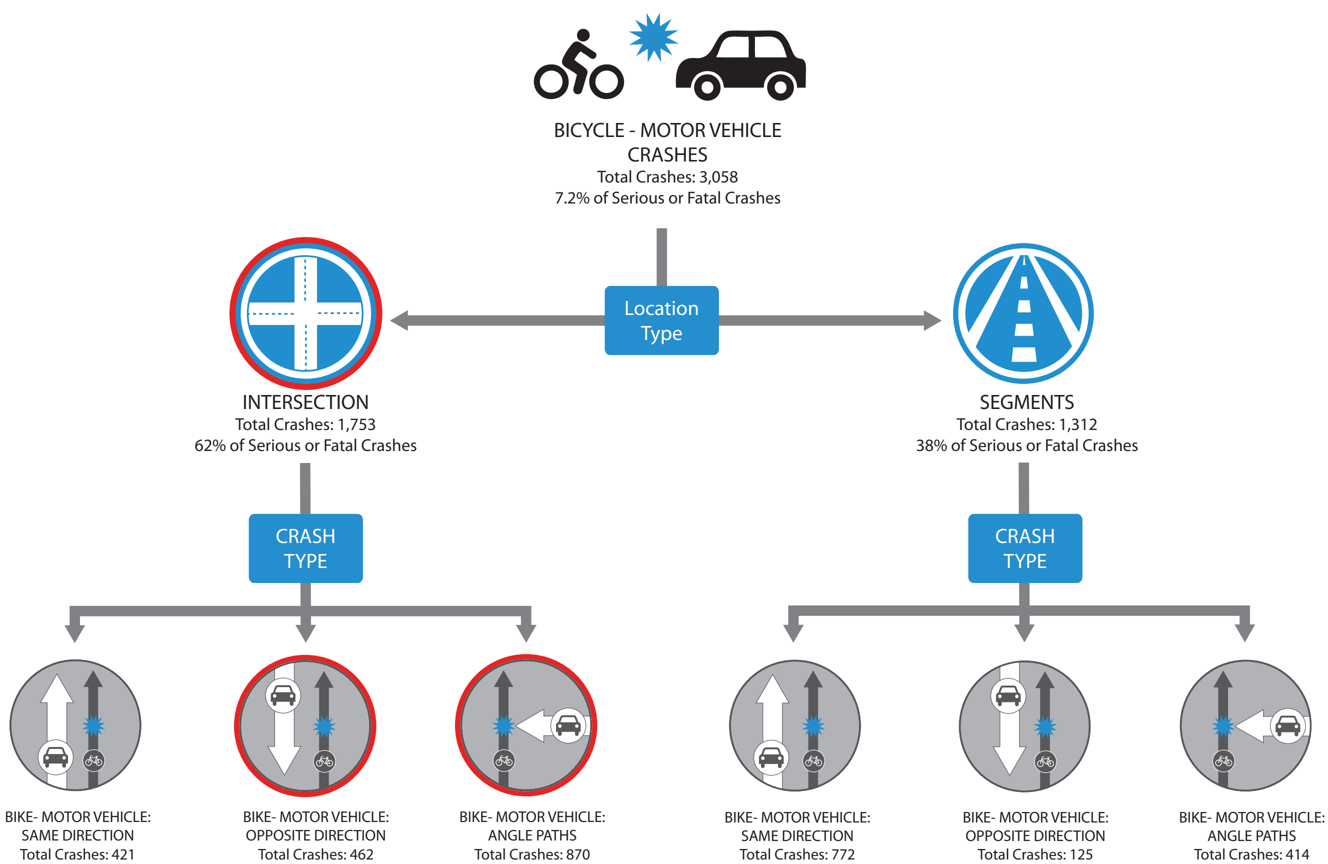


Our multivariate analysis focused on five crash types at intersections (three bicycle, two pedestrian). We selected crash types based on the findings from our exploratory data analysis, including information on pedestrian, bicyclist, and driver actions, and the number of crashes within each crash type.

In some cases, we needed to group similar crash types together to have samples large enough for statistically-valid analysis. For example, opposite direction bicycle crashes were made up of mostly 'left hook' bicycle crashes with a small number of other crash types, but we grouped them together for ease of analysis.

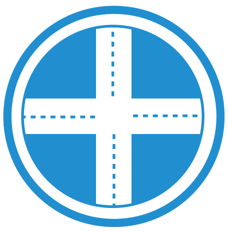
The flowchart below shows the process that led us to the bicycle intersection crash types we focused on in the multivariate analysis (highlighted in red): **all bicycle crashes**, **bicycle opposite direction crashes**, and **bicycle angle crashes**. We included all bicycle crashes as a crash type in order to examine what factors were in common with all bicycle crash types, and to shed light on which factors were more specific to certain crash types.

FIGURE 12: BICYCLE MULTIVARIATE ANALYSIS PROCESS

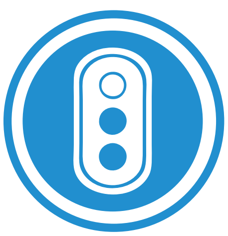


BICYCLE CRASH TYPE ANALYSIS KEY RESULTS

We developed regression models for three intersection bicycle crash types: total bicycle crashes, bicycle opposite direction crashes, and bicycle angle crashes. We used the models to estimate and test the significance of the effects of a wide array of exposure, roadway, demographic, and built environment variables on crash frequencies. We only retained the most significant variables in the models. The key results are summarized below.



Arterial street intersections and **large and complex intersections** contribute to higher potential risk for all bicycle crash types. We know that speed increases the risk of serious or fatal injury for people walking and biking, and many of our arterial streets carry faster traffic. Also, larger intersections take longer to cross and increase the exposure of people walking and biking. These findings affirm that arterial intersections should be a primary focus of our Vision Zero efforts.



While bicycle crashes are slightly more likely to happen at unsignalized intersections (51% of bicycle intersection crashes), the data revealed that **traffic signals are positively related to bicycle intersection crashes**. However, we didn't have easy-to-analyze information on signal phasing (i.e., when different roadway users are permitted to go) and cycle length. This analysis revealed how important it is to have signal phasing information and we're going to work on developing this dataset. We'll also need field observations for sites with high crash potential to better understand how various factors contribute to crashes and to identify the best solutions.

As previous studies have found, the built environment affects where crashes happen. In Seattle's case, we found that there was a greater potential for all bicycle crashes at locations near commercial buildings. **Commercial areas tend to generate more activity** on our streets, resulting in greater potential for conflicts. We found that locations with higher bicycle activity were more likely to have bicycle and pedestrian crashes. That's why we need to pay special attention to commercial areas from a pedestrian and bicycle safety point of view.

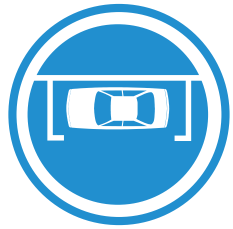
We learned that locations with high transit activity have a higher potential for pedestrian crashes. Keeping in mind that this analysis controlled for pedestrian volumes (but not motor vehicle volumes), this suggests that there are likely other factors at play. Such factors could include obstructed sight lines, aggressive maneuvering by motorists or bicyclists around transit vehicles, or other factors that are difficult to tease out of the crash data. Because **transit plays an ever-important role in our city's mobility**, we need to investigate this finding further.

When we analyzed all bicycle crashes, we found that bicycle crashes are more likely to happen at intersections with bike lanes or shared lane markings. However, we couldn't determine whether or not the crash happened in a bike lane because this information wasn't readily available in a coded format for analysis. Some work is needed to get all the information available in a police report in a format that allows for analysis.

This finding reinforces what we already know, which is that intersections require special attention. It also affirms our efforts to heighten awareness of intersection conflicts using green pavement markings and signage, and improve geometric design and traffic operations, particularly at locations with higher bicycling volumes.

Intersections with center turn lanes are associated with a higher number of bicycle crashes. As with our findings on bike lanes, one should interpret this finding cautiously, as there are likely other factors at play. We also easy-to-analyze information on when crashes occurred related to when center turn lanes were installed or past safety issues that were addressed through restriping (i.e., by going from four to three lanes).

Often, center turn lanes are present on streets that have been repainted from four to two lanes with a center turn lane and bike lanes. Research shows that center turn lanes benefit pedestrian safety, particularly at 3-lane intersection approaches. In the future, we could explore this finding by analyzing the date of roadway restriping or the type of signal timing related to crashes.



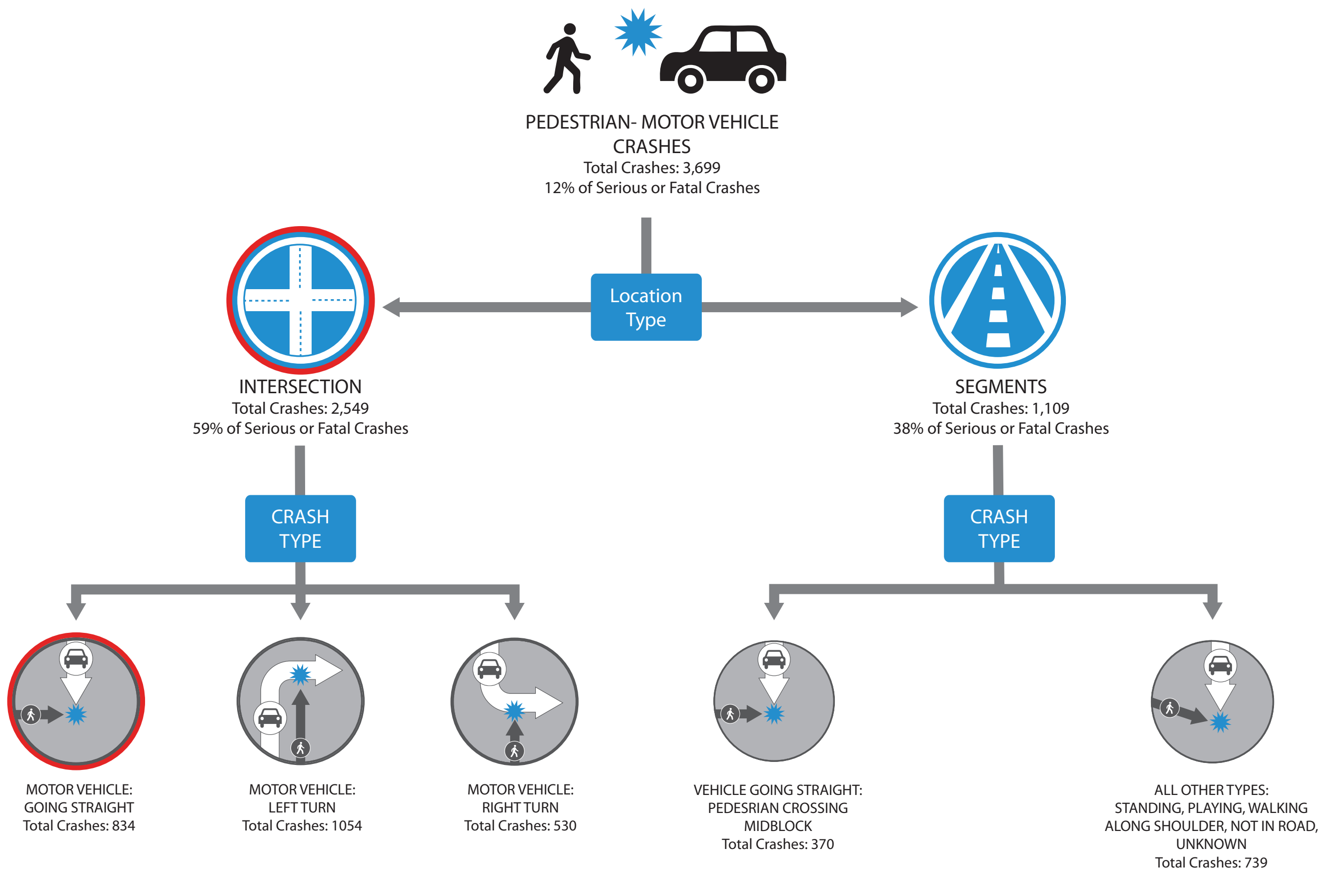
For all bicycle crashes, and in particular left-hook crashes, there's a higher potential for crashes at **locations with on-street parking**. This finding could be related to visibility or other factors. We'll need field observations to better understand how on-street parking may be contributing to bicycle and left-hook crashes.

We found that **downhill approaches** to intersections may increase the potential for bicycle left-hook crashes, but not bicycle angle crashes. We didn't focus on right-hook crashes in the multivariate analysis. We will further explore a number of related factors, including bicyclist and driver speed, traffic volumes, and visibility.

The flowchart below shows the process that led us to the pedestrian intersection crash types we focused on in the multivariate analysis (highlighted in red): **all pedestrian crashes** and **pedestrians crossing the street struck by motorists going straight**.

As with the bicycle analysis, we included all bicycle crashes as a crash type in order to examine what factors were in common with all bicycle crash types, and to shed light on which factors were more specific to certain crash types.

FIGURE 12: PEDESTRIAN MULTIVARIATE ANALYSIS PROCESS



The highest number of serious or fatal pedestrian crashes at intersections were represented by the pedestrians crossing the street struck by motorists going straight crash type.

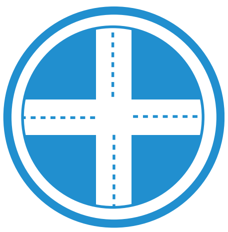
We observed some important patterns regarding **midblock crossings**. We learned that the proportion of severe midblock pedestrian crashes increased with the distance between intersections. That's why we need to reduce traffic speeds, reduce pedestrian delay at signals, and create more opportunities for safe crossings where long distances between intersections encourages people to cross midblock.

Why didn't we focus on midblock crashes?

Many serious or fatal crashes happen between intersections. Midblock crashes happen more randomly. The crash reports for many midblock crashes are less clear about contributing actions and the specific crash location of the crash. With additional missing information, we didn't have a sufficient sample size to analyze midblock crashes in our multivariate analyses.

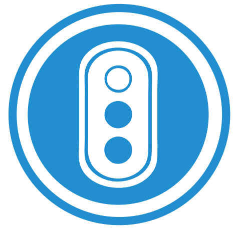
PEDESTRIAN CRASH TYPE ANALYSIS KEY RESULTS

We developed regression models for two intersection pedestrian crash types: **total pedestrian-motor vehicle intersection crashes** and **pedestrian crossing the street struck by motorist going straight** at intersection. As with the bicycle crash models, we used the pedestrian crash models to estimate and test the significance of a wide range of exposure, roadway, demographic, and built environment variables. We only retained the most significant variables in the models. We've summarized the results below:



Because **most pedestrian crashes happen at intersections**, we focused our advanced analysis on analyzing those crashes. Arterial street intersections and large and complex intersections, in particular, contributed to a higher potential risk for all pedestrian crash types. We found that there's a lower potential for pedestrian crashes on intersection legs with fewer lanes (i.e., 3-4 lanes). We also found that arterial intersections with neighborhood streets have reduced risk compared to arterial intersections.

We know that speed increases the risk of serious or fatal injury for people walking and biking, and many of our arterial streets are higher speed. We also know that larger intersections take longer to cross and increase the exposure of people walking. These findings affirm our focus on making arterial intersections safer for pedestrians in our Vision Zero efforts.



Traffic signals may increase the potential for pedestrian intersection crashes. However, one should interpret this finding cautiously. Signalized intersections tend to have much higher volumes of all users. While we controlled for pedestrian and bicycle volumes, we couldn't control for vehicle volumes. Also, we did not have signal timing data in a format readily usable for our analysis. Signal phasing information and/or field observations of sites with high crash potential will allow us to better understand how operational factors may contribute to crashes and to pinpoint the best solutions.

The data also suggest that the **built environment affects where crashes happen**.

For example, we found that there's a greater potential for pedestrian crashes at intersections near commercial buildings. Commercial areas tend to generate more activity on our streets, and thus more potential for conflicts. Our analysis confirmed that locations with higher pedestrian activity were more likely to have pedestrian crashes –We'll need to pay special attention to these areas.

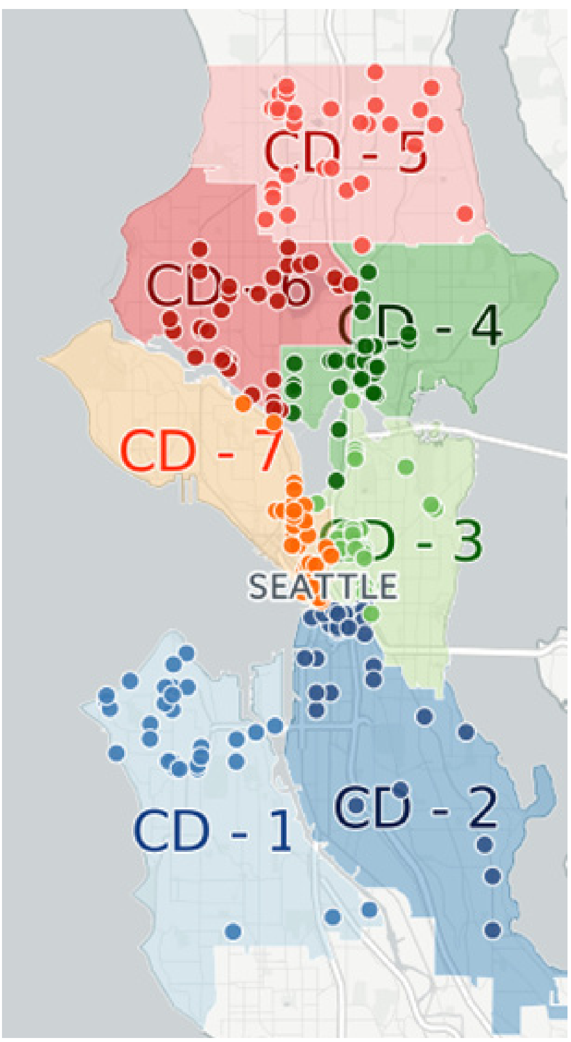
We've also learned that locations with high transit activity are associated with more pedestrian crashes, particularly crashes involving pedestrians crossing the street struck by a motorist going straight. Given the i**mportant role transit plays in our city's mobility**, this finding underscores the need to further improve the safety of crossings near transit stops.

HOW WILL WE USE THIS INFORMATION?

We'll use the safety analysis results to identify locations with a high potential for future crashes and to determine the most effective strategies to improve safety at those locations. Using Geographic Information Systems (GIS), we'll identify locations throughout the City with one or more significant factors we identified. We'll filter locations by combining risk factors and other criteria, such as crash history, geographic area, land use and topography.

Then, we'll focus our efforts on these high-risk locations to improve safety both proactively and systemically. As an example, the map below shows the top locations in each Council District with a high potential for bicycle intersection crashes. We identified these locations based on the degree to which they show the significant factors we found during the analysis.

FIGURE 13: RANKED LOCATIONS BY COUNCIL DISTRICT

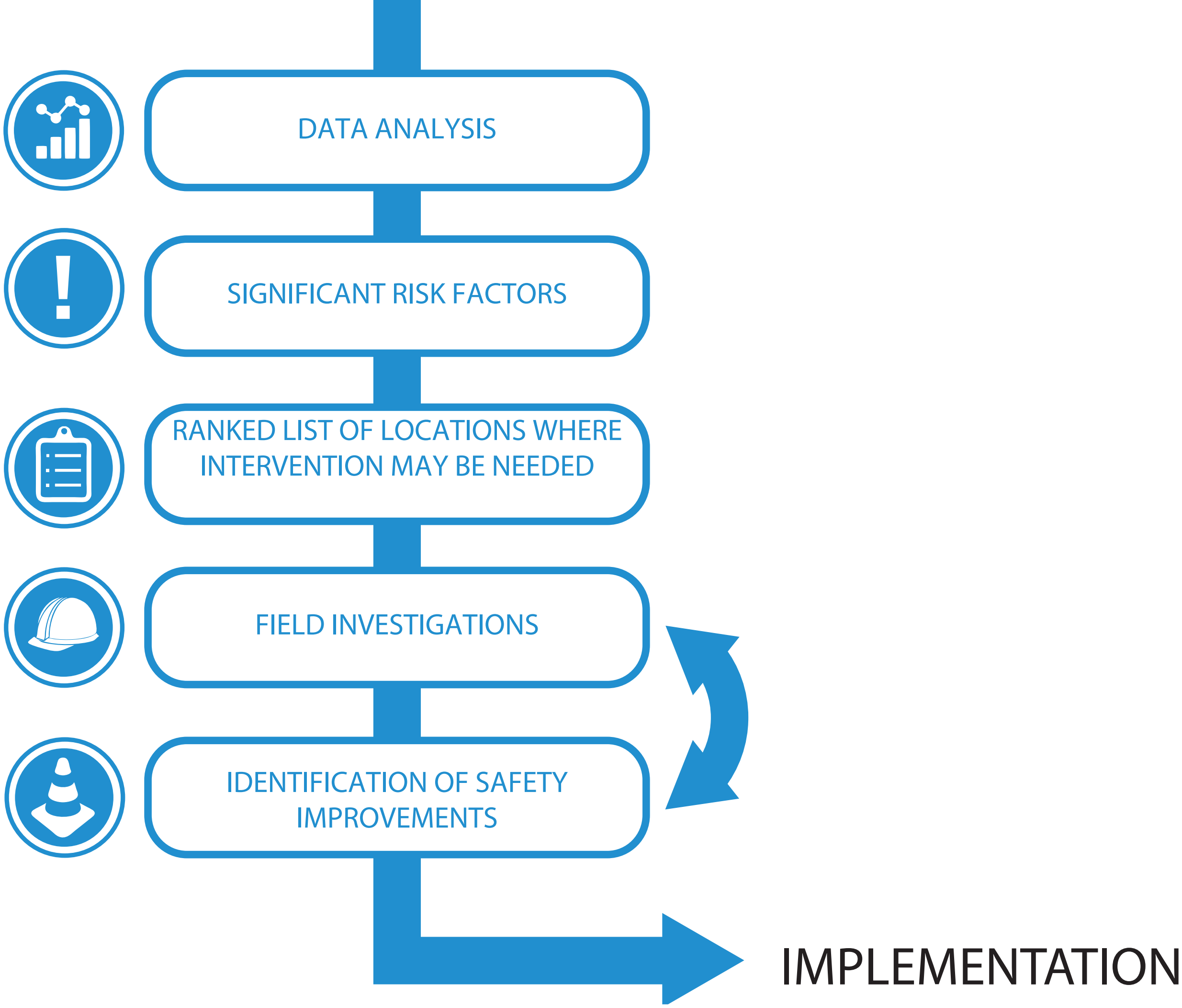


Systemic vs. High Crash Approach to Reducing Crashes

A systemic approach 1) proactively identifies sites based on risk factors associated with a particular crash type, and 2) uses cost-effective strategies to address potential safety issues system-wide. These strategies might include locations with and without a crash history. This allows us to address future safety risks before they become an issue.

This approach complements our traditional high-collision analysis, which identifies and recommends safety improvements for locations with a high number of crashes ('hot spots'). We'll also continue to address safety concerns at bicycle or pedestrian crash 'hot spot' locations.

A PROACTIVE, SYSTEMIC APPROACH



Our engineers visited locations that ranked highest based on potential for pedestrian and bicycle crashes. Our goal was to get a more complete picture of street design, traffic operations, and behavioral factors, including factors that weren't captured in available data (such as sight line obstructions, signal phasing, etc.).

Then, we identified safety countermeasures that could mitigate known risk factors and that we can apply across the system at locations with similar street design and traffic operations.

This systemic, risk-based approach allows us to **proactively address safety issues**—aiming to prevent bicycle and pedestrian crashes **before they happen**. Examples of systemic countermeasures include:

- Using leading or protected signal phases to reduce or eliminate conflicts
- Designing intersections to slow turning vehicles and improve the visibility of bicyclists and pedestrians
- Using low-cost treatments to highlight conflict areas and improve the positioning of all roadway users.

NEXT STEPS

The Bicycle and Pedestrian Safety Analysis project improves our understanding of when, where and how pedestrian and bicycle crashes happen. We now have the tools to proactively identify and prioritize locations for safety improvements. We'll apply these tools on an ongoing basis as streets change in our rapidly growing city.

We'll track performance to gauge how well the proactive approach to improving safety works over time. For example, we'll evaluate the effectiveness of our strategies by monitoring high-risk locations where we've made safety improvements. We'll integrate these measures into existing programs, such as **Vision Zero** and the **Performance Seattle** dashboard.

While the analyses summarized in this report have broadened our understanding of when, where, and how pedestrian and bicycle crashes happen, they also revealed additional questions and gaps in our data that we need to fill. Given these additional data resources, we'll focus on the following analyses:

- **Estimate vehicle volumes** across the street system, which is important to measure how traffic affects bicycle and pedestrian crashes.
- **Combine traffic, pedestrian, and bicycle volume data** to get a more complete picture of risk. We'll collect pedestrian and bicycle volume data at more locations to improve citywide volume estimates used for assessing exposure risk.
- Delve into **roadway user behavior** that may be better addressed by enforcement and education.
- Analyze **signal phasing** and how it impacts pedestrian and bicyclist safety.
- Examine mid-block pedestrian crossing crashes to better understand why they're often more severe.
- **Analyze mid-block, "right-hook" and "dooring" crashes** to better understand what contributes to these crashes.

CONCLUSION

The Bicycle and Pedestrian Safety Analysis is an important piece of our data-driven strategy to eliminate deaths and serious injuries on our streets by 2030. This analysis has helped us identify the key factors that lead to crashes. We'll use these results to implement effective projects to address those factors and improve safety. We'll continually improve our data and proactively improve safety where we need it most.

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