Seattle Department of Transportation

CITY OF SEATTLE BICYCLE AND PEDESTRIAN SAFETY ANALYSIS

PHASE 2

February 4, 2020

Rev. 2

Seattle Department of Transportation


BARTELL
DRUGS
BARTELL
DRUGS
ONE WAY

Dear Seattle-

One of our core values is that everyone should be able to move safely throughout the city. Our Vision Zero goal is to create a safe transportation environment and eliminate serious and fatal crashes. We initiated the Bicycle and Pedestrian Safety Analysis in 2015 to look at bicycle and pedestrian incident trends. We are now releasing Phase 2 of the BPSA with improved models and more years of data. This tool helps us proactively make safety enhancements across the city. This groundbreaking approach helps us prioritize locations, anticipate issues, and make decisions informed by data.

Continue reading to learn about our findings and get a more in-depth understanding of our methodology.

Sincerely,

Sam Zimbabwe, SDOT Director

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ACKNOWLEDGMENTS

SDOT, Project Development Division
Toole Design
University of North Carolina Highway Safety Research Center

Photos used in this document were provided by SDOT and Toole Design

INTRODUCTION

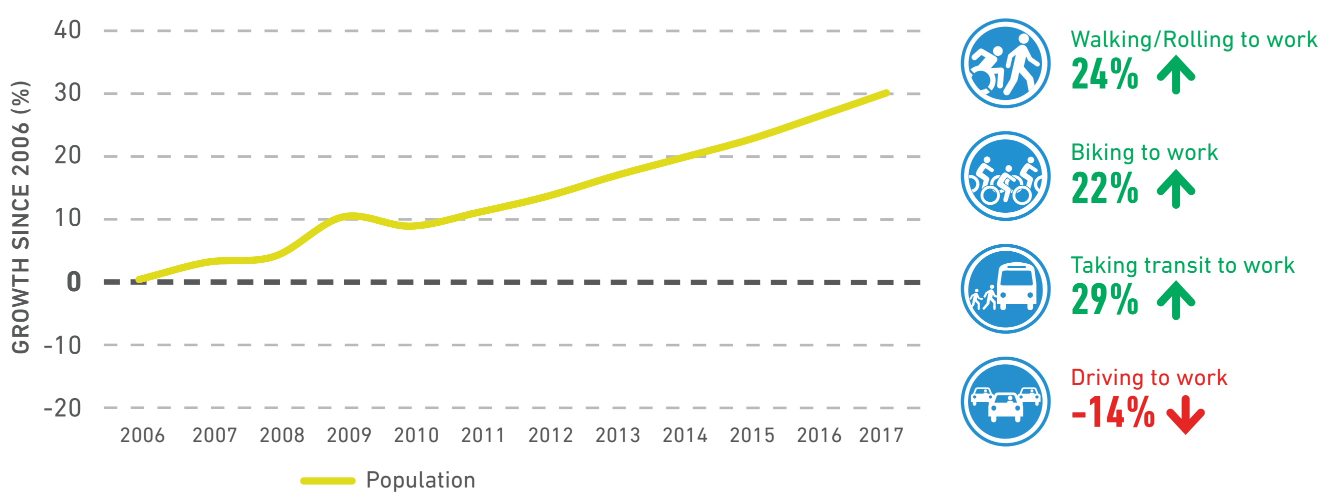
Seattle's **Vision Zero Plan** calls for eliminating traffic-related deaths and serious injuries by 2030**.** To achieve this goal, the Vision Zero Plan presents a framework that includes a combination of engineering streets to be safer for all users, education, and enforcement. Our Comprehensive Plan emphasizes traffic safety as an important component of becoming **a more equitable and sustainable city**. As our population grows, our streets must convey more and more people (Figure 1). It is imperative that we continue to evolve how we design streets to meet this growing demand while also keeping all Seattleites and visitors safe.

The Bicycle and Pedestrian Safety Analysis represents one of the most advanced, data-driven approaches in North America for **understanding where, how, and why crashes happen**. This understanding is critical for taking a more proactive approach to eliminating traffic fatalities and serious injuries rather than merely reacting to crash-related tragedies, the vast majority of which are preventable.

WHAT WE KNOW

In 2015 we embarked on the first phase of the Bicycle and Pedestrian Analysis (BPSA). This was the first comprehensive analysis of crashes involving pedestrians and bicyclists and the first time that we attempted to account for exposure – the number of people walking and biking in a given area – when assessing crash risk. Using exposure estimates, we conducted more advanced multivariate statistical analyses to attempt to understand the significance of various factors that may be contributing to crashes. This analysis greatly improved our understanding of what roadway conditions are contributing to higher crash risk and where we should be focusing our efforts to improve traffic safety and operations. For example, we found that locations with high transit activity have a higher potential for both pedestrian and bicyclist crashes. Keeping in mind that this analysis controlled for the number of bicyclists and pedestrians at these locations, this finding suggested that other factors are potentially at

FIGURE 1: POPULATION GROWTH AND CHANGE IN COMMUTE TO WORK BY MODE SINCE 2006 THROUGH 2017



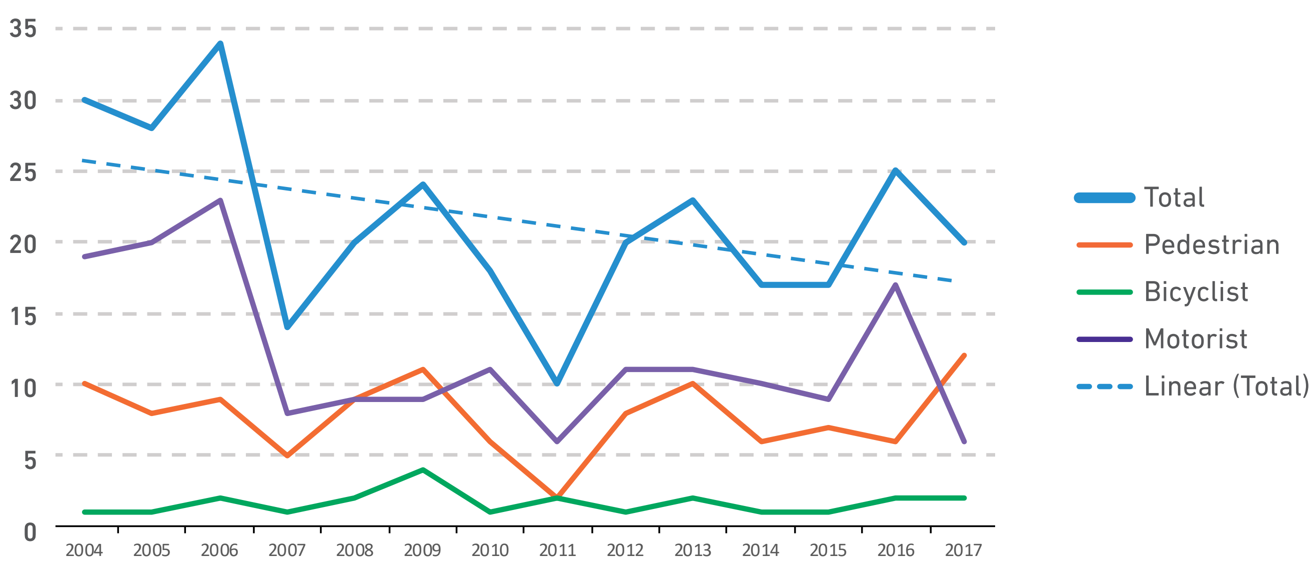
We're seeing as our population continues to grow, people are choosing to walk/roll, ride a bicycle, or use transit to travel to work instead of driving a car.

Data Source: US Census ACS 1-Year Estimates play, including obstructed sight lines, transit stop design, or maneuvering by motorists or bicyclists around transit vehicles. We have since been very focused on removing sight line obstructions (often referred to as "daylighting") at intersections and improving transit stop designs that reduce conflicts among users. A **report** published in 2016 summarizes all the key findings from the first phase of the analysis.

Seattle has added more than 120,000 residents over the past 10 years. It added 45,000 new jobs in downtown alone between 2010 and 2016. This growth has contributed to more trips being taken on our streets, including the number of people walking and biking for at least a portion of their trip. With the passing of the Move Seattle Levy in 2015, we are focused on moving more people, more efficiently and safely. **Making our streets safer for people walking, biking and using other mobility devices** is key to reducing the number of traffic fatalities and serious injuries while also attracting more people to use these modes.

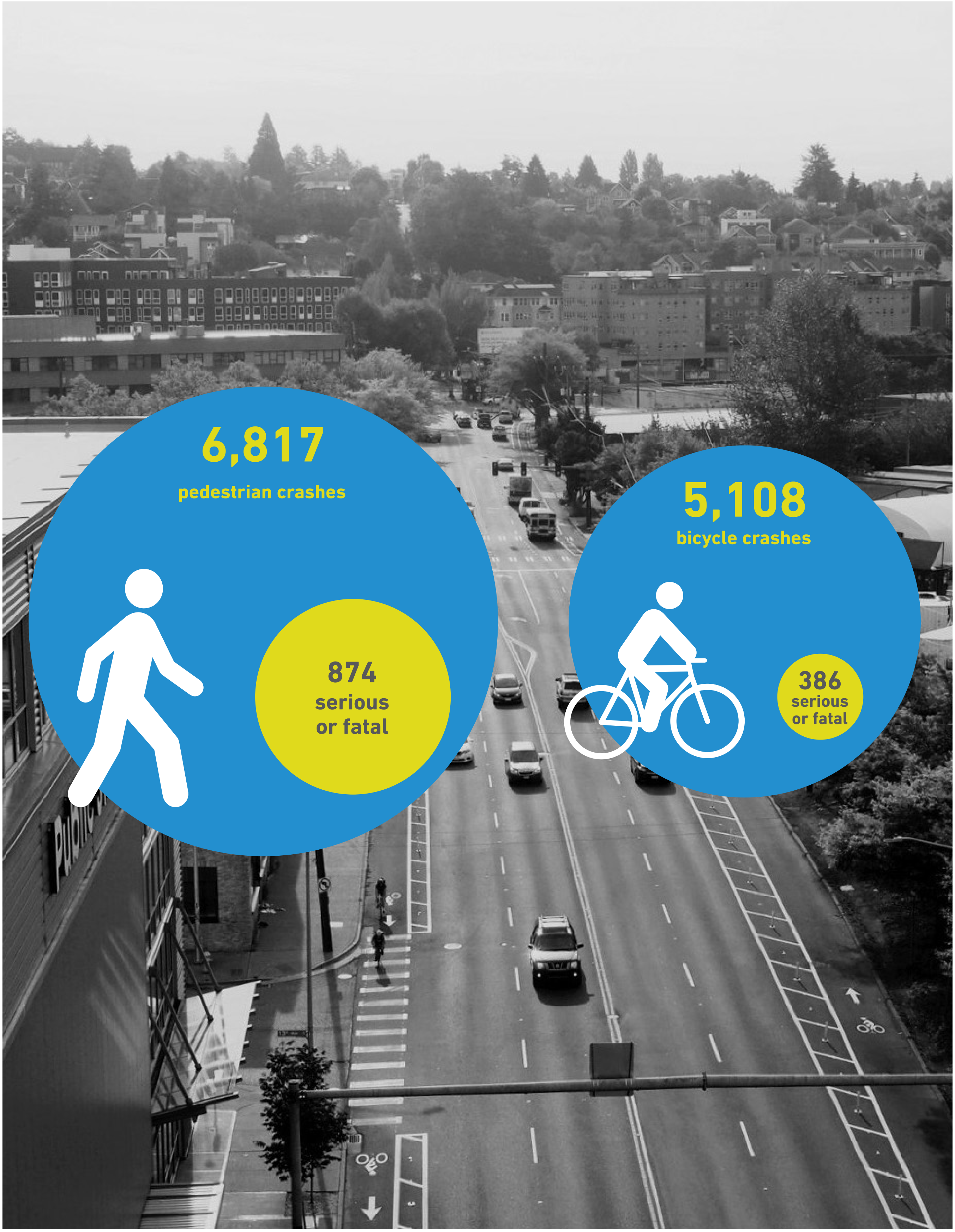
Unfortunately, in 2017 we saw more pedestrians killed than any other road user. This trend continued in 2018 with 7 of the 13 traffic fatalities being pedestrians. And 98 of the 177 reported serious injuries were pedestrians and bicyclists. There is still much we must do to achieve our Vision Zero goal, and this is particularly true for our most vulnerable roadway users, including persons with disabilities and people walking, biking, or using an ever-growing number of "micromobility" devices such as scooters and hoverboards.

FIGURE 2: TRAFFIC FATALITY TRENDS, 2004-2017



Data Source: City of Seattle

FIGURE 3: BICYCLE AND PEDESTRIAN CRASHES, 2004-2017



WHAT WE'VE LEARNED FROM ADDITIONAL ANALYSIS

WHAT'S DIFFERENT THIS TIME AROUND?

There are several notable advances in our data since the initial BPSA analysis was conducted in 2016. First, we were able to analyze three additional years of crash data (2014 – 2017). Second, we were able to use signal phasing data that was not previously available. Last, and perhaps most importantly, we were able to **refine and confirm our exposure estimates**. Understanding exposure, or the number of events that could result in a crash, is important to understanding crash risk. For the purposes of our analysis, we measure exposure in terms of the number of people estimated to be walking, biking, or driving at a given location rather than the amount of time spent or distance traveled walking, biking or driving, which are more difficult to estimate. A major impetus for a second phase of the BPSA was the availability of **estimated motor vehicle volumes** that could be used to **refine the exposure model developed in phase 1 and better assess crash risk**. The exposure estimates developed in phase 1 of the BPSA only accounted for pedestrian and bicycle volume data due to the lack of reliable network-wide motor vehicle volume estimates. In 2016, we worked with DataKind[1] to develop a vehicle volume estimate for the entire Seattle street network. The citywide vehicle volume estimates provide valuable context for understanding where bicycle and pedestrian crashes are most likely to occur. Motor vehicle volumes are known to be an important variable in analyzing traffic crashes, and without this data these effects can be misattributed to other factors, such as the presence of traffic signals, leading to less precise analysis.

1 DataKind is a multidisciplinary, global team built up of coders and statisticians, community builders and partnership organizers, all united by a common mission to use data science and AI in the service of humanity

Technical Spotlight

We used statistics to link outcome variables (e.g., number of people walking or bicycling, number of crashes) to a set of input variables (e.g, roadway and land use characteristics). This process lets us then estimate the expected outcome, or risk measured in the number of expected crashes, based on input variables, even where there may not have been any crashes yet to date. For both volume estimation and crash outcomes, we used a type of statistical analysis called Negative Binomial regression. It works on estimating outcomes for count variables (i.e., non-negative integers). We also used a separate type of modeling called random forest to help choose which input variables to use in the Negative Binomial regressions. Random forest is a type of machine learning that groups data into clusters based on the input variables and outcomes, and then repeats the groupings many times to find a model that fits the data well.

FIGURE 4: ADDITIONAL YEARS OF CRASH DATA

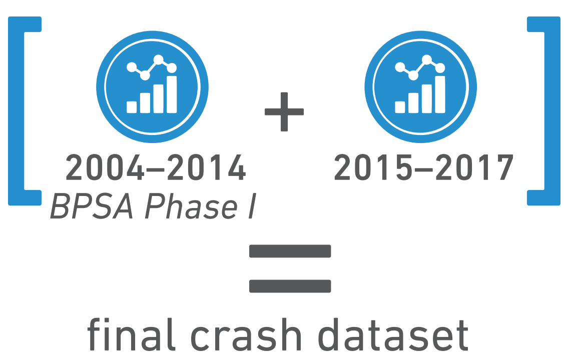
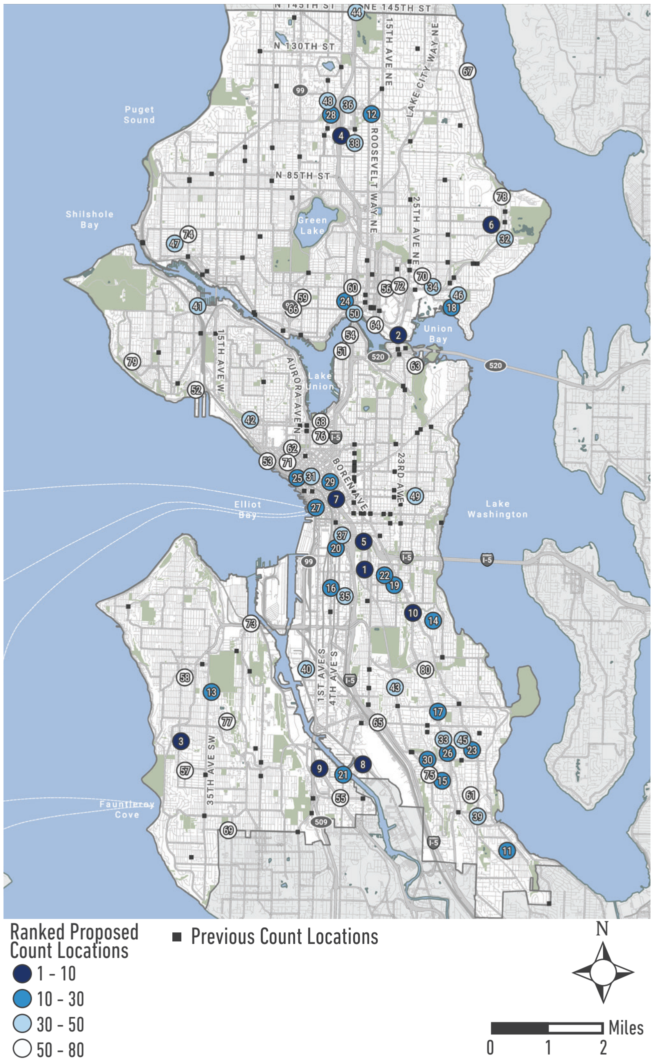


FIGURE 5: PRIORITY FUTURE COUNT LOCATIONS



Exposure estimates were developed for pedestrian crossings and bicycle segments throughout the city. This process involved calculating extrapolation factors based on permanent counters, applying these factors to observed short-duration counts to generate annual average daily bike/pedestrian traffic estimates at the observed locations, and developing statistical models to identify the surrounding land use and transportation network variables most associated with the observed volumes. While we found the effects of including motor vehicle traffic volumes did not result in a substantially improved model fit over using roadway classification (as was done in phase 1), we now have even more confidence in the exposure estimates we use for assessing crash risk.

Brief explanation of count optimization and exposure

Developing an accurate understanding of bicycle and pedestrian volumes is critical to our Vision Zero goals, as volumes (or “exposure”) are highly associated with crashes. Having more accurate volume and predicted exposure estimates can be achieved by collecting counts from locations with a greater variety of activity levels and location context. The count location optimization effort fills in gaps where volume data has not been collected and recommends future priority count locations based on factors that have been identified as predictors for volumes. The data collected at these locations can be integrated into the citywide bicycle and pedestrian exposure models to better understand exposure and improve the identification of high priority locations.

Using our refined exposure estimates, we developed **safety performance functions** for seven intersection-related crash types[2]. Safety performance functions are statistical models used to estimate the frequency of crashes at a given location (e.g., intersections) based on site characteristics. These statistical models included crash, roadway, signal phasing, transit, and land use data to estimate crash risk (i.e., the probability that a crash will occur in a given “exposure event”) throughout Seattle’s street network. The ultimate goal of the BPSA is to determine the statistical significance of factors associated with crashes and identify locations that exhibit these factors, therefore assumed to have a higher crash risk, so that we can proactively address these risks before they contribute to additional crashes.

2 Phase 1 analysis revealed that 70 percent of pedestrian crashes and nearly 60% of bicyclist crashes occur at intersections.

FIGURE 6: REFINED BICYCLE EXPOSURE MODEL VARIABLES

FIGURE 7: REFINED PEDESTRIAN EXPOSURE MODEL VARIABLES

FIGURE 8: BICYCLE SEGMENT ESTIMATED VOLUME ("EXPOSURE") MAP

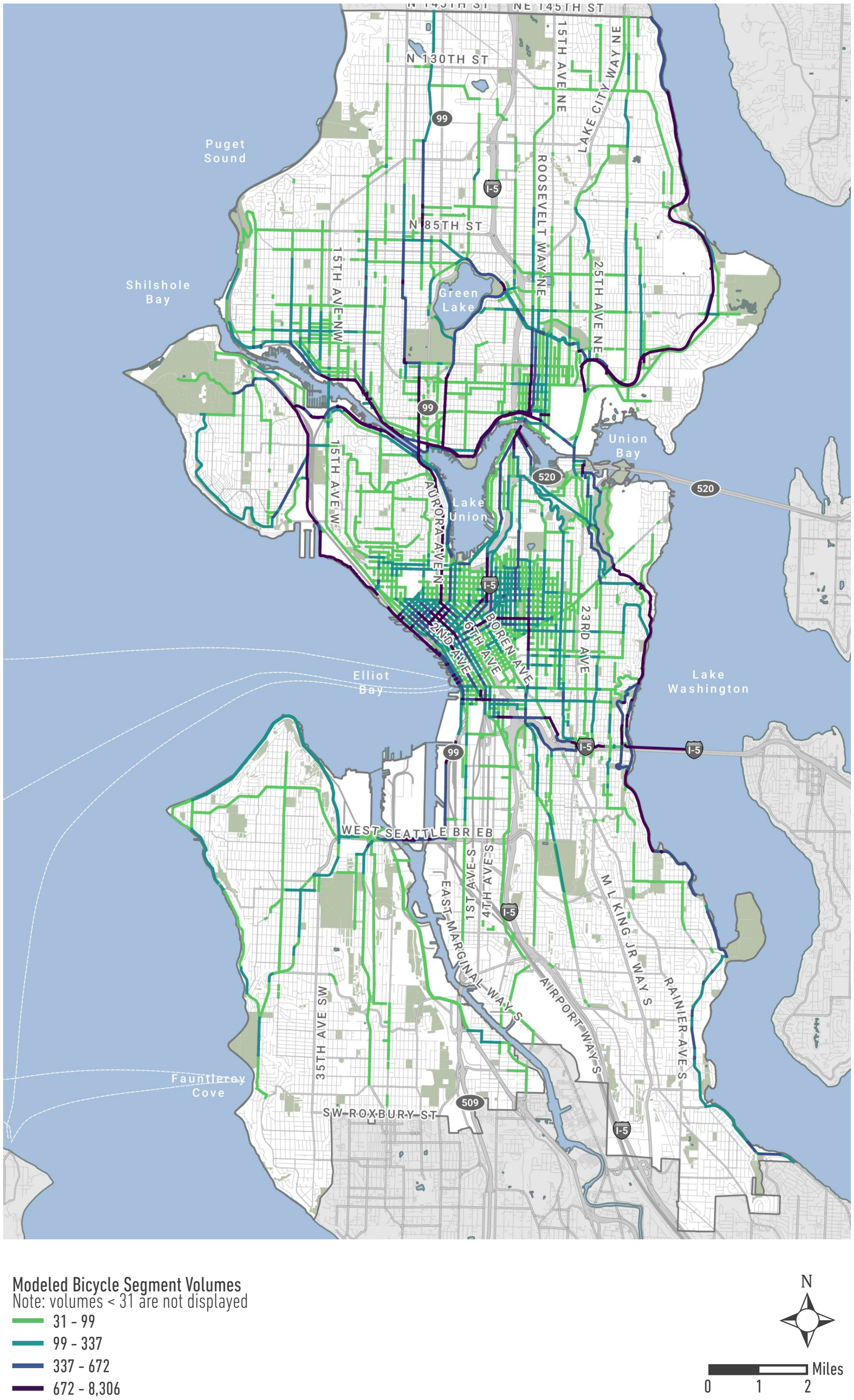


Figure 8 displays the results of the refined bicycle exposure model. The map shows the highest estimated bicycle volumes to be near the Central Business District, streets radiating from the Central Business District, and along shared use paths.

FIGURE 9: PEDESTRIAN INTERSECTION ESTIMATED VOLUME (“EXPOSURE”) MAP

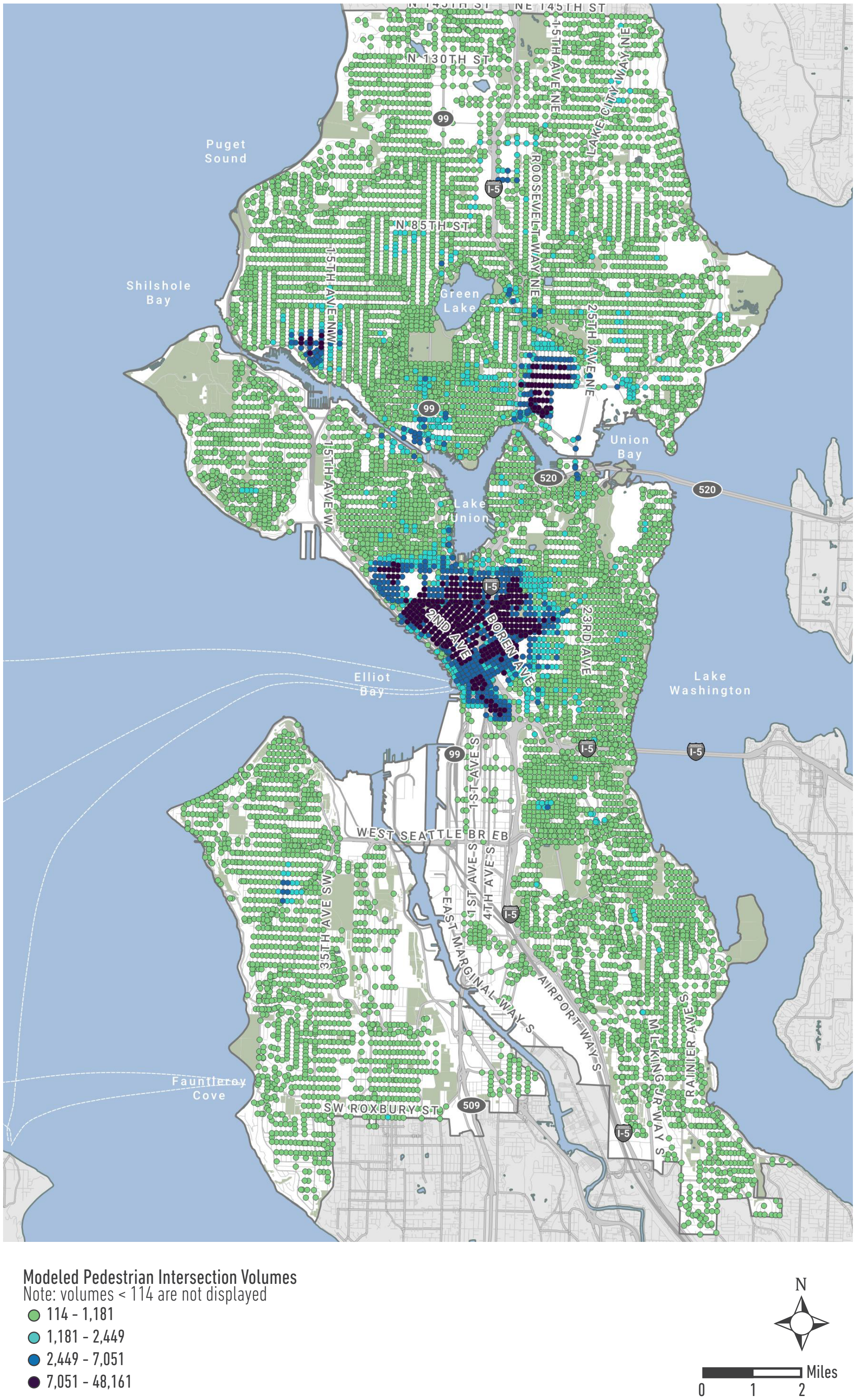


Figure 9 displays the results of the refined pedestrian exposure model. The map shows the highest estimated pedestrian volumes to be near the Central Business District University district, and Ballard neighborhood, which fits with expectations of where pedestrians are most expected. To a lesser extent, the business districts in Fremont and West Seattle also show moderately high volumes.

BICYCLIST SAFETY

We developed three statistical models to analyze and better understand the factors associated with bicyclist crashes. The models included all bicyclist crashes, opposite direction, and angle crashes. The City of Seattle has been steadily implementing projects that change the configuration of roadways including reducing the number of vehicle travel lanes and installation of bike lanes. While the models we developed incorporated crashes from 2010 to 2017, crashes that occurred on roadways that have since been reconfigured were excluded from our analysis.

The model of all bicyclist crashes included 1,041 crashes and nearly 12,000 intersections. Similar to the pedestrian crash model findings, we found that the **number of legs at an intersection** is positively associated with bicyclist crashes, although the presence of one-way legs at the intersection is negatively associated with bicyclist crashes. While all Urban Village[1] designations have a positive association with bicyclist crashes (relative to undesignated areas), the **Residential Urban Village** designation is the only designation with significant association. This could be due to the desire for people to bike on streets in these areas. For example, Eastlake Avenue, a well-traveled street with no dedicated bicycle infrastructure, passes through the appropriately named Eastlake Residential Urban Village. Another finding common to all three models is the **presence of a university** within a quarter mile of an intersection may be positively associated with additional risk.

FIGURE 11: BICYCLE CRASH TYPES USED TO BUILD STATISTICAL MODELS

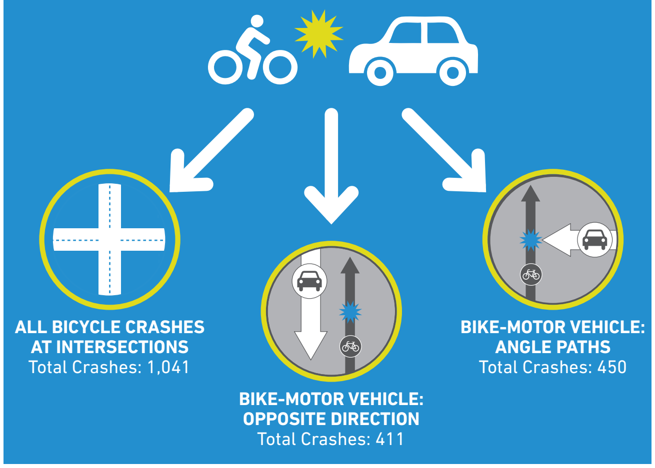
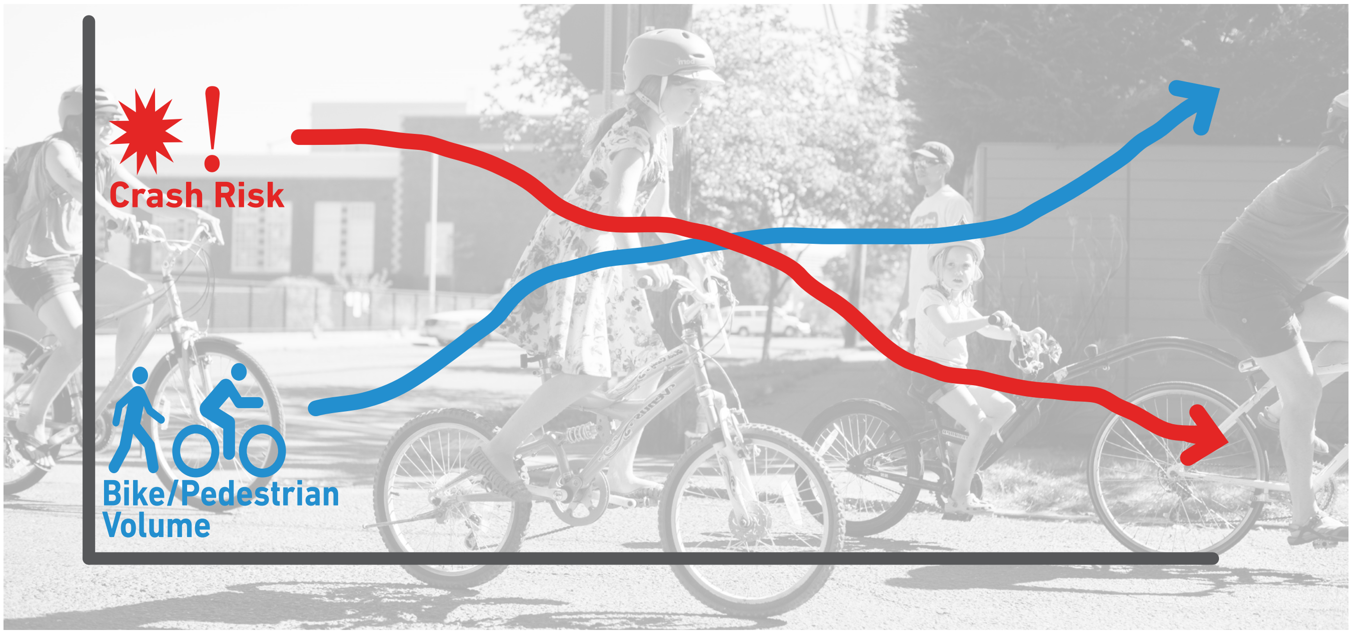


FIGURE 10: SAFETY IN NUMBERS EFFECT



1 A land use designation that reflects a package of built environment and transportation characteristics (e.g. denser, mixed use development, transit, etc); the designation itself is unlikely to have a direct influence on crash rates.

OPPOSITE DIRECTION CRASHES - KEY FINDINGS

Number of Legs
Intersections with more legs are positively associated with higher numbers of bicycle crashes.

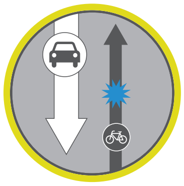
Bicycle Volume
As bicycle volumes increase, the number of bicycle crashes per capita decrease (safety in numbers effect).

Stop Signs
All-way stop-controlled intersections have lower crash risk than partially stop-controlled intersections.

Traffic Signals
Signalized intersections are likely associated with increased traffic exposure and conflicting movements.

High Traffic Volumes
Areas with higher vehicle volumes have fewer bicycle crashes, but also have lower bicycle volumes.

Urban Villages
The Urban Center Village designations were most associated (positively) with crashes, followed by the Hub Urban Village and Residential Urban Village designation.



Crashes involving motor vehicles traveling in opposite directions

We examined and developed a model for opposite direction bicyclist crashes with motor vehicles. As the name suggests, this category describes crashes in which the motorist and bicycle collided after initially traveling opposite directions due to turns by either the motorist or cyclist most typically, left turns by the motorist. This model included 411 bicyclist crashes and over 12,000 intersections. We found that as the number of bicyclists increases (i.e. greater exposure) crashes also tend to increase, though the number of crashes *per bicyclist* tends to decrease, implying a slight "**safety in numbers" effect** (Figure 10).

We also found that in areas with **higher vehicle volumes** bicyclist crash numbers trend downward. The reasons for this relationship are unclear, but may be associated with reduced bicycling in these areas that isn't fully reflected in the bicycle volume estimates. An area with very high motor vehicle traffic volumes may be perceived as too dangerous for bicyclists at a certain point, even if high automobile traffic is associated with other factors that would otherwise encourage bicycling use, such as dense land uses or a high density of destinations. The **Urban Center Village designation** was most associated with opposite direction crashes, followed by the Hub Urban Village and Residential Urban Village designation (relative to undesignated areas).

We found that several roadway design characteristics are associated with higher bicyclist crash risk. Most notably are the **number of legs entering the intersection** and **total number of through and non-through lanes entering the largest leg** of the intersection. **Intersections with five or more legs** exhibit the highest crash risk. By contrast, intersections with 5 or more legs was not significant in the pedestrian models, implying a unique safety concern for bicyclists. Five or more lanes on the largest leg of an intersection was positively associated with more opposite direction crashes when compared to the largest leg having one, two, three, or four lanes. We also found that the presence of bus lanes was positively associated with more bicyclist crashes. Lastly, we found that **fully stop-controlled intersections** (i.e., all-way) tend to have lower crash risk than partially stop-controlled and signalized intersections. Signalized intersections are likely associated with increased traffic exposure, and potentially conflicting movements. Partially sign-controlled locations or locations with no stop signs may also be more challenging for bicyclists and motorists on initial opposite paths due to turning movements.

ANGLE CRASHES - KEY FINDINGS

Number of Legs
Intersections with more legs are positively associated with higher numbers of bicycle crashes.

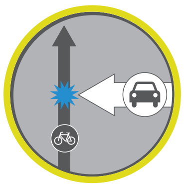
Crosswalks
All-way stop-controlled intersections have lower crash risk than partially stop-controlled intersections.

High Traffic Volumes
As motor vehicle traffic increases, angled crashes increase even when controlling for traffic volumes.

Bicycle Volume (Safety in Numbers)
We did NOT observe the safety in numbers effect. As bicycle volumes increases, so did the risk of angled crashes.

Shared Use Paths
Intersections with a shared use path were found to be positively associated with bicycle crashes.

Urban Villages
The Residential Urban Village was most associated (positive) with bicycle crashes, followed by Urban Center, Hub Urban Village, and Urban Center Village.



Angle crashes

The angle crash model includes crashes in which the motorist and bicyclist were on non-parallel paths at an intersection at the time of the crash. There were 450 crashes included in the model and over 12,000 intersections. We found that **as traffic increases, angled crashes increase** even when controlling for traffic volumes. Other variables that are likely associated with traffic volumes that had significant and positive associations with bicyclist crash risk include the **number of legs** entering the intersection, the **number of legs with an arterial designation**, and intersections involving a **raised median** on one or more legs. Intersections with these features may further contribute to crash risk by increasing the number of conflict points and complexity of intersection interactions, all else being equal. As the volume of bicyclists increases so too does the risk of angle crashes; in other words, **we did not see evidence of a safety in numbers effect for angle crashes**. The **Residential Urban Village** designation was most associated with angle path bicycle crashes, followed by Urban Center, Hub Urban Village, and Urban Center Village.

We found that there is a positive association of bicyclist crashes as the number of (marked) **crosswalks** at an intersection increases. While the reasons for this association are not entirely clear it could involve multi-modal interactions between bicyclists and pedestrians—assuming that intersections with more crosswalks are likely to be in pedestrian-heavy areas—that may lead to swerving or other types of conflicts with motor vehicles. It is also possible that the proportion of crosswalks is correlated with another factor, possibly unmeasured, that is associated with bicycle exposure to crashes. For example, crosswalks may be installed at locations reactively as a tool to address safety concerns.

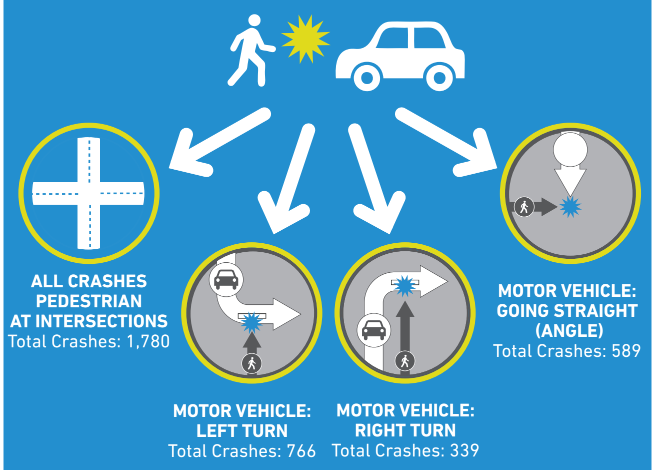
Lastly, we found that intersections with one or more **shared use paths** entering the intersection have a positive association with bicyclist crashes. This finding confirms research that has shown conflicts on shared use paths at intersections (and driveways) to be fairly common mainly due to the two-way operations of these facilities and motorists not expecting users coming from the opposite direction of traffic flow. Two-way protected bike lanes exhibit similar risks and we have been implementing effective strategies such raised crossings, conspicuous pavement markings and signage, active warning signals, and in some cases, signals to reduce these risks.

PEDESTRIAN SAFETY

We developed four statistical models to analyze and better understand the factors that are associated with pedestrian crashes. The models included all pedestrian crashes, crashes involving motorists turning left, crashes involving motorists turning right, and crashes involving motorists proceeding straight. An important finding that was common to all models is that in areas with higher numbers of people walking, the crash risk per walking trip is lower. This **safety in numbers effect** points to a positive trend: as we continue to grow as a city and more people walk to connect to transit and other daily needs (i.e., there is greater exposure to potential conflicts), the number of crashes per walking trip is decreasing. While this is a positive trend, much more needs to be done to improve pedestrian safety if we are to meet our Vision Zero goal.

Another finding common to all crash models was that the **intersection size**, including the number of lanes and number of legs, is positively associated with pedestrian crashes. **Functional classification**, particularly major and minor arterials, had a significant and strong association with pedestrian crashes, which is likely related to motor vehicle volumes (even when controlling for volumes, overall intersection size, speed, and complexity).

FIGURE 12: PEDESTRIAN CRASH TYPES USED TO BUILD STATISTICAL MODELS



We also looked at combinations of roadway types and found that intersections comprised of a **major arterial roadway and a non-arterial roadway** have a relatively strong and positive association with pedestrian crashes, more so than other combinations including non-arterial segments. These locations may be more likely to be characterized by uncontrolled crossings of the major arterial. These findings underscore the need to focus on safety improvements that promote predictability of all users, shorten pedestrian crossing distances, and provide more protection for people crossing the street.

LEFT TURN CRASHES - KEY FINDINGS

Protected Left Turn Signal Phase
Intersections with a protected left turn signal phase have lower “left hook” crash risk than permissive of protected/ permissive signal phases.

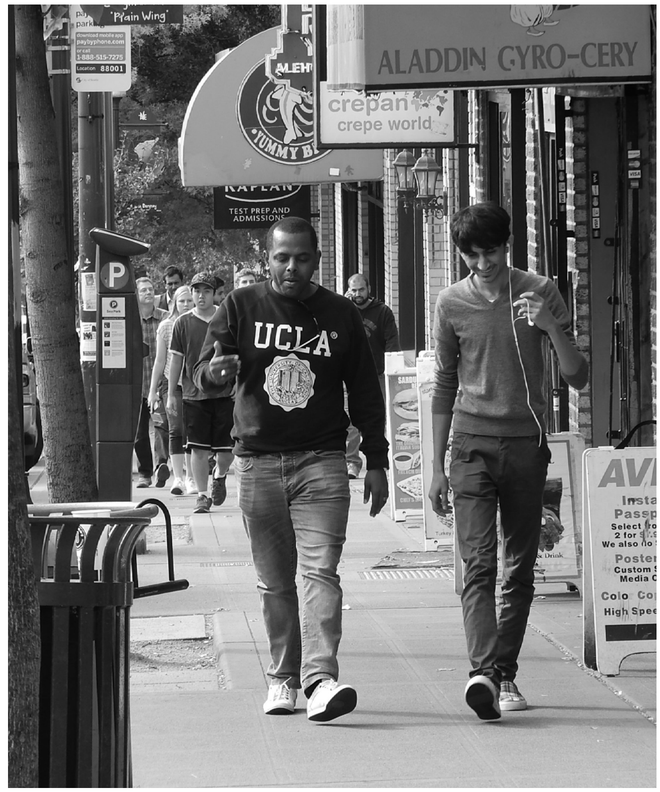
Striped Left Turn Lane
Intersections with striped left turn lanes are associated with lower risk of left hook crashes.

Speed Limit
Intersections with higher maximum posted speeds have a slightly positive association to left turn related crashes.

Crashes involving motorist turning left

Pedestrian crashes involving motorists turning left (often referred to as “left hook” crashes) can be more severe because left turning motorists have more critical decision points (oncoming traffic and two-way crossing pedestrians) and tend to accelerate on their approach to the crosswalk to avoid oncoming traffic. We looked at more than 750 left hook crashes and the roadway and operational characteristics of the locations where these crashes occurred to better understand what factors may be contributing to left hook crash risk.

Our analysis found that intersections with **protected left turn phases** (i.e., red, then green arrow) provide a safety benefit when compared to intersections with permissive phase only (i.e., no left-turn signal or red arrow) or protected/ permissive phase (i.e., green arrow, then flashing yellow, or green arrow, then green ball). We also found that **striped left turn lanes** are associated with lower risk of left hook crashes relative to intersections with no striped left turn lanes. While it is not clear whether this effect is directly attributable to the lane configuration (e.g., a center left turn lane alleviating motorist fear or pressure from vehicles approaching from behind), indirectly attributable to a possible correlation with protective signal phasing, or both mechanisms, this finding suggests that striping left turn lanes is an effective strategy for reducing pedestrian crashes involving left turning motorist, particularly when paired with protected-left signal phasing. This treatment may not be possible in many locations due to roadway constraints, but is a strategy we will consider, particularly in locations with heavier traffic volumes and a high number of pedestrians and bicyclists crossing the street perpendicular to the left turn motor vehicle movement.



We classified intersections by the **maximum posted speed** of any of the street legs adjoining the intersection and found that intersections with higher maximum posted speeds have a slightly positive association to left turn related crashes. This could have to do both with drivers making left turns at higher speeds and feeling greater “pressure” to make their turn, leading to rash gap-finding decisions. Higher speed limit segments are also likely correlated with higher functional class and motor vehicle volumes.

RIGHT TURN CRASHES - KEY FINDINGS

Transit Stops
Transit stops were found to have a positive association with right hook crashes.

Non-Through Lanes
Turn lanes and peak-hour bus lanes are positively associated with right hook crashes.

Arterial/Non-Arterial Intersections
Intersections of arterial streets and non-arterial streets had a strong and positive association with "right hook" crashes.

All-Way Stop Signs
All-way stop controlled intersections had a strong and positive association to crashes than partially stop-controlled intersections.

Crashes involving motorist turning right

Crashes involving motorists turning right are often referred to as "right hooks." We analyzed nearly 400 right hook crashes along with other factors associated with the crash locations to better understand what factors are most significantly associated with right hook crash risk. What we found is that **transit stops** have a positive association with right hook crashes. While our model attempt to control for exposure, this finding could point to higher exposure rates associated with transit than our exposure model estimated. It also might have to do with vehicles making right turns around stopped buses unable to see pedestrians in the crosswalk, or pedestrians crossing in front of stopped buses. While not always possible, locating bus stops at the far side of intersections or setting stops further back from the intersection may help to reduce the risk of right hooks near transit stops.

Right hook crash risk tends to be higher on arterial streets. For example, we found that streets with more **non-through lanes** (e.g., right turn lanes, left turn lanes, center left-turn lanes, and peak-hour bus lanes), are positively associated with right hook crashes. This could be due to the overall complexity of the intersection and/or the width of the intersection. We also found that intersections of **large arterial streets and neighborhood streets** had a strong association with right hook crashes. **All-way stop-controlled intersections** had a positive association with right hook crashes, more so than partially stop-controlled intersections. This could be due to right-turning drivers making their turn when they have the right-of-way relative to other drivers without adequately checking for crossing pedestrians.

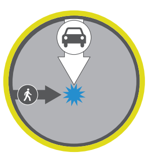
STRAIGHT CRASHES - KEY FINDINGS

Transit Stops
Transit stops were found to have a positive association with crashes, possibly related to multiple-threat scenarios.

Non-Through Lanes
Turn lanes and peak-hour bus lanes are positively associated with crashes.

Traffic Signals
Intersections with a traffic signal were found to have a positive association with crashes.

Stop Signs
All-way or partial-control (i.e. 2-way) stop controlled intersections have a strong and positive association to crashes.



Straight crashes

We analyzed nearly 600 crashes involving pedestrians and motorists proceeding at straight or perpendicular direction of travel at intersection locations with three legs or more. Similar to right hook crashes, the presence of **transit stops** have a positive association with these types of crashes, though the underlying reasons may have more to do with multiple-threat scenarios, where a pedestrian is attempting to cross the street in front of the bus, and a motorist does not see and safely stop for the crossing pedestrian. There is also a positive association with the number of **left turn lanes, right turn lanes, and peak-hour-bus only lanes**, which may also contribute to multiple threat scenarios and a higher estimated rate of these types of crashes.

We found that intersections with **partial** or **full stop control, or traffic signals**, have positive associations with these types of crashes relative to intersections without any kind of traffic control and that this association is strongest for full stop controlled intersections. The association with crashes and traffic signals may suggest either pedestrians or motorists are disobeying a traffic signal when they enter or exit the intersection.

PROTECTED BIKE LANE EVALUATION

Protected bike lanes (PBLs) are an important component of the Seattle bicycle network. The 2014 Seattle Bicycle Master Plan (BMP) emphasizes developing **a bicycle network that is safe and comfortable for people of all ages and abilities to use**. PBLs are among the bikeways identified in the Plan that have demonstrated safety benefits and provide a higher level of comfort (i.e. perceived safety). Since the BMP was adopted, SDOT has installed numerous PBLs and has continually evolved its design of these facilities. There have been few crashes on the PBL network relative to crashes citywide. Having few crashes makes it difficult to derive statistically valid findings from a crash analysis. So, while we did analyze crash data to better understand crash patterns, we also used video analysis to have a closer look at evasive and near miss interactions between bicyclists, pedestrians, and motorists.

Our PBL evaluation involved three primary steps. First, we developed a database of PBLs and available crash data from the last five (5) years, street characteristics, and estimated bicyclist, pedestrian, and vehicle volumes. We paid particular attention to the crash data, to code recorded collisions relative to the timing of PBL construction (i.e., “pre”, “during”, or “post”). We then developed descriptive statistics on bicycle, pedestrian, and vehicle crash numbers and patterns on the PBLs; these statistics serve as a snapshot of safety over time on the PBLs. Next, we used this analysis to identify PBLs with relatively higher numbers of crashes to identify locations for more in-depth study using video analysis.

Key findings from the crash analysis include:

- Most streets with PBLs saw a reduction in bicycle crashes when comparing before and after crash frequencies.

- Intersections with *both* a left turn lane and a protected left turn signal phase have lower crash frequencies than other intersection crashes.
- Two-way PBLs have had more crashes than one-way PBLs on a per mile basis. It should be noted, however, that most two-way PBLs are located in dense areas with generally more bicycling activity and motor vehicle traffic.
- Mid-block and driveway related crashes make up a relatively high share of crashes on two-way PBLs.
- When looking at solely the direction of travel, PBLs located on one-way streets have a lower number of crashes compared to two-way streets.

We conducted a video analysis at 6 locations, one of which (Eastlake Ave) currently does not have a PBL, but will in the future.

- 2nd Ave and Pike St
- 6th Ave and Pike St
- Dexter Ave N and Thomas St
- E Union St and Broadway
- Eastlake Ave E and E Edgar St
- Linden Ave N and N 135th St

We chose these locations based on context and wanting to evaluate a range of PBL intersection configurations (e.g. one-way, two-way, signalized/unsignalized, etc). We looked at three surrogate safety measures, including PET (post encroachment time)[3], collision severity measures such as road user type and arrival order, and evasive maneuvers[4]. This video analysis step added a nuanced understanding of the interactions between bicyclist, pedestrian, and motorist interactions and what conditions may be contributing to evasive maneuvers or near misses (i.e, interactions that could potentially contribute to a crash).

Key findings from the video analysis include:

- Most "close calls" or "near misses" (i.e., PET less than 3 seconds) happened between bicyclists and pedestrians, followed by bicyclist – motorists, and finally pedestrian – motorist.
- Close calls between bicyclist and motorists tend to be tend be more "severe", or closer to a near miss situation, possibly due to the speed at which bicyclists are traveling.
- In bicyclist-pedestrian interactions, we observed bicyclists were more likely to make an avoidance maneuver than pedestrians.
- The most common outcome was that the party who arrived in the intersection second made a maneuver to avoid the party that arrived first.
- In just under 20% of pedestrian-motorist and just over 30% of bicyclist-motorist interactions nobody made an avoidance maneuver. It is possible that both parties did not perceive the interaction to be risky, or that neither party noticed the "close call".
- In interactions between motorists and bicyclists when they were traveling in parallel direction of travel (same direction or opposite direction) tended to be closer than interactions with motorists and bicyclists on angled or perpendicular direction of travel.

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3 Post Encroachment Time (PET) is defined as the time between the moment when the first road user leaves the path of the second and the moment when the second reaches the path of the first.
4 Avoidance maneuvers include yielding, slowing, stopping, trajectory change, and speeding up.

WHAT ARE WE GOING TO DO WITH OUR FINDINGS?

Achieving our Vision Zero goal requires both a **proactive and reactive approach**. The power of the BPSA is in its ability to spatially identify locations that are a higher priority[1] for safety improvements so that we can proactively address safety issues ideally before a crash occurs. At the same time, we must also improve safety where crashes have already occurred, particularly locations with multiple serious and fatal crashes. Having a spatial understanding of where there are safety issues allows us to better plan for and implement safety improvements. For example, a corridor with multiple high-risk locations would be a good candidate for more corridor-wide safety improvements. We are also able to filter locations to inform other planning initiatives (See Figure 14). For example, we can filter by geographic area and demographics to further Seattle's Race and Social Justice Initiative, or by land use to inform area-wide planning efforts. The BPSA will continue to be referenced during SDOT's project development process so that proposed street designs and traffic operations address what are understood to be pedestrian or bicyclist safety issues.

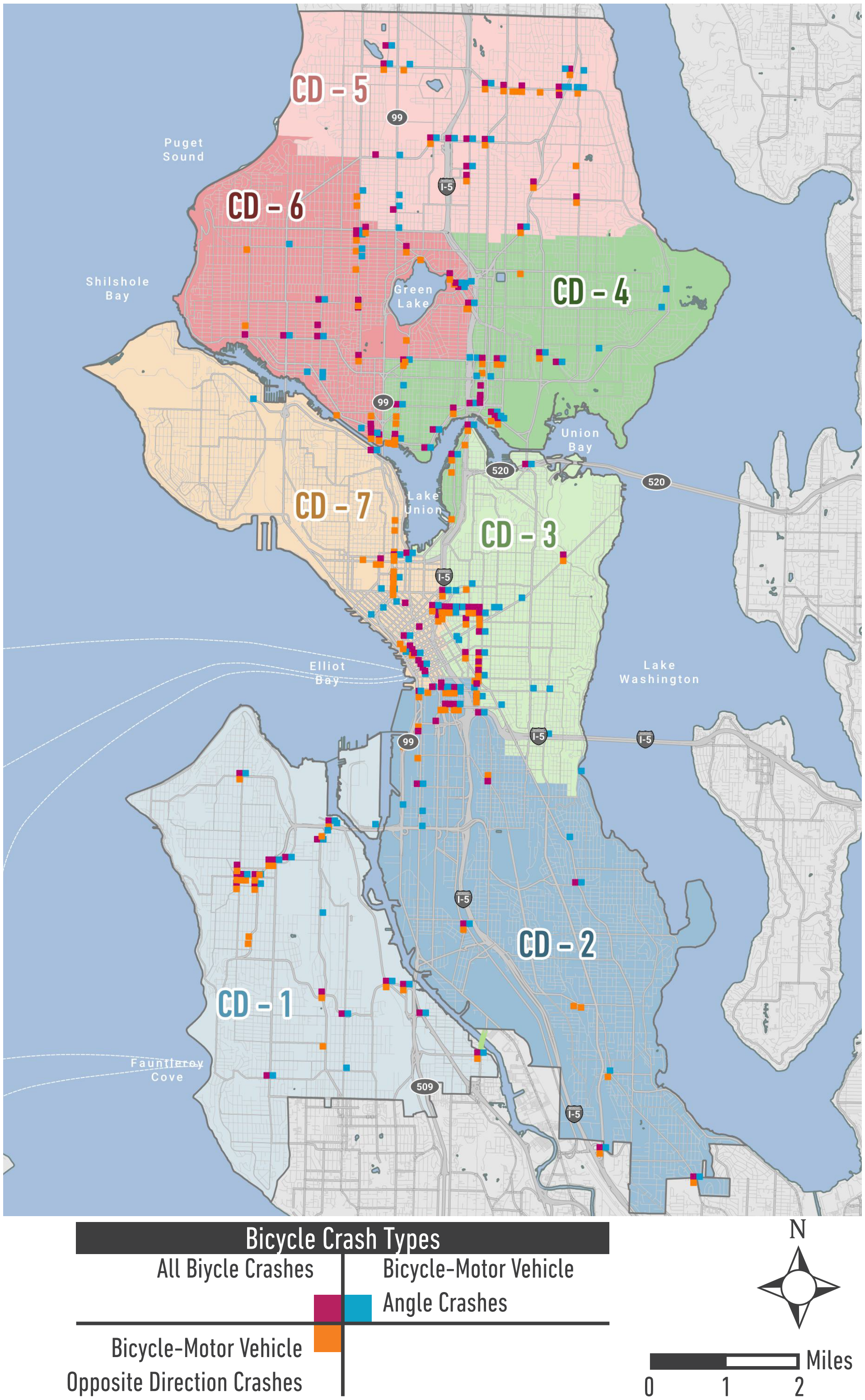
In addition to proactively improving street designs to reduce conflicts between pedestrians, bicyclists, motorists and other road users, we are also focused on education and enforcement. Many fatal and serious injury pedestrian and bicyclist crashes involve drivers traveling at unsafe speeds, or people not yielding or otherwise complying with traffic controls at intersections. While all of these behaviors, and the severity of crashes that might result from them, may be reduced through better street design, safety also depends on people understanding and complying with the law (e.g., speed limits, yielding, etc.). This is particularly true for distraction and impairment - two factors we know contribute to a significant number of crashes. SDOT and its partners, including the Seattle Police Department (SPD), King County, Commute Seattle, Cascade Bicycle Club, Seattle Neighborhood Greenways, and numerous corporate supporters, are focused on getting this message out to the public through safety campaigns, promotions, and even competition such as Seattle's Safest Driver. SPD and SDOT also coordinate regularly by sharing data that both inform enforcement priorities and where we need to focus safety improvements.

Achieving Systemic Safety: Leading Pedestrian Intervals

A central tenet of Vision Zero is taking a proactive, systemic approach to safety. A systemic safety approach focuses on cost-effective strategies to reduce risk system-wide. Leading Pedestrian Intervals (LPIs) are a systemic safety improvement that SDOT has installed, or plans to install at 120 locations in 2019. LPIs provide people walking a 3 to 7 second head start before motorists get a green light, putting them in a more visible position within the crosswalk. LPIs are relatively low-cost to implement and have been shown to reduce pedestrian-motor vehicle crashes by 60%.

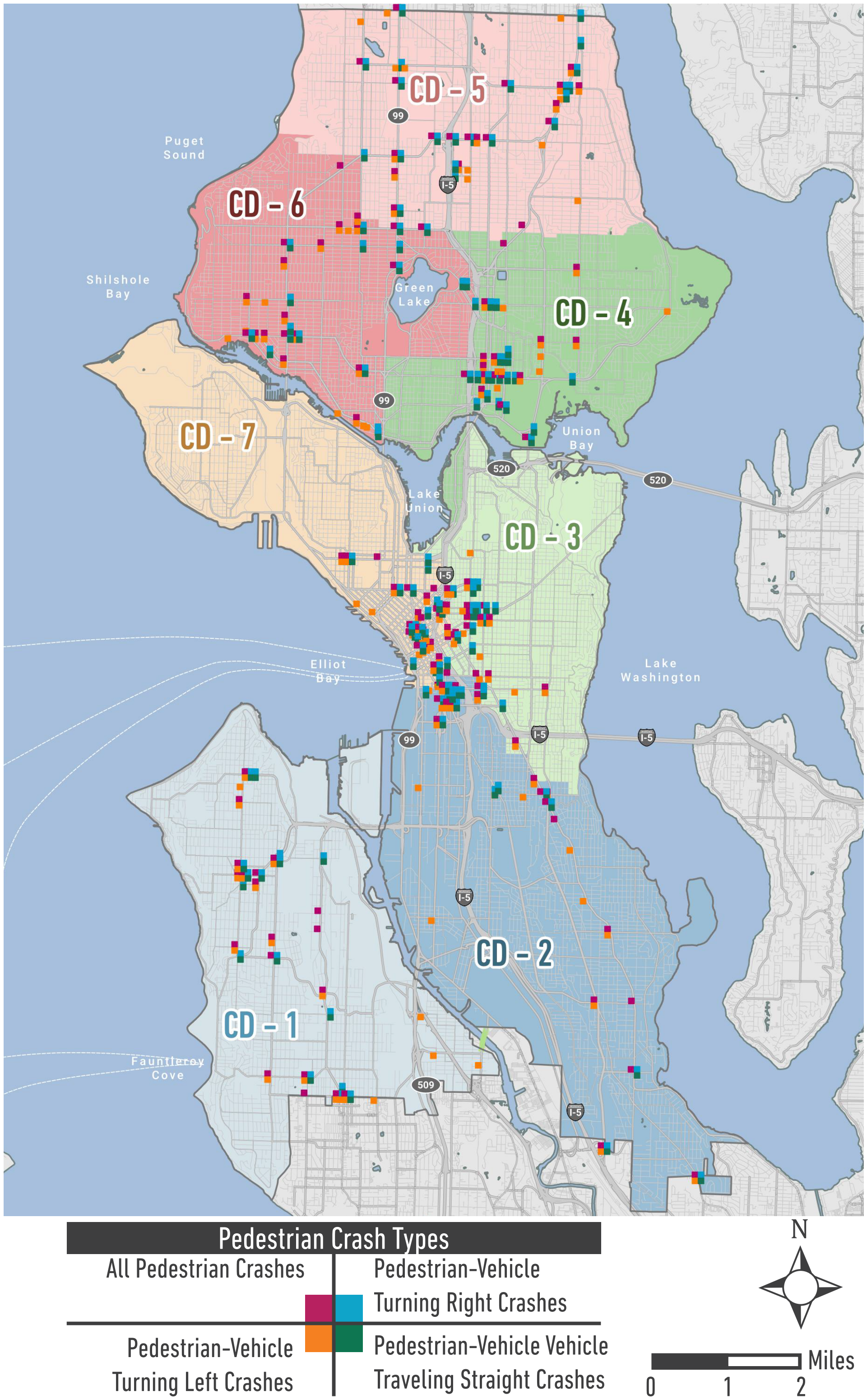
1 Higher priority indicates locations that exhibit one or more characteristics found to be significantly associated with bicyclist or pedestrian crashes and/or have a crash history.

FIGURE 13: TOP 20 PRIORITY BICYCLE LOCATIONS PER COUNCIL DISTRICT



This map illustrate our ability to use the the results from this analysis and prioritize locations throughout Seattle. These maps display the top 20 locations in every council district for each crash type discussed in this analysis.

FIGURE 14: TOP 20 PRIORITY PEDESTRIAN LOCATIONS PER COUNCIL DISTRICT



This map illustrate our ability to use the the results from this analysis and prioritize locations throughout Seattle. These maps display the top 20 locations in every council district for each crash type discussed in this analysis.

Next Steps

As Seattle continues to grow and there are ever-increasing demands on our streets, including greater numbers of people walking, biking and taking transit, we must continue to take a **proactive, multi-faceted approach to achieving Vision Zero**. We will use the results of the BPSA to identify and implement projects that enhance safety for people walking and biking and to inform enforcement and education initiatives.

Using better data, the analyses summarized in this report confirms many of our findings from Phase 1, and further contributes to our understanding of when, where, and how pedestrian and bicycle crashes happen. However, we know there is always room for refinement and new data-driven approaches to achieving Vision Zero. Additional analyses we will look to do in the near future include:

- Modeling pedestrian crashes at the crossing level rather than the intersection level to allow for more explicit consideration of factors such as the speed of the street being crossed, differences in expected exposure on each leg, and crosswalk markings. Our exposure model was developed at the crosswalk level, however we have some work to do to reconcile crashes with unmarked crosswalk locations.
- Developing crash frequency by severity models. Simultaneously modeling the number of crashes of different severity levels is a significantly more complex statistical problem than simply modeling the number of crashes, but if a reliable model were developed it would be useful for prioritizing locations based on the overall estimated injury burden, rather than simply the number of crashes.

FIGURE 15: IMPLEMENTATION DIAGRAM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