City of SeaTac Local Road Safety Plan

February 2022

Contents

Cover photo: Aerial View of SeaTac, featuring Angle Lake, Credit: ImogenCaroline, License:

Introduction

What is Vision Zero?

Vision Zero is a traffic safety philosophy based on the central belief that no one should be killed or severely injured by traffic crashes. Sweden pioneered the Vision Zero approach in the 1990s and the changes they made based on its principles reduced their national traffic fatalities by half. Since then, more than 50 cities and counties across the United States have adopted Vision Zero as the core of their approach to traffic safety, including Seattle, Tacoma, Portland, New York, San Francisco, Chicago, and Los Angeles. Crashes are neither inevitable nor acceptable, and thirty years of safety research and practice have proven that, with the right commitments and actions, communities can come together to prevent fatal and life-altering crashes. Figure 1 outlines Vision Zero principles and how they differ from the traditional approach to traffic safety.

Figure 1: Traditional Approach to Traffic Safety Compared to Vision Zero Approach

TRADITIONAL APPROACH	VISION ZERO
Traffic deaths are INEVITABLE	Traffic deaths are PREVENTABLE
GEOGRAPHIC EQUALITY in resource allocation	EQUITABLE investment to address disparities
PERFECT human behavior	Integrate HUMAN ERROR into approach
Prevent COLLISIONS	Focus on preventing FATAL AND SEVERE INJURY CRASHES
INDIVIDUAL responsibility, enforced through TRAFFIC STOPS	COLLECTIVE RESPONSIBILITY based on SAFE SYSTEMS approach

Purpose of the Local Road Safety Plan

The Local Road Safety Plan (LRSP) provides a basis for systemic safety improvements along a roadway network. The process of preparing the LRSP creates a framework to systematically identify, analyze, and understand safety issues, then use this knowledge to recommend improvements through a prioritized list of projects. Rather than solely focusing safety improvements at locations where collisions have occurred, the LRSP approaches collision reduction using a systemic safety approach that recommends project locations based on high-risk roadway features correlated with specific serious collision types. LRSPs allow cities to understand the types of crashes that are taking place along roadways in their jurisdiction and enable a plan for data-driven safety decisions. In addition, LRSPs can be used for coordination across city agencies and are required to qualify for funding sources including the Highway Safety Improvement Program (HSIP). A LRSP is made up of seven discrete steps that are outlined in Table 1.

Table 1: LRSP Development Process

	WSDOT Local Road Safety Plan (LRSP) Step	Section in This LRSP
1	Analyze crash data to identify priorities	Descriptive Analysis (p. 12) and Crash Tree Analysis (p. 33)
2	Analyze individual fatal and severe injury crashes to identify risk factors	
3	Select most common or critical risk factors	
4	Analyze roadway network for presence of factors	Roadway and Environmental Characteristics (p. 17)
5	Create a prioritized list of roadway locations where factors are present	Risk Factor Locations (p. 44)
6	Identify countermeasures to address prioritized locations	Countermeasure Toolbox (p. 46)
7	Develop a prioritized list of projects	Project Prioritization (p. 58)

Limitations on Use

Under 23 U.S. Code § 409 and 23 U.S. Code § 148, safety data, reports, surveys, schedules, lists compiled or collected for the purpose of identifying, evaluating, or planning the safety enhancement of potential crash sites, hazardous roadway conditions, or railway-highway crossings are not subject to discovery or admitted into evidence in a Federal or State court proceeding or considered for other purposes in any action for damages arising from any occurrence at a location mentioned or addressed in such reports, surveys, schedules, lists, or data.

Information contained in this document is for planning purposes and should not be used for final design of any project. All results, recommendations, concept drawings, cost opinions, and commentary contained herein are based on limited data and information and on existing conditions that are subject to change. Further analysis and engineering design are necessary prior to implementing any of the recommendations contained herein. Geographic and mapping information presented in this document is for informational purposes only, and is not suitable for legal, engineering, or surveying purposes. Data products presented herein are based on information collected at the time of preparation. Toole Design Group, LLC makes no warranties, expressed or implied, concerning the accuracy, completeness, or suitability of the underlying source data used in this analysis, or recommendations and conclusions derived therefrom.

Opinions of probable cost were developed by identifying major pay items and establishing rough quantities to determine a rough order of magnitude cost. Additional pay items have been assigned approximate lump sum prices based on a percentage of the anticipated construction cost. Planning-level cost opinions include a contingency to cover items that are undefined or are typically unknown early in the planning phase of a project. Unit costs are based on 2021 dollars and were assigned based on historical cost data from the Seattle Department of Transportation, FHWA, and other sources. Cost opinions do not include easement and right-of-way acquisition or the cost for ongoing maintenance. The overall cost opinions are intended to be general and used only for planning purposes. Toole Design Group, LLC makes no guarantees or warranties regarding the cost estimate herein. Construction costs will vary based on the ultimate project scope, actual site conditions and constraints, schedule, and economic conditions at the time of construction.

SeaTac Citywide Crash Analysis

Identification of Potential Risk Factors

This section summarizes the results of the crash analysis element of the City of SeaTac LRSP. The crash analysis aims to systematically analyze fatal (i.e., "Killed") and serious injury (KSI) crashes that have occurred throughout the City of SeaTac using a data-driven approach that identifies systemic safety issues.

The general process began with data consolidation, crash data contextualization, and a descriptive crash analysis. A series of high-level descriptive summary tables capture relationships between citywide crash data, infrastructure data, and contextual variables. These tables explore overall crash trends that are a useful guide for the selection of variables warranting deeper analysis. Crash Trees were developed for the top crash types. Crash types are constructed using crash location, reported pre-crash motor vehicle movements, and location types (e.g., segment, signalized intersection, stop-controlled intersection). Crash Trees are used to identify countermeasures for the top crash types. Following the identification and analysis of high-risk factors, the transportation network was screened to identify where high-risk factors are present. Lastly, locations with high-risk factors present were prioritized and recommended for consideration for countermeasure selection and project development.

Washington State Department of Transportation's (WSDOT) *Strategic Highway Safety Plan (SHSP): Target Zero* lays out an ambitious vision for the State of Washington: zero traffic-related fatalities and serious injuries on Washington's roadways by 2030. The SHSP notes a statewide increase in traffic fatalities (23 percent) and serious injuries (7 percent). The SHSP provides state, regional, and local agencies a clear and action-based plan to eliminate KSI crashes using data-driven decision making and implementing new and innovative systemic safety analysis approaches. The Highway Safety Improvement Program allows state and local agencies to target safety funds for projects to address their most critical safety related needs. WSDOT provides project funding through their County and City Safety Programs to agencies that have safety goals that align with Target Zero and have their own LRSP. The LRSP must address fatal and series injury crashes and systemic safety needs in order for the LRSP to be considered eligible for funding.

City of SeaTac Safety Related Goals from Other Planning Efforts

In addition to supporting state safety goals, the development of the LRSP supports many of the traffic safety related goals included in SeaTac's Comprehensive Plan and Transportation Master plan (see goals listed below):

Transportation Element of the Comprehensive Plan

- **GOAL 4.1** For the benefit of SeaTac's residents, businesses, and visitors, promote the safe and efficient transport of people and goods by implementing and maintaining an integrated multi-modal transportation system that also supports and encourages alternative and active transportation modes.
- **GOAL 4.2** Develop and maintain an arterial street and highway system that reduces the adverse impact of regional and airport traffic on City arterials, and cost-effectively improves safety for all travel modes, manages congestion to reduce delays and the impacts of traffic diverting through neighborhoods, and enhances the look and feel of the City.
- **GOAL 4.3** Design and operate neighborhood streets to maximize safety of all appropriate travel modes, reduce cut-through traffic, and enhance the look and feel of the City's transportation system in a cost-effective manner.

- **Policy 4.4A** Promote safe pedestrian movement as a basic means of transportation and assure adequate pedestrian facilities, amenities, and connections are provided for in conjunction with other transportation facilities and developments.
- **Policy 4.4C** Work to design and construct arterials to include safe and attractive pedestrian facilities (including crossings) on both sides of the street.
- **Policy 4.4E** Prioritize safety and pedestrian capacity improvements on streets that provide access to schools, parks, transit facilities, public facilities, and within the Urban Center.
- **Policy 4.4F** Develop and implement criteria for installing pedestrian crossing treatments and appropriate traffic controls to improve safety and comfort throughout the City.

Transportation Master Plan

Referenced goals from the Safe & Complete Streets Plan, as summarized in the TMP:

- **Improve safety.** Providing non-motorized facilities gives pedestrians and bicyclists a safer space to travel.
- **Support Safe Routes to Schools**. Improvements throughout the City focus on creating pedestrian facilities where students could safely get to schools, including McMicken Heights Elementary, Madrona Elementary, and Bow Lake Elementary.
- **Fill-in missing gaps.** In order for more people to choose walking or bicycling as a means of travel there needs to be infrastructure for them to get where they need to go.
- **Reduce barriers to non-motorized travel.** Barriers to walking and biking can be natural (such as a river or steep grade) or man-made (such as a freeway or a building). Reducing the barriers helps make non-motorized travel an easier and more convenient choice.

Summary of Key Findings from Crash Analysis

This analysis is made up of three primary components: data consolidation, descriptive analysis, and a screen of the roadway network for high-risk factors. The key findings from the descriptive analysis and the network screen are summarized below.

Descriptive Analysis

In alignment with WSDOT's LRSP guidance, this crash analysis approach focused on systemic safety issues and prioritizes crash risk related to KSI crashes. High-risk factors were identified through a descriptive analysis. The following crash types and factors were found in the majority of KSI crashes:

- **Crashes involving at least one pedestrian** accounted for the largest share of KSI crashes compared to all other modes and crash types
- **Motor vehicle striking fixed object** crash types had the second largest share of KSI crashes
- Crashes involving **motor vehicle(s) traveling straight** prior to crash (i.e., not turning left or right)
- Crashes that occurred **at intersections, particularly signalized intersections**
- Crashes **along or at intersections with principal arterials or minor arterials**
- Crashes that occurred at location **during dark lighting condition but with streetlights turned on**
- **Streets with 35+ mph speed limits, more specifically 40+ mph**
- Crashes at **intersections with a bus stop**

- Streets with **cross sections at least 60 feet wide, more specifically streets at least 80 feet wide**
- Streets with **more than 5 through lanes** (specifically along International Boulevard)
- **International Boulevard has the largest share and density of KSI crashes**

A descriptive Crash Tree analysis was conducted for the top 5 crash types (5 branches) based on the number of KSI crashes. Only the branches for the top 2 crash types are summarized in this LRSP as the lower 3 did not provide additional insight into where KSI crashes occurred due to the low sample size of KSI crashes.

Pedestrian Crashes with a Vehicle Going Straight at Intersections

Signalized intersections, along principal arterials, with any approach leg between 80-89 feet wide, and had a posted speed limit of 40 mph were found to have a high number of KSI crashes per number of matching intersections.

Fixed Object Crashes with Vehicle Going Straight at Intersections

Signalized intersections, along principal arterials, with a posted speed limit of 40 mph, and with the largest leg having a total of 5 through lanes were found to have a large number of KSI crashes per number of matching intersections.

Network Screen and Location Prioritization

The roadway network was systematically analyzed and screened to identify locations with high-risk factors that were identified during the descriptive analysis. Locations were prioritized based on the overall number of risk factors present. The high-risk factors include:

- Signalized intersections
- Posted speed 40+ mph
- Bus stop at intersection
- Principal arterial or minor arterial functional classification
- Largest leg at intersection is at least 80 feet wide
- There have been 50 or more crashes in the last 5 years

The prioritization results can be viewed in Table 24 and Map 4.

Analysis Methodology

This section describes the steps taken to assemble the working datasets, as well as the analytical framework used to develop the summary statistics. It presents descriptive statistics (frequencies and percentages) of crashes stratified by various attributes including injury severity, environmental conditions, behaviors, movement types, etc.

The analyses reported here do not adjust for exposure rates, so the results should be interpreted carefully to understand why certain patterns may emerge. For example, in many communities, pedestrian crashes are more common during daylight conditions than dark conditions. This does not mean that daylight conditions are more dangerous than dark conditions; rather, it reflects the fact that people are more likely to travel, and especially more likely to travel by walking, in light conditions than in dark conditions. Looking at relative crash severity within a category can help the reader understand these dynamics. In the aforementioned daylight/dark example, the percentage of crashes under each lighting condition that are severe versus non-severe provides a better indicator of how the environmental condition impacts safety than relative frequency of occurrence.

Crash data

Geocoded crash data is critical to understanding collision patterns. Police reports of collisions are the primary source for crash data. While this data is known to have problems with underreporting[1, 2], it is often the most complete data source and provides necessary details for informing engineering treatments, such as the location of the collision and dynamics between the parties involved in the crash.

Crash data used in this analysis was provided to the consultant team through submitting a data request on the City of SeaTac's behalf to WSDOT. Crash data was requested for all crashes that occurred within the City of SeaTac from 2015 through July 2020 for all modes. For the purposes of this analysis, the consultant team coded cashes that involved at least one pedestrian as a pedestrian crash, bicycle crashes involved at least one bicyclist and no pedestrians, motor vehicle crashes did not involve any pedestrians or bicyclists, and a motor vehicle crash involving only one motor vehicle and no other modes was coded as a solo motor vehicle crash.

WSDOT's crash data and attributes are sourced from Police Traffic Collision Reports (PTCR). Data derived from specific PTCR attributes (e.g., officer's narrative and diagram) are identified and included in the WSDOT crash data to support safety analysis and engineering[3].

The crash data provided by WSDOT does not provide the full datasets for the incident, unit, and party tables. Reported information such as crash location, date/time, injury severity, weather/lighting/roadway conditions, and select behavioral factors were included in the crash data used in this analysis. The crash data did not have information related to pedestrian action and pedestrian locations. The consultant team queried Washington State Patrol's (WSP) crash data to supplement the WSDOT crash data with the pedestrian action and location attributes. It should be noted that the WSP Collision Analysis Tool that stores raw crash data has not undergone

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[1] Stutts, J., & Hunter, W. (1998). Police reporting of pedestrians and bicyclists treated in hospital emergency rooms. Transportation Research Record: Journal of the Transportation Research Board, (1635), 88-92.

[2] San Francisco Department of Public Health-Program on Health, Equity and Sustainability. 2017. Vision Zero High Injury Network: 2017 Update – A Methodology for San Francisco, California. San Francisco, CA. Available at: https://www.sfdph.org/dph/files/EHSdocs/PHES/VisionZero/2017_Vision_Zero_Network_Update_Methodology_Final_20170725.pdf

[3] https://www.wsdot.wa.gov/mapsdata/crash/crashdatafaq.htm

any quality assurance by WSP. For a full list of attributes that are recorded in PTCR data, please review the Washington State Police Traffic Collision Report Instruction Manual (updated January 2020)[4].

The crash data used in this analysis was reviewed and assessed by the consultant team for accuracy and consistency. Crashes were removed from this analysis if the crash had missing spatial coordinates, occurred in a parking lot[5], or was located along limited access roadways (see Table 2).

Table 2: Crashes Removed from Analysis Dataset

Criteria	**# of Crashes**	**% of Crashes**
Missing coordinates	120	1.82%
Occurred along freeway or limited access road	2,750	41.7%
Crashes used in this analysis	3,879	59.1%
All Crashes (raw data received from WSDOT)	6,597	100%

Network Data Consolidation

The purpose of data consolidation is to allow for analysis of transportation system attributes at the location of each individual crash in the dataset. Many of the network attributes being consolidated and joined to the crash data are not collected in the PCTR or have accuracy issues in those reports.

For crashes occurring at non-intersection locations (segments), attributes were spatially joined directly from nearby roadway data to the crashes. For intersection crashes, the consultant team built and populated a dataset of intersections throughout the City of SeaTac, aggregated attributes from roadway segments, and then joined intersection data to crashes within 150 feet of the intersection centroid. This allowed the consultant team to measure nuanced or complex concepts like the differential of speeds or number of lanes (street width was used as a proxy) coming together at an intersection. The following sections describe the consolidation process and resultant variables.

[4] https://www.wsp.wa.gov/wp-content/uploads/2020/01/2020-Police-Traffic-Collision-Instruction-Manual-Tenth-Edition.pdf

[5] **Crashes that occurred in parking lots were removed by WSDOT staff as part of their quality control process. The number of removed crashes was not available at the time of this analysis.**

Consolidated Street Centerline Dataset

To contextualize the crash data, the consultant team assembled and analyzed a spatial dataset using various roadway characteristic datasets. The City of SeaTac provided the consultant team with several GIS datasets used in this crash analysis to contextualize the crash data with roadway attributes not provided in the crash data. Table 3 summarizes the datasets consolidated to form the single centerline dataset.

Table 3: Consolidated Street Centerline Data

Dataset	**Variable**	**Notes**
City of SeaTac Centerline	Functional Classification	Type of roadway functional classification
City of SeaTac Centerline	One-way	Type of one-way street
King County Transportation Network	Posted Speed Limit	Posted speed limit validated and revised using Google Street View at some locations
Pedestrian Network	Sidewalk Coverage	Sidewalk coverage by side of street.
Pedestrian Network	Driveways	Number or driveways by side of street
City of SeaTac Street Truck Routes	Truck Route	Yes/No if truck route is along the street
City of SeaTac Landscaped Areas	Median	Medians with landscaping
City of SeaTac	Median	Paved medians without landscaping
City of SeaTac Centerline	Long Block Length	Length of segment is > 600 feet
City of SeaTac Centerline	Pavement Condition Index	Condition of roadway surface
Aerial Imagery	Number of Through Lanes	Number of striped through lanes mid-block along International Blvd. Does not include additional lanes added near intersections as those are related to intersection crashes
City of SeaTac Centerline	Street Width	Average street width along a block

Consolidated Intersection Dataset

An Intersection Dataset was developed and derived from the Street Centerline Dataset by the consultant team. Several roadway characteristic datasets were joined to the Intersection Dataset such as traffic control devices and crosswalk types. Most of the variables joined to the Intersection Dataset were either joined from the consolidated Street Centerline Dataset or were derived from the Centerline Dataset.

The consultant team calculated variables for intersection leg attributes (e.g., street width, widest street width per leg, highest and lowest speed limit at intersection, etc.) as follows. First, the team generated a 50-foot radius around the intersection centroid. Then a point was created for each intersection approach where the street centerline features intersect the radius (see example in Figure 2). Intersection leg attributes were then consolidated to the approach points. Attributes from the consolidated Street Centerline Dataset (Table 3) were then consolidated onto these points to represent the segment attributes along each leg of the intersection. Table 4 outlines the consolidated variables onto the intersection dataset.

Figure 2: Example Data Points Along Legs at Intersections

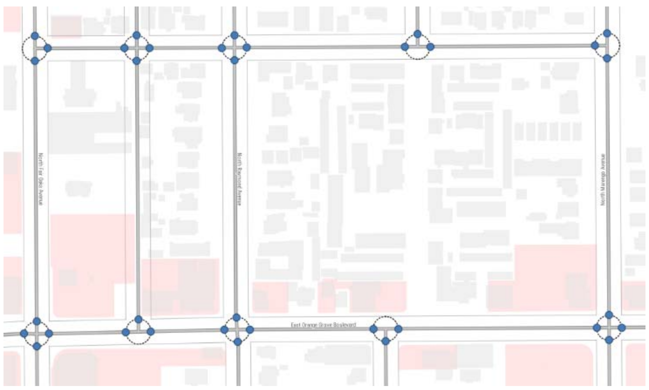


Table 4: Consolidated Intersection Data

Dataset	Variable	Notes
City of SeaTac Centerline	Number of Legs	Number of legs at intersection
City of SeaTac Street Signals	Traffic Signals	Presence and type of signal at intersection
Derived from intersection dataset and City of SeaTac Street Signals	Distance to Nearest Signalized Intersection	Euclidean distance to the nearest signalized intersection along International Blvd
Derived from intersection dataset	Distance to Nearest Intersection	Euclidean distance to the nearest intersection along International Blvd
City of SeaTac crosswalks	Marked Crosswalks	Number of legs with a marked crosswalk. Number of marked crosswalks that cross International Blvd were also calculated
King County Transportation Network	Posted Speed Limit	Posted speed limit per leg and highest and lowest posted speed limit present at the intersection
City of SeaTac Pedestrian Network	Driveways	Number or driveways by side of street
City of SeaTac Centerline	Functional Classification	Number of legs by functional classification, higher functional classification, and lowest functional classification
City of SeaTac Pavement Areas	Median	Number of legs with a median
City of SeaTac Curb Ramps	Curb Ramps	Number of curb ramps
City of SeaTac Signal Push Button	Pedestrian Push Buttons	Number of pedestrian push buttons
City of SeaTac Centerline	Street Width	Largest and smallest legs and aggregate street width at intersection
Aerial Imagery	Through Lanes	Total number of through turn lanes per leg and aggregate total at intersection. Only available along International Blvd
Aerial Imagery	Lett Turn Lanes	Total number of left turn lanes per leg and aggregate total at intersection. Only available along International Blvd
Aerial Imagery	Right Turn Lanes	Total number of right turn lanes per leg and aggregate total at intersection. Only available along International Blvd
Aerial Imagery	Total Number of Lanes	Total number of lanes per leg, aggregate total at intersection, and largest leg by number of lanes. Only available along International Blvd

Descriptive Crash Analysis

This section provides summaries of reported crashes within the City of SeaTac using the officer-reported attributes and the contextualized attributes outlined in the previous section. The primary goal of this descriptive analysis is to identify high-risk factors that are associated with KSI crashes.

This section is organized into three sections. The first section describes general trends and temporal attributes such as crashes by year and crash frequency by injury type. The next section summarizes crashes on roadway and environmental attributes such as intersection control, posted speed limit, and lighting conditions. The final section summarizes crashes based on reported behaviors such as the movement types preceding the crash and violation types. The roadway and crash attributes have been analyzed in this section will help inform what variables will be examined further through the development of Crash Trees.

The priority of the SeaTac LRSP is to focus on reducing or eliminating KSI crashes. Most tables in this section will include figures summarizing the number of crashes, KSI crashes, and Equivalent Property Damage Only (EPDO) scores. The EPDO scores weigh crashes according to the highest severity injury sustained in the crash by converting each crash to an equivalent number of Property Damage Only (PDO) crashes. For example, a crash that results in a possible injury is equivalent to approximately 10 PDO crashes, whereas a fatal crash is equivalent to approximately 231 PDO crashes. These EPDO factors are informed by the comprehensive societal costs of crashes and are scaled relative to PDO comprehensive crash cost estimates. The EPDO technique is utilized because normalizing crashes to a base unit in this way allows crashes to be easily compared. Additionally, subcategories of crashes can be compared based on the average EPDO score by crash factor to identify which factors resulted in higher severity injuries. Total EPDO scores are a measure of overall crash intensity and the average EPDO score per crash is a measurement of average crash intensity/severity. See Table 5 for the comprehensive crash costs for each crash severity provided by WSDOT.

Table 5: WSDOT Crash Costs Estimates (2020 Values)

Crash Severity	EPDO Score	Comprehensive Crash Cost
Fatal (K)[6], Suspected Serious Injury (A)	231.31	$3,423,400
Suspected Minor Injury (B)	16.04	$237,400
Possible Injury (C)	9.61	$142,300
Property Damage Only (PDO)	1.0	$14,800

[6] Letters within the parenthesis refer to injury severity levels used by WSDOT (KABCO scale)

General Crash Trends

The following sections summarize the January 2015 through July 2020 crash data to provide insight into temporal patterns. Rows that are particularly insightful or are considered high-risk factors are highlighted in purple.

Crashes by Year

Table 6 summarizes crash frequency for crashes by year. Aside from minor year-to-year fluctuations in KSI crashes, all injury crashes, and EPDO scores, crash frequencies are relatively evenly distributed during the analysis period showing little to no discernable pattern. No noticeable downward or upward trend is present. 2019 had the lowest crash frequency for all crashes (n=644), and highest KSI crashes (n=20). Crashes during this year tended to be more severe, with crashes having an average EPDO score of 11.14.

Table 6: Crashes by Year, All Modes, 2015-20020

Year	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes
2015	14	16%	2.1%	6,130	17%	9.39	653	17%
2016	19	22%	2.4%	7,596	21%	9.76	778	20%
2017	14	16%	1.7%	6,451	18%	7.76	831	21%
2018	14	16%	1.9%	6,157	17%	8.58	718	19%
2019	20	23%	3.1%	7,176	20%	11.14	644	17%
2020[7]	7	8%	2.7%	2,684	7%	10.52	255	7%
Total	**88**	**100%**	**2.3%**	**36,193**	**100%**	**9.33**	**3,879**	**100%**

[7] **Crash data was not available for all of 2020. Only crashes that occurred between 2015 through July 2020 are included in this analysis.**

Crash by Mode

Table 7 summarizes crash frequencies for each mode[8]. Motor vehicle crashes accounted for the largest share of all crashes (87 percent) and EPDO score (58 percent). However, when looking at KSI crashes, pedestrian crashes accounted for the largest share of KSI crashes (41 percent) but only 4 percent of crashes. This imbalance of overall crashes to KSI crashes highlights the vulnerability of pedestrians when involved in a crash. On average, 26.3 percent of pedestrian crashes resulted in a KSI crash and had an average EPDO score of 69.81, both of which are the highest of any mode by a substantial margin.

Table 7: Crashes by Injury Severity and Mode, 2015 - 2020

Mode	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes
Pedestrian	36	41%	26.3%	9,563	26%	69.81	137	4%
Motor vehicle	34	39%	1.0%	21,048	58%	6.27	3,356	87%
Solo motor vehicle	17	19%	4.6%	5,150	14%	14.00	368	9%
Bike	1	1%	5.6%	431	1%	23.95	18	0%
Total	**88**	**100%**	**2.3%**	**36,222**	**100%**	**9.33**	**3,899**	**100%**

[8] Crash mode were assigned by the consultant team based on the unit types involved in the crash. Crashes that involved one or more pedestrians were coded as a pedestrian crash. Crashes with one or more bicyclist were coded as a bicycle crash. Crashes with one or more motor vehicles and no pedestrians or bicyclists were coded as a motor vehicle crash. Crashes with only one motor vehicle and no pedestrians or bicyclists was coded as solo motor vehicle.

Time of Day

Table 8 summarizes crash frequency for pedestrian crashes by time of day. Most KSI crashes occurred during peak commute periods in the morning and evening. There are relatively high shares of KSI crashes that occurred between 9pm and 3am. Crashes tend to be most severe during the 12-3am time period with 4.9 percent of crashes resulting in a KSI and had an average of 14.8 EPDO score while only accounting for 6 percent of crashes. This is notable as there are likely fewer trips being made at night compared to daytime, highlighting higher KSI crash risk at night. However, trips around the Link light rail station, airport, and hotel/convention center may not have drastically lower traffic volumes immediately following the PM peak commuting, though we can expect lower volumes during the off-peak airport travel times.

Table 8: Crashes by Time of Day, 2015 - 2020

Time of Day	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes
12:00-2:59 AM	11	13%	4.9%	3,344	9%	14.80	226	6%
3:00-5:59 AM	5	6%	3.4%	1,627	4%	11.07	147	4%
6:00-8:59 AM	6	7%	1.3%	3,409	9%	7.32	466	12%
9:00-11:59 AM	7	8%	1.5%	3,533	10%	7.82	452	12%
12:00-2:59 PM	12	14%	1.8%	5,285	15%	7.98	662	17%
3:00-5:59 PM	15	17%	1.6%	7,286	20%	7.79	935	24%
6:00-8:59 PM	15	17%	2.5%	5,905	16%	9.87	598	15%
9:00-11:59 PM	16	18%	4.0%	5,592	15%	13.94	401	10%
Unknown	1	1%	8.3%	240	1%	20.03	12	0%
Total	**88**	**100%**	**2.3%**	**36,222**	**100%**	**9.29**	**3,899**	**100%**

Roadway and Environmental Characteristics

The following topics summarized in this section are related to roadway and environmental characteristics that were either reported by the responding officer or were joined by the consolidated GIS network datasets. Rows that are particularly insightful or are considered high-risk factors are highlighted in purple.

Crash Location Type (Intersection vs. Segment)

Table 9 summarizes crash frequencies by location type (intersection vs. segment). The majority of crashes regardless of severity occurred within 150 ft of intersections with 70 percent of KSI and 75 percent of all crashes having occurred at intersections. Interestingly, crashes within segments tend to be slightly more severe than at intersection locations with 2.7 percent of crashes resulting in a KSI and an average EPDO value of 9.85 per crash, compared to 2.1 percent and 9.16 respectively. The slightly higher EPDO scores for segment crashes may be related to higher travel speeds at the time of the crash.

Table 9: Crashes by Location Type, 2015 - 2020

Location Type	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes
Intersection	62	70%	2.1%	26,581	73%	9.16	2,903	75%
Segment	26	30%	2.7%	9,612	27%	9.85	976	25%
Total	**88**	**100%**	**2.3%**	**36,193**	**100%**	**9.33**	**3,879**	**100%**

Intersection Control Type

Table 10 summarizes crashes by location type and traffic control type (for intersections). Adding to what was reported in Table 9, intersection control played a significant role in where crashes occurred. This does not mean that the presence of these traffic control devices is the primary factor that contributed to crashes, but simply these locations had a high crash frequency, likely due to there being higher traffic volumes (i.e., exposure) at these locations. Signalized intersections had the largest share of KSI crashes (44 percent) and overall crashes (43 percent). In addition to higher traffic volumes, signalized intersection locations tend to have more complicated roadway geometries (turn lanes, wide cross sections, etc.), higher speed vehicle movements, and more interactions between roadway users. When looking at crashes per intersection, signalized intersections have substantially more KSI crashes and overall crashes per location with a rate of 0.78 and 33.28 KSI and overall crashes per intersection, respectively. Intersections with all-way stop control have zero KSI crashes and very few overall crashes compared to intersections with partial stop control. Again, this is likely related to exposure with all-way stop controlled intersection being located along lower volume streets, and partial stop-controlled intersections being located at intersections between higher and lower functional classification roadways (e.g., arterial and local).

Table 10: Crashes by Intersection Control Type, 2015 - 2020

Intersection Control Type	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	KSI/ Inters-ection	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes	Crash/ Inters-ection
Intersection - Signalized	39	44%	2.3%	0.78	6,068	44%	9.66	1,664	43%	33.28
Intersection - Partial	16	18%	1.9%	0.07	7,387	20%	8.63	856	22%	3.89
Intersection - All-Way Stop	0	0%	0.0%	0.00	138	0%	3.95	35	1%	2.19
Intersection - Unknown	7	8%	2.0%	0.02	2,988	8%	8.59	348	9%	1.00
Segment	26	30%	2.6%	--	9,641	27%	9.68	996	26%	--
Total	**88**	**100%**	**2.3%**	**--**	**6,222**	**100%**	**9.29**	**3,899**	**100%**	**--**

Functional Classification

Table 11 summarizes crashes by functional classification. For crashes that occurred at intersections, the highest functional classification was selected and assigned to the crash. In general, crashes occurred more frequently and were more severe at locations with higher functional classification. Principal arterials accounted for 49 percent of crashes, 59 percent of KSI crashes, and 55 percent of EPDO scores. Principal arterials also accounted for the majority share of overall and KSI crashes on a per mile basis with 193.22 crashes and 5.28 KSI crashes per mile.

Table 11: Crashes by Functional Classification, 2015 - 2020

Functional Classification	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	KSI/ Mile	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes	Crash/ Mile
Principal Arterial	52	59%	2.7%	5.28	19,998	55%	10.50	1,904	49%	193.22
Minor Arterial	23	26%	1.8%	1.34	10,531	29%	8.23	1,280	33%	74.83
Collector	8	9%	1.9%	0.97	3,771	10%	9.06	416	11%	50.56
Local	4	5%	1.6%	0.07	1,583	4%	6.14	258	7%	4.25
Driveway	1	1%	4.8%	0.11	309	1%	14.73	21	1%	2.32
Total	**88**	**100%**	**2.3%**		**36,193**	**100%**	**9.33**	**3,879**	**100%**	

Table 12 summarizes intersection crashes (excluding mid-block crashes) by highest and lowest functional classifications present at the intersection. Consistent with the results displayed in Table 11, intersections with at least one principal arterial accounted for some of the largest shares of crashes and KSI crashes. Intersections along principal arterials with a local roadway had the largest share of KSI crashes (23 percent) followed by minor arterials (18 percent), and principal arterials (16 percent). Of the intersections at principal arterials, local roadways represent the largest group in terms of the number of locations (44 intersections) whereas locations at minor arterials and other principal arterials represent a combined total of 11 intersections. With there being fewer locations at other principal arterials and minor arterials, there appears to be higher risk for a KSI crash to occur with principal arterial-principal arterial intersections having 3.33 KSI crashes per location and principal arterial-minor arterial intersections having 1.38 KSI crashes per intersection.

Table 12: Crashes by Highest and Lowest Functional Classification, Intersection Crashes, 2016-2020

Highest Functional Classification	Lowest Functional Classification	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	KSI per IX[9]	# Crashes	% Crashes	Crashes Per IX	# of IX
Principal Arterial	Collector	2	3%	4.2%	0.67	105	4%	35.0	3
Principal Arterial	Principal Arterial	10	16%	2.3%	3.33	240	8%	80.0	3
Principal Arterial	Minor Arterial	11	18%	1.9%	1.38	471	16%	58.9	8
Principal Arterial	Driveway	3	5%	1.9%	0.43	156	5%	22.3	7
Principal Arterial	Freeway Ramp	1	2%	1.7%	0.50	58	2%	29.0	2
Principal Arterial	Other	1	2%	1.9%	0.14	53	2%	7.6	7
Principal Arterial	Local	14	23%	3.3%	0.32	423	15%	9.6	44
Minor Arterial	Collector	2	3%	1.6%	0.18	185	6%	16.8	11
Minor Arterial	Minor Arterial	1	2%	0.0%	0.05	189	7%	9.0	21
Minor Arterial	Driveway	0	0%	2.7%	0.00	5	0%	1.0	5
Minor Arterial	Other	0	0%	0.5%	0.00	2	0%	2.0	1
Minor Arterial	Local	8	13%	1.1%	0.07	589	20%	5.1	115
Collector	Collector	1	2%	0.0%	0.11	62	2%	6.9	9
Collector	Other	0	0%	0.0%	0.00	1	0%	0.3	3

[9] "IX" = shorthand for "intersection"

Collector	Local	6	10%	1.4%	0.08	224	8%	3.0	75
Local	Driveway	0	0%	0.0%	0.00	9	0%	0.7	13
Local	Local	2	3%	1.5%	0.01	131	5%	0.4	306
Total		**62**	**100%**	**2.1%**		**2,903**	**100%**		

Lighting Condition

Table 13 summarizes crashes by officer-reported lighting conditions. Most crashes occurred during daylight hours, accounting for 61 percent of overall crashes. This is expected as most trips are made during the day. However, 58 percent of KSI crashes happened during dark lighting conditions with the streetlights turned on. KSI crashes more commonly occurred in dark conditions with streetlights turned on (58 percent of crashes) compared to 33 percent of crashes that happened during daylight hours. Additionally, crashes during dark hours with streetlights turned on are on average more severe than daylight crashes with 4.2 percent of crashes resulting in a KSI and an average EPDO score of 13.87 compared to 1.2 percent and 6.96 for daylight crashes. While streetlights were present and activated, the streetlight placement, coverage, and luminosity may have been a factor in the pedestrian crash. Further engineering analyses is recommended to evaluate the effectiveness of the street lighting along the corridor.

The majority share of crashes having occurred during dark lighting conditions is something to note. Trips most often occur during the day for commuting, recreation, or utility trips. Therefore, there are expected higher rates of exposure and higher frequencies of crashes during the day. With there being a majority of crashes that occurred during dark lighting conditions throughout the city, particularly along International Boulevard, the data suggest higher crash risk for roadway users at night.

Table 13: Crashes by Reported Lighting Condition, 2015 - 2020

Reported Lighting Condition	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes
Dark-Street Lights On	51	58%	4.2%	16,668	46%	13.87	1,202	31%
Daylight	29	33%	1.2%	16,587	46%	6.96	2,384	61%
Dusk	5	6%	5.4%	1,526	4%	16.58	92	2%
Dark-No Street Lights	2	2%	2.2%	750	2%	8.24	91	2%
Dawn	1	1%	1.8%	473	1%	8.31	57	1%
Unknown	0	0%	0.0%	24	0%	1.31	18	0%
Other	0	0%	0.0%	13	0%	3.15	4	0%
Dark-Street Lights Off	0	0%	0.0%	137	0%	4.55	30	1%
Dark - Unknown Lighting	0	0%	0.0%	16	0%	16.04	1	0%
Total	**88**	**100%**	**2.3%**	**36,193**	**100%**	**9.29**	**3,879**	**100%**

Posted Speed Limit

Table 14 summarizes crashes by posted speed limit and by lowest and highest posted speed limit present at each intersection for intersection crashes. Research has found roadways with higher speeds are positively associated with crash risk and crash severity. This analysis found intersections with a highest posted speed limit of 35mph accounted for the largest share of all crashes (51 percent), whereas intersections with a posted speed limit of 25mph accounted for only 11 percent of crashes. However, intersections with a highest posted speed limit of 40mph had the largest share of KSI crashes (52 percent). When looking at the combinations of speed limits present at each intersection, speed limit combinations of 35mph/25mph accounted for the largest share of crashes (38 percent), but both 35mph/25mph and 40mph/25mph accounted for the largest share of KSI crashes with 31 percent of KSI crashes each. When looking at the number of crashes per intersection, intersections with a posted speed limit of 40mph/35mph had the largest number of crashes and KSI crashes per intersection, accounting for 91.6 crashes and 3.8 KSI crashes per intersection. It should be noted that streets with higher posted speed limits tend to have higher traffic volumes, therefore higher exposure rates between roadway users.

Table 14: Crashes by Posted Speed Limit, Intersection Crashes, 2016-2020

Highest Speed Limit	Lowest Speed Limit	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	KSI/ Inter-section	# Crashes	% Crashes	Crashes/ Intersection	# Inter-sections
25	25	4	6%	1.3%	0.01	318	11%	0.88	361
35	25	19	31%	1.7%	0.09	1,109	38%	5.28	210
35	35	6	10%	1.6%	0.18	379	13%	11.15	34
40	25	13	21%	2.1%	0.72	624	21%	34.67	18
40	35	19	31%	4.1%	3.80	458	16%	91.60	5
45	25	0	0%	0.0%	0.00	3	0%	1.50	2
45	35	1	2%	12.5%	0.50	8	0%	4.00	2
60	25	0	0%	0.0%	0.00	4	0%	4.00	1
Total		**62**	**100%**	**2.1%**		**2,903**	**100%**		

Table 15 summarizes segment crashes (crashes more than 150 ft from an intersection) by posted speed limit. Streets with higher speed limits tend to have a higher number of overall crashes and KSI crashes on a per mile basis. Streets with a posted speed limit of 40mph had 73.68 crashes per mile and 1.94 KSI crashes per mile, followed by streets with a posted speed limit of 35mph, having 13.86 crashes and 0.53 KSI crashes per mile. This finding suggests that while there is only 4.1 miles of roadway that has a posted speed limit of 40mph, both severe and non-severe crashes disproportionately occurred along higher-speed roadways.

Table 15: Crashes by Posted Speed Limit, Segment Crashes, 2016-2020

Speed Limit	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	KSI/ Mile	# Crashes	% Crashes	Crashes/ Mile	Street Miles
25	5	19%	1.6%	0.06	317	32%	4.05	78.3
35	13	50%	3.8%	0.53	338	35%	13.86	24.4
40	8	31%	2.6%	1.94	304	31%	73.68	4.1
60	0	0%	0.0%	0.00	2	0%	10.29	0.2
Unknown	0	0%	0.0%	--	15	2%	--	--
Total	**26**	**100%**	**2.7%**		**976**	**100%**		

Street Width

Table 16 summarizes intersection crashes by widest leg (in terms of feet) at the intersection. Intersections with the largest leg between 80-89 feet wide accounted for the largest share of KSI crashes (39 percent), the second largest share of overall crashes (21 percent), and the highest number of KSI crashes per intersection (1.71). Intersections with the largest leg between 40-49 feet wide had the largest overall number of crashes (26 percent) and the second largest number of KSI crashes (19 percent), though there are a relatively large number of these intersections with a 0.15 KSI and 7.3 crashes per intersection.

Table 16: Intersection Crashes by Max Street Width Street Width at intersection, 2015 - 2020

Max Street Width at Intersection	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	KSI/ Inter-section	# Crashes	% Crashes	Crashes/ Intersection	# Inter-sections
20-29	4	6%	3%	0.02	152	5%	0.7	225
30-39	5	8%	1%	0.02	741	26%	2.8	265
40-49	12	19%	2%	0.15	575	20%	7.3	79
50-59	2	3%	2%	0.11	85	3%	4.5	19
60-69	4	6%	3%	0.29	160	6%	11.4	14
70-79	9	15%	3%	0.60	354	12%	23.6	15
80-89	24	39%	4%	1.71	622	21%	44.4	14
90-99	2	3%	1%	0.67	214	7%	71.3	3
Total	**62**	**100%**	**2.1%**		**2,903**	**100%**		

Table 17 summarizes segment crashes street width at non-intersection locations. Most KSI crashes and overall crashes occurred on narrower streets less than 50 feet wide, accounting for 62 percent of KSI crashes and 52 percent of overall crashes. When looking at the number of crashes by network milage for each street width, wider streets have a higher number of crashes on a per mile basis compared to narrower streets. Streets that are at least 60 feet wide represents roughly 7.6 miles, or 7 percent of centerline milage in SeaTac, but 38 percent of KSI crashes occurred along these roadways (at non-intersection locations).

Table 17: Segment Crashes by Street Width Street Width, 2015 - 2020

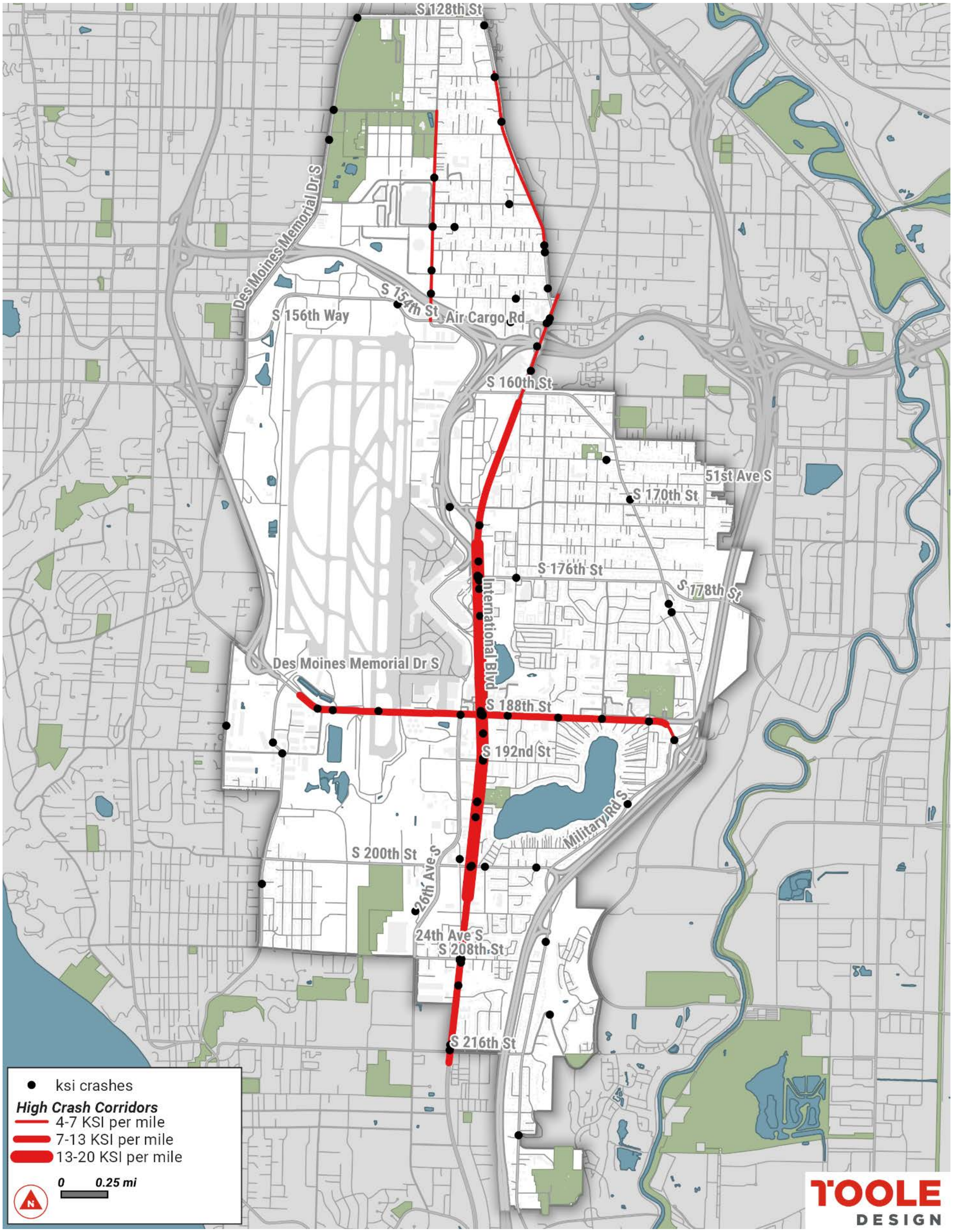
Street Width	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	KSI/ Mile	# Crashes	% Crashes	Crashes/ Mile	# Miles
20-29	7	27%	4.4%	0.11	159	16%	2.56	62.1
30-39	6	23%	2.3%	0.21	256	26%	9.02	28.4
40-49	3	12%	3.2%	0.44	94	10%	13.82	6.8
50-59	0	0%	0.0%	0.00	32	3%	17.07	1.9
60-69	3	12%	2.4%	1.00	123	13%	40.81	3.0
70-79	4	15%	3.0%	1.80	135	14%	60.87	2.2
80-89	2	8%	1.4%	0.99	142	15%	70.09	2.0
90-99	1	4%	5.0%	3.33	20	2%	66.63	0.3
Total	**26**	**100%**	**2.7%**		**927**	**100%**		

KSI Crash Density

A sliding windows analysis was conducted to measure KSI crash density estimates along street corridors throughout the city. The displayed corridors in Map 1 are identified by applying a one mile sliding window aggregation to the street network in SeaTac. The one mile sliding windows were created to form corridors using the roadway street name. In this approach, a virtual "window" is moved along each street in 1/10-mile increments, counting the number of KSI crashes that occurred within each successive one mile segment. Both intersection and segment crashes were included in this evaluation, as the focus is on overall corridor conditions. The intent of this analysis is to explore if there are any corridors that have a high concentration of crashes.

The results from this sliding windows analysis confirms the finding in the previous sections: higher speed, higher motor vehicle volume, wider streets, and along corridors with signalized locations (likely correlated with higher vehicle volumes) have higher concentrations of KSI crashes. The highest concentrations of KSI crashes occurred along International Boulevard, followed by S 188th St, Military Rd S, and 24th Ave S.

Map 1: Sliding Windows Analysis Results



Behaviors

The following section summarizes unit behaviors that occurred prior to the crash. These behaviors provide insight into the actions from the parties involved that may have contributed to the crash. Behaviors that are particularly insightful or are considered high-risk factors are highlighted in purple.

Collision Description

Table 18 summarizes the officer reported collision description for crashes that resulted in a KSI. These collision descriptions generally include the direction of travel in relation to both units involved (i.e., opposite direction), movements preceding the cash, as well as the commonly coded descriptive collision type (i.e., rear end). The top two collision descriptions accounted for over half of the KSI crashes which occurred in SeaTac. These two collision types have been analyzed in more detail through the development of Crash Trees and are summarized in the next section.

Motorists traveling straight striking a pedestrian accounted for the largest share of KSI crashes (34 percent) but only 2 percent of all crashes. This highlights the overall vulnerability of pedestrians traveling in SeaTac, with roughly 43 percent of pedestrian crashes with motorists traveling straight crashes resulting in a KSI. Fixed object – going straight ahead crashes accounted for the second

largest share of KSI crashes with 20 percent of KSI crashes and only 7 percent of overall crashes. Rear end crashes, specifically from crashes involving motorists traveling in the same direction both going straight – one stop – rear end crashes, accounted for the largest share of overall crashes with 18 percent of all crashes. However, less than 1 percent of these crashes resulted in a KSI, highlighting the relative lower risk for severe injuries resulting from this collision type.

Table 18: KSI Crashes by Reported Collision Type, 2015 - 2020

Collision Description	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes
Vehicle Going Straight Hits Pedestrian	30	34%	42.9%	7,403	20%	105.76	70	2%
Fixed Object - Going Straight Ahead	18	20%	6.5%	4,989	14%	18.14	275	7%
Entering at Angle - Going Straight Ahead - Going Straight Ahead	8	9%	1.8%	4,163	12%	9.11	457	12%
From Opposite Direction - One Left Turn - One Straight	5	6%	1.6%	2,715	8%	8.93	304	8%
From Opposite Direction - Both Moving - Head-On	5	6%	12.5%	1,386	4%	34.66	40	1%
From Same Direction - Both Going Straight -	4	5%	0.6%	4,070	11%	5.81	700	18%

Collision Description	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes
One Stopped - Rear-End								
Vehicle Turning Left Hits Pedestrian	4	5%	16.0%	1,204	3%	48.17	25	1%
From Opposite Direction - Both Going Straight - Sideswipe	1	1%	1.9%	517	1%	9.57	54	1%
From Opposite Direction - All Others	1	1%	0.9%	869	2%	7.90	110	3%
Vehicle - Pedalcyclist	1	1%	9.1%	351	1%	31.90	11	0%
Vehicle Overturned	1	1%	5.3%	393	1%	20.70	19	0%
From Same Direction - Both Going Straight - Both Moving - Sideswipe	1	1%	0.3%	801	2%	2.78	288	7%
From Same Direction - Both Going Straight - Both Moving - Rear-End	1	1%	0.3%	1,421	4%	4.71	302	8%
Entering at Angle - Making Right Turn - Going Straight Ahead	1	1%	0.8%	648	2%	5.02	129	3%
Vehicle Turning Right Hits Pedestrian	1	1%	3.0%	629	2%	19.06	33	1%
From Same Direction - One Left Turn - One Straight	1	1%	2.2%	422	1%	9.37	45	1%
All Other Non-Collision	1	1%	50.0%	232	1%	116.16	2	0%
Entering at Angle - Going Straight Ahead - Making Left Turn	1	1%	1.7%	457	1%	7.75	59	2%
Not Stated	1	1%	50.0%	232	1%	116.16	2	0%
From Same Direction - One Right Turn - One Straight	1	1%	1.4%	392	1%	5.60	70	2%

Collision Description	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes
Entering at Angle - Making Left Turn - Going Straight Ahead	1	1%	0.4%	1,087	3%	4.75	229	6%
Total	**88**	**100%**	**2.3%**	**36,222**	**100%**	**9.29**	**3,899**	**100%**

Primary Pre-Crash Movement

Table 19 summarizes the primary motor vehicle pre-crash movement. Crashes involving a motor vehicle proceeding straight prior to the crash accounted for the overwhelming majority of crashes (69 percent) and KSI crashes (83 percent) throughout the city. Of the 73 KSI crashes that involved a motor vehicle going straight, 30 of those crashes involved a pedestrian and 18 involved a fixed object.

Table 19: Crashes by Primary Motor Vehicle Pre-Crash Movement, 2015 - 2020

Primary Motor Vehicle Pre-Crash Movement	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes
Going Straight Ahead	73	83%	2.7%	27,954	77%	10.46	2,672	69%
Making Left Turn	9	10%	1.3%	5,148	14%	7.25	710	18%
Making Right Turn	4	5%	1.5%	2,020	6%	7.35	275	7%
Unknown	1	1%	25.0%	273	1%	68.25	4	0%
Backing	1	1%	1.2%	448	1%	5.33	84	2%
Parked	0	0%	0.0%	24	0%	1.00	24	1%
Starting from Parked Position	0	0%	0.0%	96	0%	5.97	16	0%
Other*	0	0%	0.0%	146	0%	2.18	67	2%
Merging (Entering Traffic)	0	0%	0.0%	85	0%	3.15	27	1%
Total	**1**	**1%**	**2.3%**	**36,193**	**100%**	**9.33**	**3,879**	**100%**

Contributing Factors (Violations)

Table 19 summarizes the top officer-reported contributing factors (violations)[10]. The majority of crashes involved a motorist who was distracted/inattentive and/or failed to yield the right of way to another motorist (non-bicyclist or pedestrian) accounted for 21 and 20 percent of crashes, respectively. While these two types of violations accounted for the largest share of crashes, the crashes tend to be less severe than other violations when reviewing average EPDO scores and the percent of crashes resulting in a KSI. Crashes that involved a motorist exceeding the speed limit and crashes with a distracted driver both had the largest share of KSI crashes (17 percent) and exceeding the speed limit crashes being more severe on average. Alcohol related crashes did not have the largest share of KSI crashes, but these crashes tended to be more severe with 7 percent of crashes resulting in a KSI and an average EPDO score of 21.20.

Crashes involving a pedestrian failure to grant the right of way were most severe on average, which align with pedestrian crashes regardless of contributing factors, having an average of 61.1 percent of crashes resulting in a KSI. It should be noted that both the motor vehicle not granting right or way or the pedestrian not granting the right of way are ambiguous and difficult to understand what actions or what factors were related to the crash.

Table 20: Crashes by Reported Contributing Factors, 2015 - 2020

Contributing Factor	# KSI Crashes	% KSI Crashes	% of Crashes Resulting in KSI	EPDO Score	% EPDO Score	EPDO/ Crash	# Crashes	% Crashes
Exceeding Speed Limit	15	17%	4.0%	5,274	15%	13.95	378	10%
Distraction or Inattention	15	17%	1.8%	7,162	20%	8.64	829	21%
Alcohol	10	11%	7.0%	3,032	8%	21.20	143	4%
Motor Vehicle did not Grant ROW	9	10%	1.2%	5,168	14%	6.65	777	20%
Pedestrian did not Grant ROW	11	13%	61.1%	2,616	7%	145.33	18	<1%

[10] Crashes may involve multiple contributing factors (i.e. speeding and inattention). As such, the number and percent of crashes reported here reflect the number of crashes where these factors were reported. Additionally, reported citations are issued at the officer’s discretion. Some of which may be difficult for the officer to prove, such as distracted driving or exceeding the posted speed limit.

Crash Tree Analysis

Crash Trees are a method of identifying the circumstances or characteristics associated with the crash events across a road network. Crash Tree diagrams can therefore be used to help identify potential combinations of area types, location types, traffic control types, or similar characteristics, which are associated with high crash histories.

The general Crash Tree diagram approach used in this analysis began with querying all non-freeway KSI crashes. The KSI crashes were then split based on reported collision types (i.e., fixed object, vehicle going straight strikes pedestrian, opposite direction - one left turn - one straight, etc.) transportation mode involvement, and a high-level location type (segment/signalized intersection/intersection with all stops/intersection partial stops). The grouping of these variables creates crash types. Crash types are typically used as the foundation of Crash Trees to help identify similar crash circumstances that could be addressed using related safety countermeasures. For this project, the consultant team constructed crash types using the reported collision type, mode, and location type. These crash types make up the initial branches of the Crash Tree in which the branches were further explored individually by adding roadway and land use characteristics using Excel Pivot Tables. Typical variables added to the branches include roadway width (proxy for number of lanes), posted speed limit, functional classification, sidewalk coverage, traffic signal types, and presence of a median. The number of KSI crashes for each set of location characteristics branch was then compared to the number of KSI crashes. This influenced the decision-making process of adding and removing roadway variables to find unique combinations that led to a relatively high number of crashes or a high number or proportion of KSI crashes.

The ultimate goal of a Crash Trees is to identify combinations of contextual and infrastructure factors that are closely linked to specific crash types, so that packages of countermeasures can be recommended that target systemic problems. At this stage of the analysis, we are identifying the branches and nodes of the tree – the combinations of factors for future use in countermeasure identification and application. A total of five branches have been developed for this analysis. This analysis focuses on the top 2 branches. The remaining three branches have been excluded due to the low number of KSI crashes.

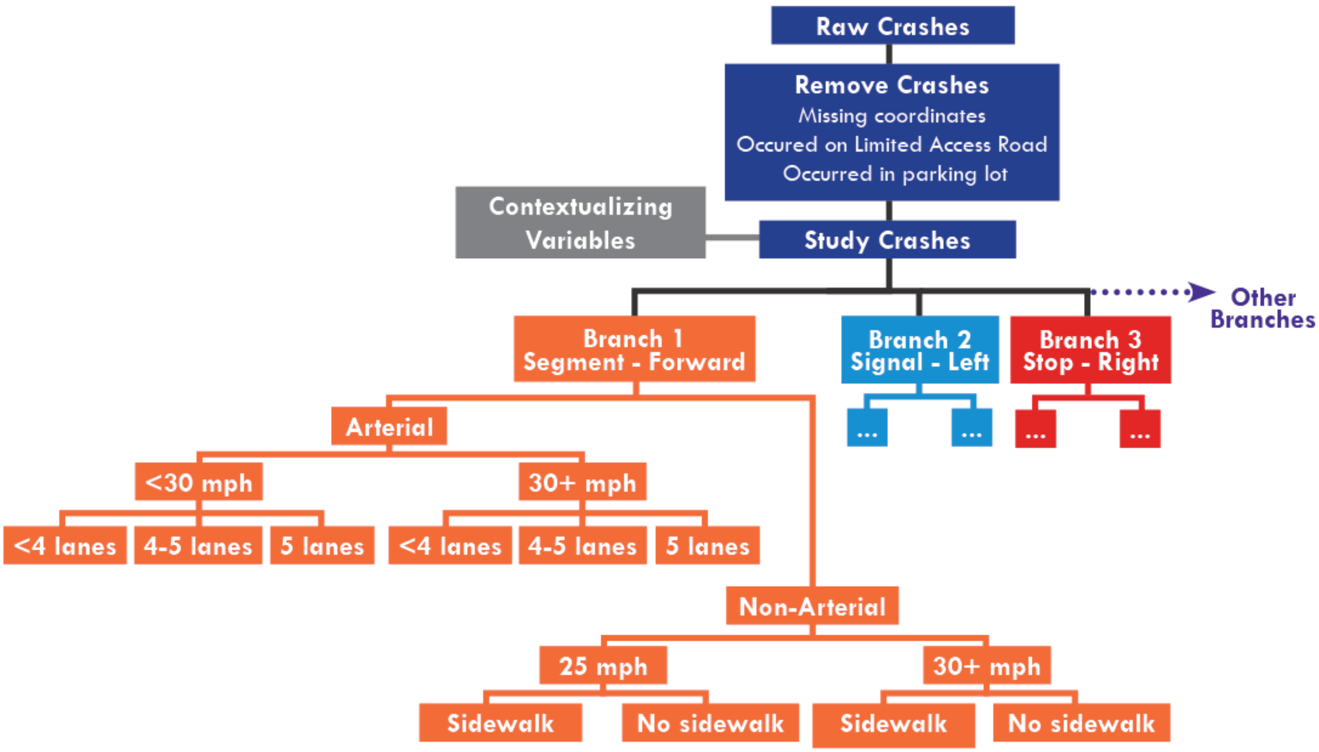


Figure 3: Generalized Example of the Crash Tree Process and Structure

Crash Typology

As described above, crash typing defines sub-sets of crashes based on the actors and actions that contributed to the crash event, often using party/unit types (i.e., mode), pre-crash movement types, and roadway characteristic information. For this analysis, unit types, vehicle movement preceding the crash, and location type were used to develop the crash types used in this analysis (see Figure 4). The purpose of using these three variables in the development of these crash types is to group related characteristics that likely have similar potential countermeasures.

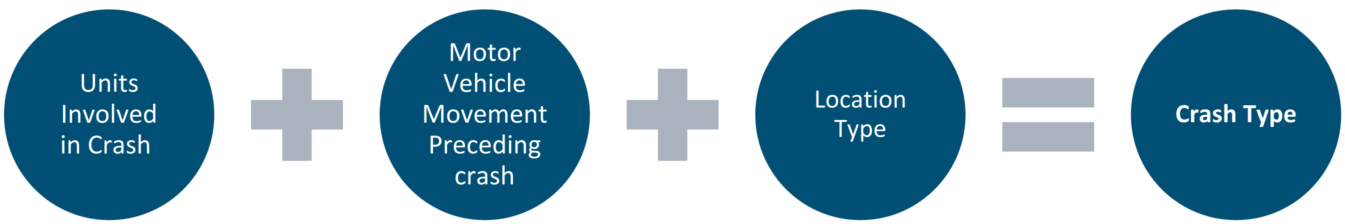


Figure 4: General Crash Typing Process

The top two crash types shown in bold and highlighted in red in Table 21 have been selected for analyzing in greater detail. The top five crash types were included in the Crash Tree analysis as individual branches, as they comprise a large share of KSI crashes and have complete crash type information (motorist movement, location, and intersection control). The top five crash types accounted for 64 percent of KSI crashes. However, due to the relatively low KSI crashes for branches 3-5 only branches 1-2 have been included.

The following sections will summarize the results of the Crash Tree analysis. The variables included for each branch will be unique to that specific branch. The purpose for selecting unique variables for each branch, as

opposed to using the same variables for each branch, is due to the specific factors related to crashes varying between each of these crash types. For instance, *Vehicle Going Straight Hits Pedestrian* at intersection crashes likely have different factors compared to *Fixed Object – Going Straight Crashes* at intersections.

Table 21: Top 10 Crash Types

#	Crash Description and Pre-Crash Movement	Location[11]	# KSI Crashes	% KSI Crashes
1	Vehicle Going Straight Hits Pedestrian	Intersection	22	25%
2	Fixed Object - Going Straight Ahead	Intersection	12	14%
3	Vehicle Going Straight Hits Pedestrian	Segment	8	9%
4	Entering at Angle - Going Straight Ahead - Going Straight Ahead	Intersection	8	9%
5	Fixed Object - Going Straight Ahead	Segment	6	7%
6	From Opposite Direction - One Left Turn - One Straight	Intersection	4	5%
7	From Same Direction - Both Going Straight - One Stopped - Rear-End	Intersection	3	3%
8	From Opposite Direction - Both Moving - Head-On	Intersection	3	3%
9	Vehicle Turning Left Hits Pedestrian	Intersection	3	3%
10	From Opposite Direction - Both Moving - Head-On	Segment	2	2%

Branch 1 – Vehicle Going Straight Hits Pedestrian – Intersection

Branch 1 is displayed in Table 22 and does not display the crash type portion (Vehicle Going Straight Hits Pedestrian – Pedestrian) of the branch to reduce the overall table size. This branch accounted for the largest share of crashes with 22 KSI crashes or 25 percent of all KSI crashes. Roughly 39 percent of these crashes resulted in a KSI. This analysis analyzed intersection control type, the highest functional classification at intersections, largest leg at the intersection in terms of street width, as well as the highest posted speed limit. These variables revealed a noteworthy pattern associated with high pedestrian KSI crash frequencies. Signalized intersections along principal arterials that are between 80-89 feet wide with a highest posted speed limit of 40mph accounted for the largest share of KSI crashes. This location type also has a relatively high number of KSI crashes per intersection of 0.91, or 10 KSI crashes per 11 intersections.

[11] Intersection crashes include any crash that occurred within 150 feet of an intersection. Crashes outside of 150 feet from an intersection are categorized as a segment crash. Intersections categorized as a stop-controlled intersection were identified if there was a stop sign at an unsignalized intersection. Partial stop-controlled intersections (i.e., 2-way) are flagged if the number of stop signs were fewer than the number of approach legs present at the intersection. All-way stop controlled intersection are flagged if the number of striped stop bars equals the number of approach legs at the intersection.

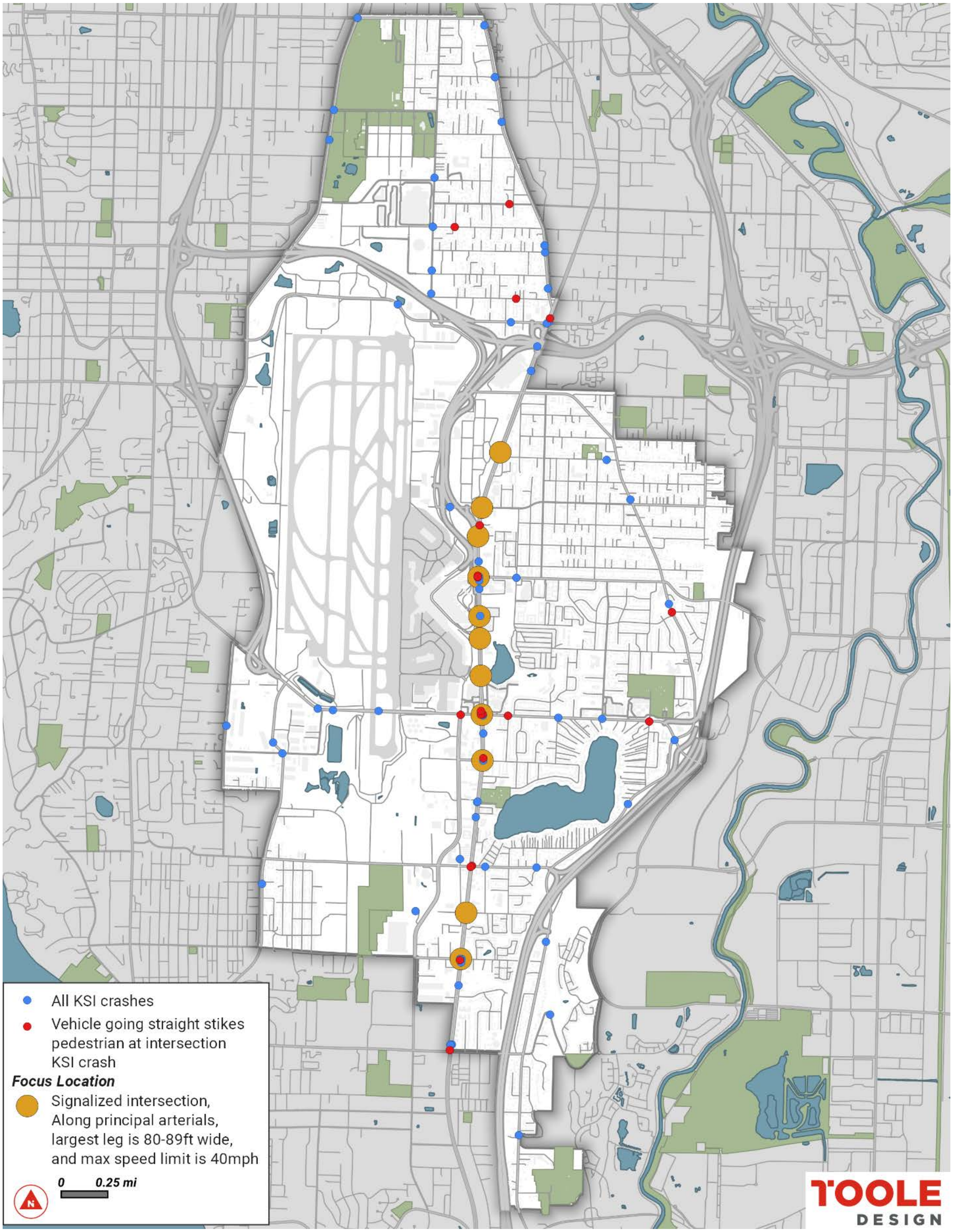
Table 22: Branch 1 – Vehicle Going Straight Hits Pedestrian – Intersections

Intersection Control	Highest Functional Classification	Largest Leg Street Width (feet)	Highest Speed Limit (mph)	# of KSI	KSI/ Intersection	# of Intersections
Partial	Principal Arterial	70-79	40	0	0.00	3
Partial	Principal Arterial	80-89	40	1	1.00	1
Partial	Collector	40-49	35	0	0.00	11
Partial	Minor Arterial	30-39	35	0	0.00	29
Partial	Minor Arterial	40-49	35	1	0.04	24
Partial	Local	20-29	25	1	0.04	26
Signalized	Principal Arterial	60-69	35	0	0.00	1
Signalized	Principal Arterial	60-69	40	2	2.00	1
Signalized	Principal Arterial	70-79	35	2	1.00	2
Signalized	Principal Arterial	70-79	40	1	0.33	3
Signalized	Principal Arterial	70-79	45	1	1.00	1
Signalized	Principal Arterial	80-89	40	10	0.91	11
Signalized	Collector	30-39	35	0	0.00	1
Unknown	Principal Arterial	60-69	35	1	0.20	5
Unknown	Principal Arterial	70-79	40	0	0.00	1
Unknown	Collector	20-29	25	1	0.33	3
Unknown	Collector	30-39	25	0	0.00	14
Unknown	Minor Arterial	30-39	35	0	0.00	20
Unknown	Local	20-29	25	1	0.01	133
Unknown	Local	30-39	25	0	0.00	63

Possible countermeasures for consideration (non-exhaustive list):

- Reduce number of lanes (street width) at intersections
- Reduce posted speed limit along principal arterials
- Adjust the roadway design speed along principal arterials
- Install leading pedestrian interval at signalized intersections
- Implement pedestrian crossing signal phase recall
- Increase pedestrian crossing times
- Reduce pedestrian wait times between signal cycles

Map 2: Branch 1 - Vehicle Going Straight Hits Pedestrian – Intersections, Focus Locations



Branch 2 –Fixed Object – Going Straight – Intersections

Table 23 illustrates Branch 2 that includes fixed object crashes involving a motor vehicle going straight at an intersection. Intersection control type, highest functional classification at the intersection, and the highest posted speed limit at the intersection were found to be meaningful variables to analyze. When looking at the number of KSI crashes for all of these variables, fixed object crashes at signalized intersections, along principal arterials, with a posted speed limit of 40 mph, accounted for the largest share of KSI crashes with 7 crashes. All seven of these crashes occurred along International Boulevard, which is the only corridor where lane data is available. All 7 of these crashes occurred at intersections where the largest leg in terms on the number of through lanes had 5 through lanes.

Of the 12 KSI crashes in this branch, 8 occurred along International Boulevard, 10 were at intersections between principal arterials and non-arterial roadways, 7 were at signalized intersections, and 6 were alcohol related.

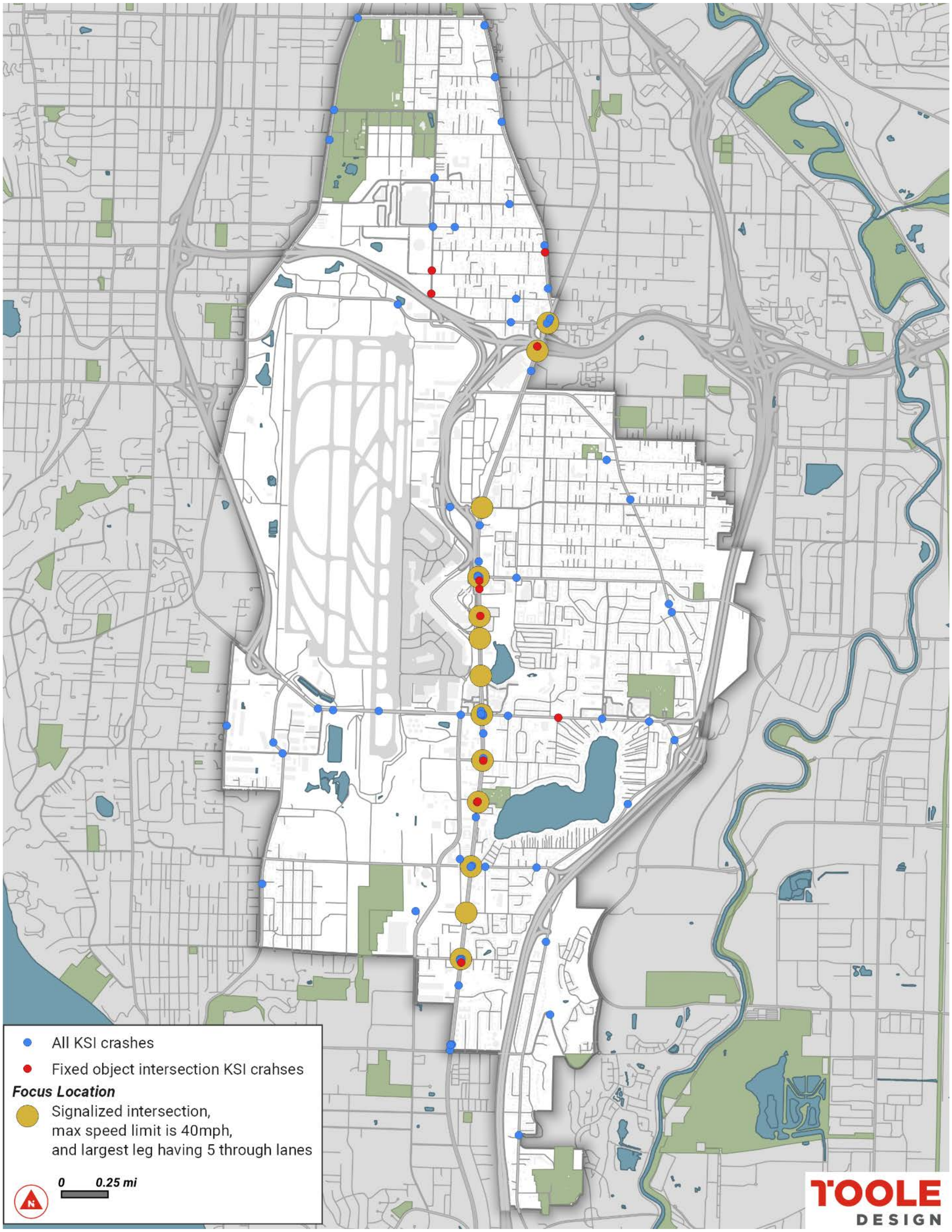
Table 23: Branch 2 – Fixed Object – Going Straight – Intersections

Intersection Control	Highest Functional Classification	Highest Speed Limit (mph)	# of KSI	KSI/ Intersection	# of Intersections
All-Way Stop	Collector	25	0	0.00	2
All-Way Stop	Local	25	0	0.00	13
Partial	Principal Arterial	35	1	0.07	14
Partial	Principal Arterial	40	0	0.00	4
Partial	Collector	25	0	0.00	30
Partial	Collector	35	2	0.11	18
Partial	Minor Arterial	25	0	0.00	5
Partial	Minor Arterial	35	1	0.01	71
Partial	Local	25	0	0.00	72
Partial	Local	35	0	0.00	5
Signalized	Principal Arterial	35	0	0.00	10
Signalized	Principal Arterial	40	7	0.41 (0.54)	17 (13)
Signalized	Collector	35	0	0.00	1
Signalized	Minor Arterial	35	0	0.00	17
Unknown	Principal Arterial	35	0	0.00	22
Unknown	Principal Arterial	40	1	0.50	2
Unknown	Collector	25	0	0.00	17
Unknown	Collector	35	0	0.00	17
Unknown	Minor Arterial	25	0	0.00	14
Unknown	Minor Arterial	35	0	0.00	44
Unknown	Local	25	0	0.00	202
Unknown	Local	35	0	0.00	24
Unknown	Local	45	0	0.00	3

Possible countermeasures for consideration (non-exhaustive list):

- Reduce posted speed limit and design speed along principal arterials
- Reduce number of lanes while increasing sidewalk buffer space
- Improve lane delineations or markings
- Install rumble strips
- Install delineation on fixed objects that cannot be removed from the clear zone

Map 3: Branch 2 – Fixed Object – Going Straight – Intersections, Focus Locations



Identified Risk Factors

To systematically identify high-risk locations throughout the city, the roadway network was screened to identify where high-risk factors are present. During the network screen process, intersections and street segments were assessed and flagged if any of the high-risk factors identified in the descriptive analysis section of the LRSP were present. The below items are the identified risk factors:

- Intersections:
  - Signalized
  - Posted speed limit of 40mph along major street and 25 mph along minor street
  - Posted speed limit of 40mph along major street and 35 mph along minor street
  - Bus stop at intersection
  - Only principal arterial and minor arterial functional classification present at intersection
  - Largest leg at intersection is at least 80 feet wide
  - 50 or more crashes over the last 5 years
- Segments:
  - Posted speed limit 35+ mph
  - Bus route
  - Principal or minor arterial
  - Street width 70+ feet wide
  - Along a sliding window analysis corridor with a weighted score of 100+

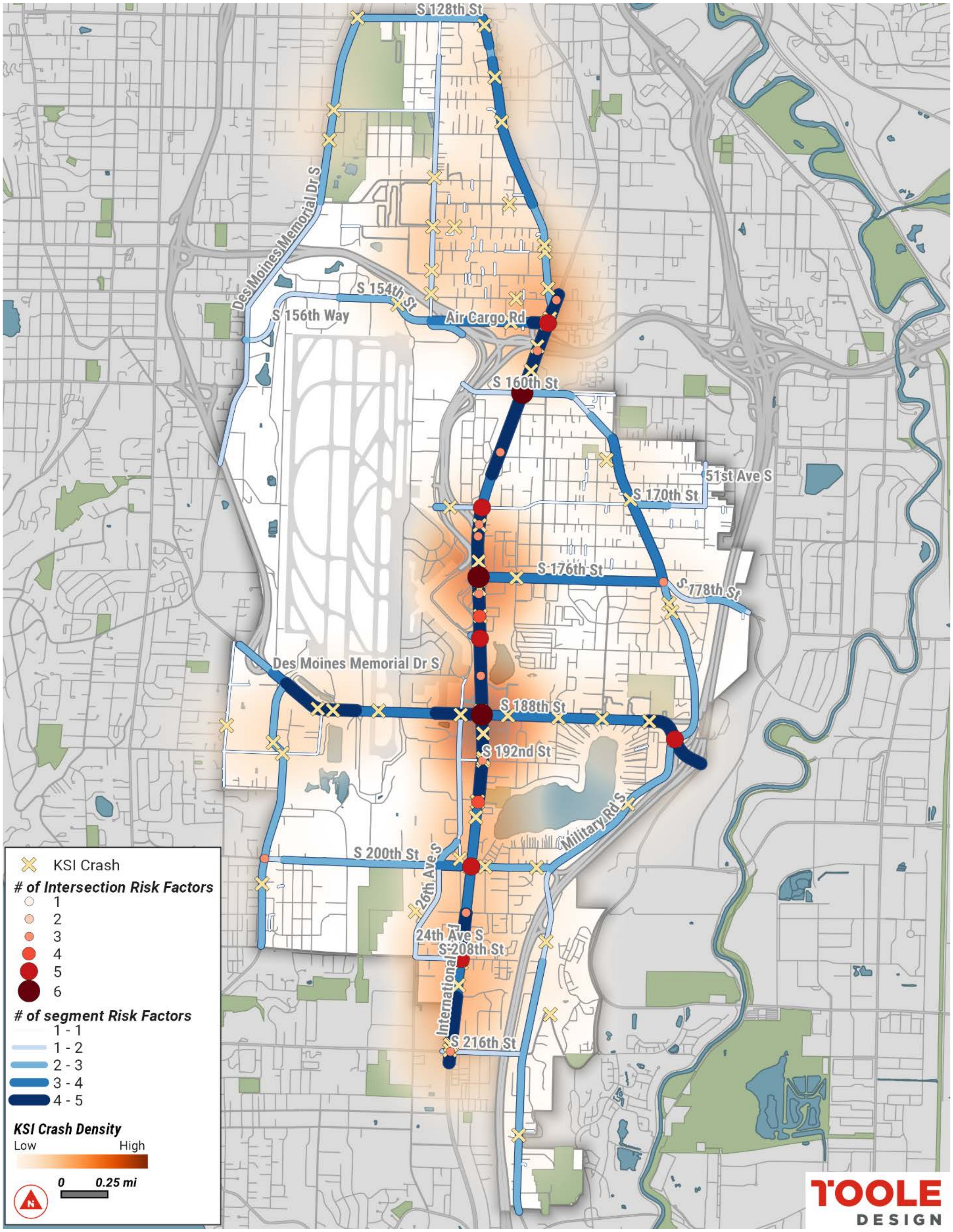
To prioritize the network locations, the number of high-risk factors that were present were counted at each location. Intersections with three or more risk factors are summarized in Table 24. Map 4 displays the number of risk factors present at intersections, along segments, and the location of KSI crashes. The majority of locations that have a high number of risk factors present are along International Boulevard, which was found to have the highest concentration of KSI crashes throughout the city.

Table 24: Intersections with Number of Risk Factors Present

Total Risk Factors	Intersection Name	Total EPDO	Signalized	Speed Limit 40+ mph	Bus Stop	Arterial	80+ feet wide	50+ crashes
6	International Blvd and S 188th St	2,333	X	X	X	X	X	X
6	International Blvd and S 176th St	1,875	X	X	X	X	X	X
6	International Blvd and S 160th St	420	X	X	X	X	X	X
5	International Blvd and S 208th St	1,436	X	X	X		X	X
5	International Blvd and S 154th St	1,206	X	X	X	X		X
5	International Blvd and S 200th St	791	X	X	X	X		X
5	S 188th St and Military Rd S	519	X		X	X	X	X
5	International Blvd and Sea-Tac Airport Entrance	302	X	X	X		X	X
5	International Blvd and S 170th St	289	X	X	X		X	X
4	International Blvd and S 195th St	650	X	X	X			X
4	International Blvd and S 180th St	427	X	X	X		X	
3	International Blvd and S 192nd St	682	X	X			X	
3	International Blvd and B 518 On-Ramp	407	X	X			X	
3	International Blvd and S 171st St	263		X	X		X	
3	International Blvd and S 216th St	256	X		X	X		
3	International Blvd and Major Driveway (south of S 176th St)	237		X	X		X	
3	International Blvd and S 204th St	164	X	X			X	

Total Risk Factors	Intersection Name	Total EPDO	Signalized	Speed Limit 40+ mph	Bus Stop	Arterial	80+ feet wide	50+ crashes
3	International Blvd and S 152nd St	148	X	X	X			
3	Des Moines Memorial Dr S and S 200th St	142	X		X	X		
3	S 176th St and Military Rd S	141	X		X			X
3	International Blvd and Major Driveway (north of S 188th St)	99	X	X			X	
3	International Blvd and S 166th St	74	X	X			X	
3	International Blvd and midblock crossing	48	X	X			X	

Map 4: Risk Factor Locations



Study Limitations

The limitations of the study included data access limitations as well as limitations to do with temporal consistency over the years included in the study.

Limited Crash Data Fields

Crash data provided by WSDOT to the consultant team had a subset of the actual crash datasets that makeup a crash database. A “flat” file was provided to the consultant team that includes crash location, date/time, injury severity, modes involved, vehicle movement types, weather/lighting/roadway condition, and reported contributing factors (violations) by mode. The WSDOT crash data was supplemented with select fields using WSP crash data, though not every WSDOT crash record had a corresponding record in the WSP crash data.

Temporal Consistency Limitations

The consultant team is studying crashes that occurred over a period of a little over five years, from 2015 through July 2020. The compiled roadway data reflect current conditions. It can be assumed that some changes in the roadway have occurred over the previous 5 years that cannot be accounted for. For example, if a crash occurred in 2015 and a segment narrowed from 4 lanes to 3 lanes in 2018, this analysis would link the 2015 crash with the present day 3-lane configuration.

Signal Phasing

Specific traffic signal phasing was not available to the consultant team during the time this analysis was conducted. Signal phasing for motor vehicles and pedestrian movement would provide insight into expected travel patterns and possible interactions between roadway users. Information for each approach and crossing related to turn signal phasing, pedestrian signal actuation, and presence of pedestrian leading intervals would provide additional utility to future analyses.

Exposure Data

Citywide volumes for motor vehicles along all streets, pedestrians, and bicyclists were not available at the time of this analysis. Data on pedestrian and bicyclist volumes would help provide a better picture of crash risk for those two modes.

Countermeasure Toolbox

Countermeasures are interventions the City can make to reduce the frequency and severity of fatal and severe injury crashes. To identify potential countermeasures, the City referenced material from WSDOT Target Zero as well as recent Vision Zero work in peer cities. The consultant team evaluated these countermeasures based on efficacy, complexity, and cost.[12] While we prioritized countermeasures with a high efficacy relative to cost and complexity, we also included countermeasures that did not meet these criteria but still offer high potential benefits in particular contexts. We selected 40 countermeasures based on their potential to address the risk factors identified in the City of SeaTac and their appropriateness for the local context:

1. Install concrete c-curb centerline at intersection approaches
2. Create directional median openings to allow (and restrict) left turns and U-turns.
3. Install left turn lane
4. Install pedestrian median fencing on approaches
5. Convert to all-way STOP control
6. Install new traffic signal
7. Convert intersection to roundabout
8. Construct bus boarding island with raised bicycle lane behind
9. Construct bus bulb
10. Construct curb extensions
11. Install splitter islands on the minor road approaches
12. Reduce curb radii
13. Add intersection lighting
14. Add segment lighting
15. Road Diet (4-to-3 lane conversion with a two way left-turn lane and bicycle lanes)
16. Install bicycle lanes
17. Create neighborhood greenways on low volume, low speed streets
18. Install pedestrian crossing at signalized intersection
19. Install pedestrian crossing at uncontrolled locations
20. Install Pedestrian Signal (including Pedestrian Hybrid Beacon (HAWK))
21. Construct sidewalk
22. Install edgeline rumble strips/stripes
23. Install dynamic/variable speed warning signs
24. Install Flashing Beacons at Stop-Controlled Intersections
25. Install curve advance warning signs
26. Improve pavement friction
27. Install reflective object markers
28. Install raised pavement markers and striping through intersection
29. Install/upgrade larger or additional stop signs or other intersection warning/regulatory signs
30. Lower speed limit
31. Install in-street pedestrian crossing sign
32. Construct pedestrian refuge island
33. Install Rectangular Rapid Flashing Beacon (RRFB)
34. Construct raised pedestrian crossing

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[12] See Table 28 in the appendix for the complete SeaTac countermeasure toolbox.

35. Install pedestrian countdown signal heads
36. Modify signal phasing to implement a Leading Pedestrian Interval (LPI)
37. Provide protected left turn phase (left turn lane already exists)
38. Modify signal phasing to implement pedestrian signal recall
39. Hardened centerline for left turn traffic calming
40. Install truck aprons

The complete countermeasure toolbox, which includes CMFs and unit costs, as well as information on efficacy, complexity, and applications, is included in the appendix. For countermeasures that do not have an established CMF, we evaluated their efficacy based on engineering judgement. This complete toolbox includes 44 items rather than 40 because it provides both a quick-build and a more permanent version for 4 of the countermeasures. These quick-build versions may be appropriate for testing countermeasures before implementing them with more permanent materials. Most of these countermeasures have been implemented at various locations in SeaTac. See Table 25 for images and a description of some of the less familiar countermeasures.

Table 25: A Sample of Proposed Treatments from the Countermeasure Toolbox

Proposed Countermeasure	Description
 Curb Radius Reduction (Seattle, WA)	Reconstructing a curb to a tighter radius can improve pedestrian safety by requiring drivers to reduce vehicle speed in order to make a sharper turn. In addition, a smaller radius can give a larger waiting space for pedestrians at corners and can shorten the pedestrian crossing.

Proposed Countermeasure	Description
 Neighborhood Greenways (Seattle, WA)	Neighborhood Greenways are streets with low motorized traffic volumes and low speeds, designed and designated to give priority to bicycle travel. They use signage, pavement markings, traffic calming measures, and crossing treatments to create an all-ages, all-abilities bicycle connection while limiting the volume and speed of motorized traffic.
 Rubber Speed Bump Left Turn Traffic Calming (Seattle, WA)	Rubber speed bumps can be installed to slow down drivers when making a left turn across crosswalks. By reducing vehicle speed, these bumps improve visibility of pedestrians and cyclists crossing the street and encourage slower and more controlled turning movements.

Proposed Countermeasure	Description
 Truck Aprons (Portland, OR and Seattle, WA)	Truck aprons are areas that are raised slightly to accommodate off-tracking of large vehicles, such as trucks and buses, while navigating a turn or roundabout. They are used to calm turning movements and improve pedestrian safety at locations where extending the curb is infeasible due to large vehicle turning movements.

Safety Project Development

Methodology

After identifying appropriate countermeasures, we matched the countermeasures from the Toolbox to specific locations based on the crash context, previous planning recommendations, and roadway characteristics. This process yielded three sets of projects:

- Countermeasure-Based Projects apply a particular countermeasure (i.e., leading pedestrian intervals or pedestrian refuge islands) to a set of relevant intersections or roadway segments citywide.
- Corridor-Based Projects focus on the city's highest crash corridors and apply a variety of countermeasures to address safety issues throughout the corridor.
- Data Collection Projects focus on developing additional data that can inform future investments in safety improvements.

Countermeasure-Based Projects

Eight citywide countermeasure-based projects are proposed. These projects apply a specific countermeasure to a set of intersections or street segments where they would be most impactful. Many of these projects rank very highly in the prioritization (see Table 28) because they focus on particular intersections and segments with a high number of crashes and/or substantial pedestrian traffic.

Table 26: Countermeasure-Based Projects and Estimated Project Costs

Countermeasure	Locations	Estimated Project Cost (rounded)
Installing hardened centerline left-turn traffic calming treatment using rubber speed bumps	Intersections with permissive left turns and pedestrian crashes that are also at bus stops or within a quarter mile of schools, parks, light rail stations, or commercial areas	$39,000 (11 intersections)
Converting permissive left turn signals to protected only	Permissive left turn signals at the intersection of two arterials	$71,000 (3 intersections)
Installing c-curb to eliminate dangerous turning movements	High crash intersections with adjacent driveways	$45,000 (4 intersections)
Installing leading pedestrian intervals (LPIs) and pedestrian recall	Intersections with bus stops or within a quarter mile of schools, parks, light rail stations, or commercial areas	$110,000 (37 intersections)
Filling in missing links in the pedestrian network with new sidewalk[13]	Key missing links in the pedestrian network	$3,000,000 (5 corridors)
Installing additional intersection lighting	Intersections with insufficient illumination and a high incidence of dark lighting condition crashes	$720,000 (20 intersections)
Installing RRFBs	Priority unsignalized pedestrian crossings	$320,000 (6 locations)

[13] For the prioritization process, the project to fill in missing links in the pedestrian network was broken up by corridor into 5 separate projects.

Constructing pedestrian refuge islands	Priority pedestrian crossings where feasible	$410,000 (6 locations)

Corridor-Based Projects

We propose 12 corridor-based projects. These projects include both corridor-wide countermeasures as well as countermeasures focused at particular intersections along those corridors.

Location	Countermeasures	Estimated Project Cost (rounded)
S 188 St: International Blvd to Orillia Rd S	> Speed limit reduction > Pedestrian signal > Curb radius reduction	$500,000
S 188 St: Des Moines Memorial Dr to International Blvd	> Reflective materials > Refuge island > Sidewalk > Curb radius reduction	$240,000
S 200 St: Des Moines Memorial Dr S to Military Rd S	> Road diet with bike lanes, median, and turn bays	$110,000
S 160 St: Military Rd to International Blvd	> Road diet with bike lanes, median, and turn bays > Curb extension	$190,000
Military Rd S: S 150 St to S 128 St	> Road reconstruction with sidewalks, bike lanes, left turn lanes > Curb extensions > All-way stop	$8,400,000
Military Rd: S 188 St to S 160 St	> Speed limit reduction > Curb extension > Dynamic speed warning signs > Median refuge island	$260,000
Military Rd: S 229 Pl to S 188 St	> Rumble strips > Reflective materials	$950,000

Location	Countermeasures	Estimated Project Cost (rounded)
	> Curb radius reduction	
42 Ave S, 40 Ave S, 37 Ave S, S 192 St and **33 Ave S**	> Neighborhood greenway including intersection crossing treatments, traffic calming, and wayfinding	$570,000
Des Moines Memorial Dr S: S 160 St to S 128 St	> Curb radius reductions > Bus boarding platforms and bus bulb > In-street pedestrian crossing sign	$510,000
Des Moines Memorial Dr S: S 208 St to S 192 St	> Truck aprons > Reflective materials > Dynamic speed warning signs	$950,000
24 Ave S: S 154 St to S 128 St	> Speed limit reduction > Walkway/bike lanes > All-way stop > Raised crossing > Bus bulb > Curb extension	$650,000
35 Ave S at 37 Pl S	> Curve advance warning signs	$1,600

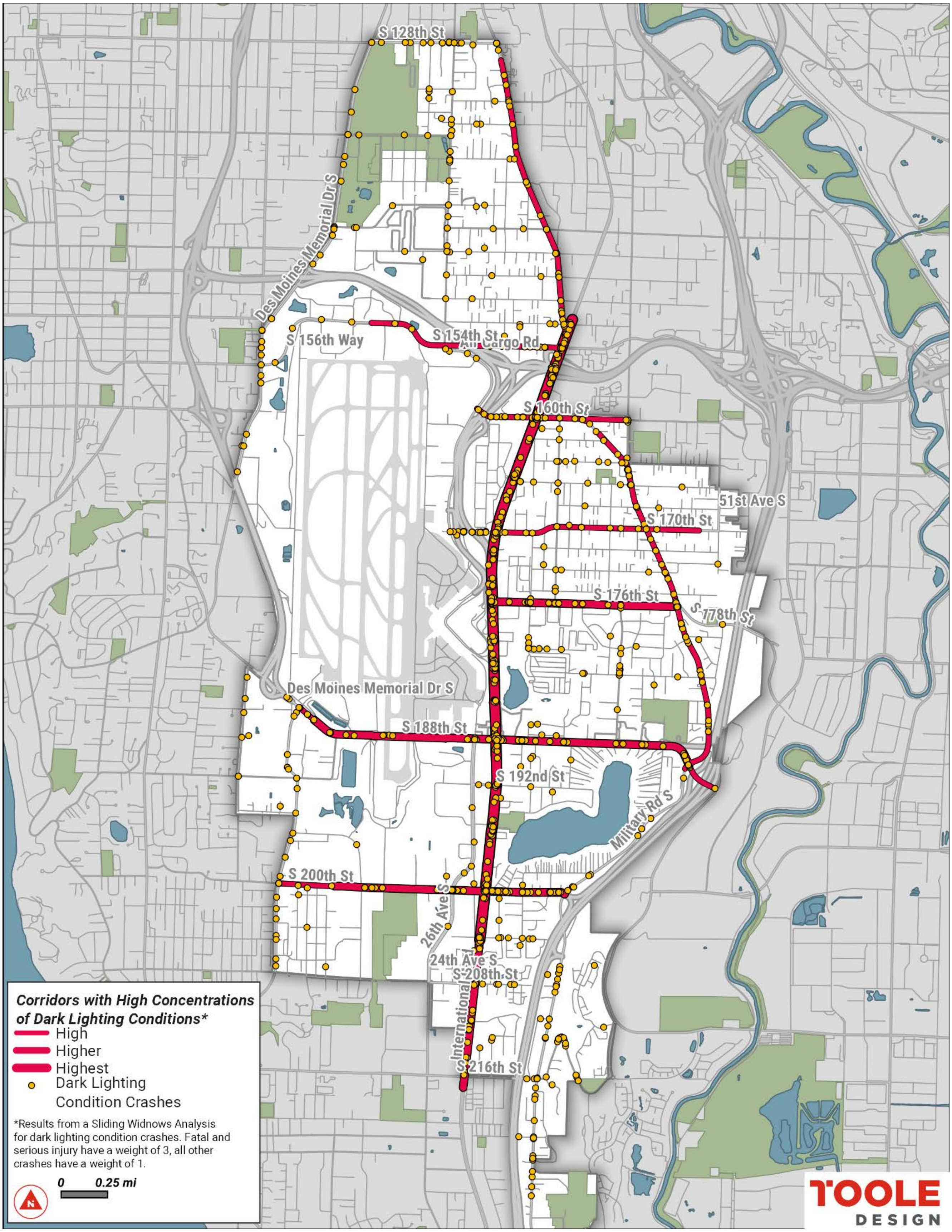
Data Collection Projects

The crash analysis points to a need for better street lighting along several corridors with a high incidence of dark lighting condition crashes. However, there was insufficient information about lighting conditions to make comprehensive recommendations. Therefore, a lighting study to identify locations and strategies to improve lighting is recommended. 8.5 miles of roadways with the highest occurrence of dark lighting condition crashes (see Table 5 below) were identified, but the study could also include other corridors where a need for improved street lighting has been identified.

Data Collection	Locations	Estimated Project Cost (rounded)
Conduct a lighting study on 8.5 miles of roadways with the	> International Blvd from S 216th St to Military Rd S (4 miles)	$270,000

highest occurrence of dark lighting condition crashes	> S 200th St from 14th Ave S to Military Rd (1.25 miles) > S 188th St from Des Moines Memorial Dr S to Military Rd S (2.25 miles) > S 176th from International Blvd to Military Rd (1 mile)

Map 5: Corridors with High Concentrations of Dark Lighting Condition Crashes



Alignment of Project Recommendations with Other SeaTac Planning Efforts

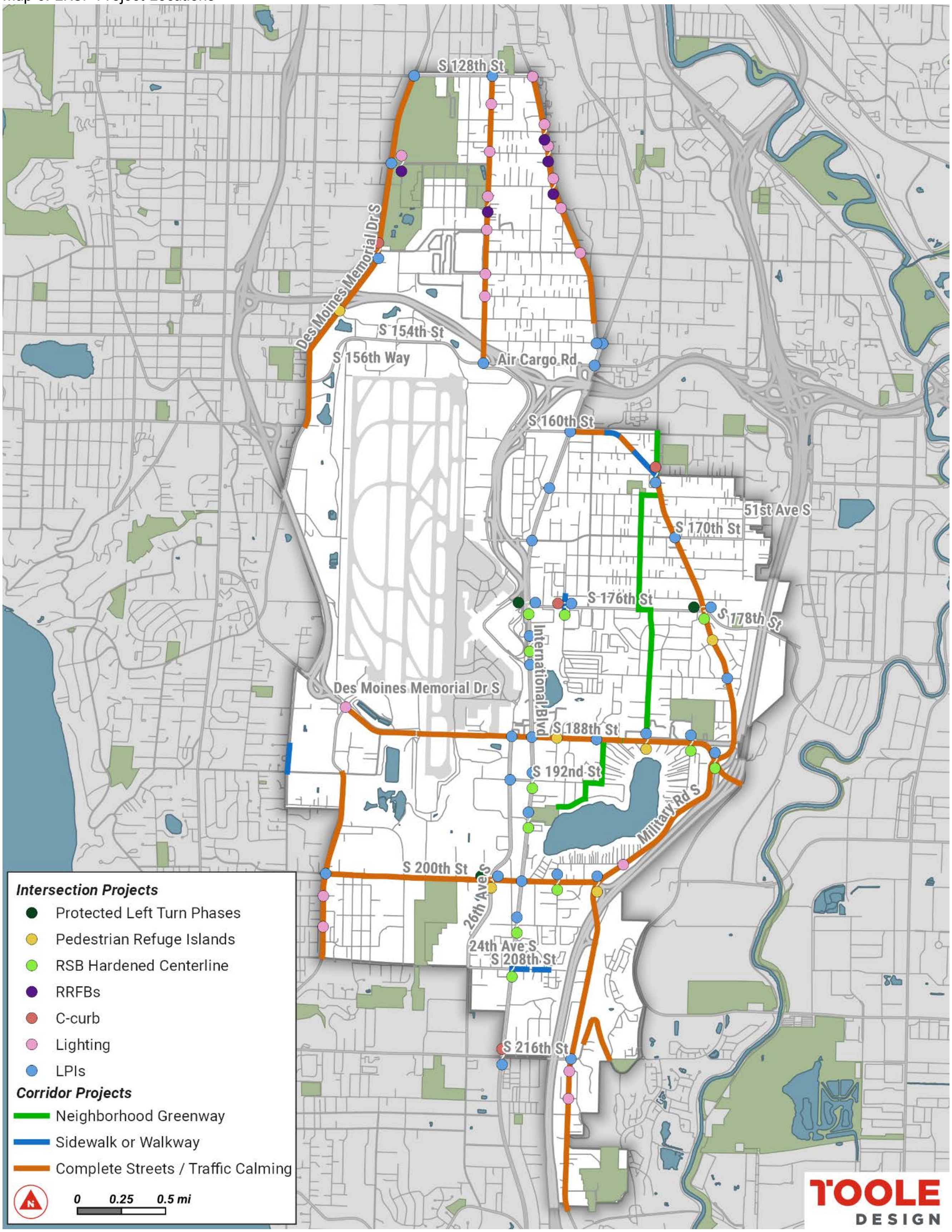
The projects identified through this planning effort represent significant investments within SeaTac and are largely in alignment with several of the City's adopted planning documents and guidelines. In particular, many of the new pedestrian and bicycle facilities proposed were also included in the City's Transportation Master Plan (2015). In the case of the proposed neighborhood greenway, the proposed route includes several roadways where shared lanes were already proposed but brings them together into a 2.8-mile, all-ages, all-abilities facility. The attached Prioritization Spreadsheet notes many of the instances where proposed safety projects overlap with projects proposed in the TMP.

These project proposals supplement the previous set of proposals focused on International Boulevard. Besides signal changes and centerline treatments on adjacent streets, these projects do not include substantial work on International Boulevard.

Improvements that create bus bulbs, reduce curb radii, or install concrete curb extensions also present opportunities to upgrade the non-compliant curb ramps, sidewalks, and crossings identified in the ADA Transition Plan (2018).

Some of the proposed projects require coordination with the City's partner agencies, including King County Metro, Sound Transit, and WSDOT.

Map 6: LRSP Project Locations



Project Prioritization

After identifying and refining the proposed projects, the next step was to prioritize them. Prioritization consisted of two elements: the first being location priority and the second being a Benefit-Cost comparison (see Table 27). Each of these elements includes one or more factors. Further, some of these factors have several variables based on how the factor is best measured.

The location priority variables aim to prioritize locations that have a history of pedestrian crashes in terms of frequency and severity, those that have a high number of risk factors for potential crashes, and proximity to nearby common pedestrian activity generators. These activity generating variables serve as proxies for pedestrian exposure as pedestrian volume data is not available at the time of this analysis.

The Benefit-Cost comparison aims to assess individual countermeasures as well as selected countermeasure(s) at intersections along the corridors on how effective the countermeasures are expected to reduce pedestrian crashes (and the associated societal costs of these crashes) compared to estimated countermeasure costs. Additional background information is provided below for the Benefit-Cost comparison metrics.

Table 27: Prioritization Factors

Factor	Details	Weighting
	Location Priority	
Locations with high crash injury weighting	Aggregate weighted crash scores per mile or per intersection	3 points if in top third 2 points if in middle third 1 point if in bottom third
Locations with high number of risk factors	Average number of risk factors present at segments / intersections for each project	6 points if 6 risk factors 5 points if 5 risk factors etc.
High Pedestrian Activity Location: Transit	Light rail or bus stop	3 points for a light rail station and a bus stop 2 points for a light rail 1 point for bus stop
High Pedestrian Activity Location: Destinations	Location is adjacent to restaurants, bars, grocery stores, retail, schools, parks, or other similar pedestrian destinations. Weighting based on the number of destinations per mile or per intersection.	3 points if in top third 2 points if in middle third 0 points if in bottom third
	Benefit-Cost Comparison	
Benefit-Cost Ratio	When CMFs are available: Federal Highway Administration (FHWA) Benefit Cost Analysis (BCA) tool to obtain the Benefit-Cost Ratio (BCR)	10 points if BCR is in top third 5 points if BCR is in middle third 0 points if BCR is in bottom third
	[or]	
Generalized benefit vs. cost	When CMFs are not available, either because the recommendation is programmatic or because a CMF has not yet been evaluated, develop a generalized high-medium-low benefit/cost ratio based on estimated costs as well as expected safety benefit informed by research and engineering judgment.	10 points if generalized benefit vs. cost is high 5 points if generalized benefit vs. cost is medium 0 points if generalized benefit vs. cost is low
		Total Points Possible: 25

Benefit-Cost Ratio Development

Development of a Benefit-Cost Ratio (BCR) is based on the estimated cost of each countermeasure compared to the expected safety benefit. The BCR is developed using the Federal Highway Administration (FHWA) Benefit Cost Analysis (BCA) tool.[14] The Tool calculates the present value costs and weighs that against the project benefits. While the increase in safety and resulting reduction in crashes is the main benefit, the tool also accounts for expected effects on travel time, reliability, vehicle operations, and emission benefits. For each project, we input the estimated crashes of each severity level, based on crash history, and the expected reduction based on Crash Modification Factor (CMF) values for the proposed countermeasure(s).[15] The BCR is developed by multiplying the countermeasures' CMF by the cost valuation of the location's applicable crash history and then dividing this number by the planning-level cost estimate for each project or countermeasure.

Generalized Benefit vs. Cost Comparison

Not all pedestrian safety countermeasures have been rigorously studied and many have yet to be assigned a CMF. As a result of several known safety countermeasures lacking estimated CMFs, an additional method is needed to review and prioritize benefits and costs qualitatively. To do this, the countermeasures' cost is compared with the overall safety expectation of the countermeasure based on research and engineering judgement. This enables a relative comparison of costs and benefits.

Prioritization Results

The following table summarizes the results of the prioritization analysis. The Overall Score gives the sum of all of the prioritization factors. See Map 6 (p. 55) for project locations and types.

Table 28: Combined Project Prioritization

Rank	Location	Countermeasures	Overall Score	Estimated Project Cost
1	Permissive left turns and pedestrian crashes that are also at bus stops or within a quarter mile of schools, parks, light rail stations, or commercial areas (11 intersections)	> Rubber speed bump (RSB) hardened centerline (HC) treatment to calm left turns	22	$39,000
2	Intersections of two arterials with permissive left turns (3 intersections)	> Protected only left turn phases	21	$71,000
3	High crash intersection legs with driveways	> C-curb	19	$45,000

[14] For more information on the FHWA BCA too, see the Highway Safety Benefit-Cost Analysis Guide: https://safety.fhwa.dot.gov/hsip/docs/fhwasa18001.pdf

[15] The efficacy of a given countermeasure can be measured using a Crash Modification Factor (CMF). A Crash Modification Factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific location. For example, if a roadway is averaging 100 bicycle and pedestrian crashes per year and you implement a countermeasure that has a CMF of 0.70 for bicycle and pedestrian crashes, then you can expect to see 70 bicycle and pedestrian crashes per year following the implementation of the countermeasure (100 x 0.70 = 70).

Rank	Location	Countermeasures	Overall Score	Estimated Project Cost
4	S 188 St: International Blvd to Orillia Rd S	> Speed limit reduction > Pedestrian signal > Curb radius reduction	17	$500,000
4	S 188 St: Des Moines Memorial Dr to International Blvd	> Reflective materials > Refuge island > Sidewalk > Curb radius reduction	17	$240,000
6	Signalized pedestrian crossings at intersections with bus stops or within a quarter mile of schools, parks, light rail stations, or commercial areas (38 intersections)	> Leading pedestrian intervals (LPIs) > Pedestrian recall	16	$110,000
6	S 200 St: Des Moines Memorial Dr S to Military Rd S	> Road diet with bike lanes, median, and turn bays	16	$110,000
6	Military Rd S: S 150 St to S 128 St	> Road reconstruction with sidewalks, bike lanes, left turn lanes > Curb extensions > All-way stop	16	$8,400,000
9	42 Ave S, 40 Ave S, 37 Ave S, S 192 St and 33 Ave S (2.8 miles)	> Neighborhood greenway including intersection crossing treatments, traffic calming, and wayfinding	15	$570,000
9	Military Rd: S 188 St to S 160 St	> Speed limit reduction > Curb extension > Dynamic speed warning signs > Median refuge island	15	$260,000
11	Fill missing links in pedestrian network: 208 St	> Concrete sidewalks	14	$400,000
11	Fill missing links in pedestrian network: 8 Ave	> Concrete sidewalks	14	$170,000
11	Fill missing links in pedestrian network: 188 St	> Concrete sidewalks	14	$450,000

Rank	Location	Countermeasures	Overall Score	Estimated Project Cost
11	Fill missing links in pedestrian network: 160 St and Military Rd	> Concrete sidewalks	14	$1,700,000
11	35 Ave S at 37 Pl S	> Curve advance warning signs	14	$1,600
16	24 Ave S: S 154 St to S 128 St	> Speed limit reduction > Walkway/bike lanes > All-way stop > Raised crossing > Bus bulb > Curb extension	13	$650,000
17	Fill missing links in pedestrian network: 32 Ave	> Concrete sidewalks	12	$280,000
18	Intersection with insufficient illumination and a high incidence of dark lighting condition crashes (20 intersections)	> Intersection lighting	11	$720,000
18	S 160 St: Military Rd to International Blvd	> Road diet with bike lanes, median, and turn bays > Curb extension	11	$190,000
18	Des Moines Memorial Dr S: S 208 St to S 192 St	> Truck aprons > Reflective materials > Dynamic speed warning signs	11	$68,000
21	Military Rd: S 229 Pl to S 188 St	> Rumble strips > Reflective materials > Curb radius reduction	9	$950,000
22	Des Moines Memorial Dr S: S 160 St to S 128 St	> Curb radius reductions > Bus boarding platforms and bus bulb > In-street pedestrian crossing sign	7	$510,000
23	Priority pedestrian crossings (6 locations)	> RRFBs	5	$320,000
23	Various high crash locations (6 locations)	> Pedestrian Refuge Islands	5	$410,000
N/A	Lighting evaluation study		N/A	$270,000

Conclusion

Key Takeaways

The SeaTac LRSP was developed to support the City in understanding trends in safety issues along the roadway network and to provide a basis for systemic safety improvements through a prioritized list of projects. Using seven discrete steps, the plan started by analyzing crash data, which was consolidated for each intersection. Then, since the focus of the LRSP is to reduce or eliminate KSI crashes, the next step was to conduct an analysis of individual KSI crashes from officer-reported data and identify high-risk factors using EPDO scores and the development of Crash Trees.

From the spatial analysis of the network datasets, it identified the most common risk factors and analyzed the roadway network for the presence of these high-risk factors. Crash analysis also revealed other crash trends including the high share of KSI crashes that involved pedestrians and fixed objects.

The study screened each intersection to identify where the high-risk factors are present. The majority of these locations are along International Boulevard, which was found to have the highest number of risk factors present as well as having the highest concentration of KSI crashes throughout the city.[16] To reduce the occurrence of KSI crashes, this LRSP proposes a toolbox of 40 countermeasures intended to mitigate risk factors which are suitable to the local context, ranging from traffic signal modifications to bike lanes. The LRSP applies these countermeasures to locations where high-risk factors are present, resulting in a set of 8 countermeasure-based projects and 12 corridor-based projects, including cost estimates. Through a prioritization process that included location priority (areas that have a high number of risk factors for potential crashes and proximity to nearby common pedestrian activity generators) and a benefit-cost comparison (how effective countermeasures are expected to reduce pedestrian crashes compared to their costs), priority projects were identified.

[16] For more information on International Boulevard and the City's plans to address safety issues along the corridor, see the International Boulevard Pedestrian Safety Study.

Implementation and Next Steps

The goal of the LSRP is to provide useful recommendations for improving road safety consistent with Vision Zero goals. Projects recommended in the plan can be designed and implemented with the support of various state and national funding sources including but not limited to HSIP. The proposed projects and countermeasures should also be considered for implementation as part of other roadway projects, including routine resurfacing.

Finally, to further advance Vision Zero goals, the City should also consider other measures to improve road safety including but not limited to:

- Education and outreach programs to encourage safe driving behavior and instill a sense of shared responsibility for each other's safety
- Bicycle and pedestrian safety improvements using low-cost, quick-build projects
- Automated enforcement to reduce speeding and red light running
- Safe Routes to School (SRTS) programs to educate the next generation of responsible road users
- Transportation Demand Management (TDM) programs to reduce vehicle miles travelled (VMT), in turn reducing overall exposure and crash risk

Appendix

Complete Countermeasure Toolbox

Table 29: Complete Countermeasure Toolbox

CM ID	Countermeasure Name	CM Group	Crash Types Addressed	CMF	Overall Efficacy (High, Medium, Low)	Complexity	Cost	Unit Price	Cost Unit	Cost Notes	CMF Source	Notes
S1	**Install concrete c-curb centerline at approaches**	Corridor Spot Treatments	All	0.29	High	Low	$$	$ 40	LF		SCHULTZ ET AL., 2008 via cmfclearinghouse.org (Install raised median)	Applicable for turning-movement crashes related to access points near an intersection. CMF based on signalized intersection.
S2	**Create directional median openings to allow (and restrict) left-turns and u-turns**	Corridor Spot Treatments	All	0.76	Medium	Medium	$$	$ 20,000	Each	Assume remove 100' raised median (width=12'), and add 100' turn pocket with 0.5' AC and 1.5' AB	ZHOU ET AL., 2013 via cmfclearinghouse.org (Convert an open median to a directional median)	A cluster of similar turning movement-related crashes may indicate a candidate movement to restrict.
S3	**Install left-turn lane**	Corridor Spot Treatments	All		Medium	Medium	$$	$ 20,000	Intersection	Assume installation as part of roadway reconstruction. Assumes 100 LF turn bay and 100' Transition to existing lane configuration. Both sides of major road intersection.		Look for turning collisions. Cannot be at all-way stop. Requires additional ROW to widen roadway.
S4	**Install pedestrian median fencing on approaches**	Corridor Spot Treatments	Ped & Bike		Low	Low	$	$ 7,500	Approach	Cost depends on material used and length of fencing, assuming 150 ft of chain link fence per approach.		
C1	**Convert to all-way STOP control (from 2-way or Yield control)**	Intersection Control	All	0.32	High	Low	$	$ 2,500	Intersection		SIMPSON AND HUMMER, 2010 via cmfclearinghouse.org (Convert minor-road stop control to an all-way stop control)	
C2	**Install new traffic signal**	Intersection Control	All		High	Medium	$$$	$ 500,000	Intersection	Assume 4-leg intersection		
C3	**Convert intersection to roundabout**	Intersection Control	All	0.62	High	High	$$$	$ 6,000,000	Intersection	Source: https://safety.fhwa.dot.gov/intersection/innovative/roundabouts/case_studies/fhwasa09018/	GBOLOGAH ET AL., 2019 via http://www.cmfclearinghouse.org/ (Conversion of intersection to roundabout)	Significant crash history, complex geometry. CMF based on conversion from signal.
G1	**Construct bus boarding island with raised bicycle lane behind**	Intersection Geometry	All		Medium	High	$$$	$ 70,000	Each	Assume 12' Wide x 60' long Bus Island with ramp from crosswalk, pedestrian waiting zone nose, and 5" raised Bike Lane behind bus island. This is built entirely within the existing roadway.		May calm traffic and improve safety for riders waiting on the bus. Also improves accessibility and streamlines bus service. Also eliminates conflict between buses and bikes.

CM ID	Countermeasure Name	CM Group	Crash Types Addressed	CMF	Overall Efficacy (High, Medium, Low)	Complexity	Cost	Unit Price	Cost Unit	Cost Notes	CMF Source	Notes
G2	**Construct bus bulb**	Intersection Geometry	All		Medium	Medium	$$$	$ 40,000	Each	Assume removal of existing roadway lane to construct bus bulb (60' x 12') +(15' taper to ex curb). DOES NOT ASSUME RECONSTRUCTION OF ENTIRE CORNER FOR NEAR AND FAR SIDE BUS STOPS		May calm traffic and improve safety for riders waiting on the bus. Also improves accessibility and streamlines bus service.
G3	**Install "paint and post" curb extensions using temporary materials**	Intersection Geometry	All		Medium	Medium	$	$ 4,400	Corner			
G4	**Construct curb extensions**	Intersection Geometry	All		Medium	High	$$	$ 30,000	Corner	May be more expensive if catch basin relocation is required.		
G5	**Install splitter islands on the minor road approaches**	Intersection Geometry	All		High	Medium	$$	$ 20,000	Approach			Provides a pedestrian refuge while also calming turning movements. Look for minor street with relatively high speed; visibility issues.
G6	**Install "paint and post" splitter islands using temporary materials**	Intersection Geometry	All		Medium	Low	$	$ 10	SF			
G7	**Reduce curb radii**	Intersection Geometry	All		Low	Medium	$$	$ 17,000	Corner	Tightening from radius from 30' to 15'		If truck turning movements require larger curb radii, consider installing truck aprons instead.
G8	**Reduce curb radii using "paint and post" curb extensions using temporary materials**	Intersection Geometry	All		Low	Low	$	$ 3,800	Corner	Tightening from radius from 30' to 15'		If truck turning movements require larger curb radii, consider installing truck aprons instead.
L1	**Add intersection lighting**	Lighting	Night	0.73	Medium	Low	$$	$ 7,000	Light	Assume adding one additional light where nearby lighting is already present	SACCHI AND TAYEBIKHORAMI, 2021 via cmfclearinghouse.org (Install intersection lighting)	Must be night-time crashes, no lighting present. CMF based on signalized intersection.
L2	**Add segment lighting**	Lighting	Night	0.79	Medium	Low	$$	$ 200,000	Mile	One streetlight placed in an alternating pattern every 180 ft.		Night crashes, particularly rear-end, right-angle, turning or roadway departure collisions. Consider impact to visibility for non-motorists.
B3	**Road Diet (Reduce travel lanes from 4 to 3 and add a two**	New Bicycle Facilities	All	0.53	High	Medium	$$	$ 100,000	Mile	Assume scarification and restriping only	PERSAUD ET. AL, 2010 via cmfclearinghouse.org (Converting four-lane roadways to three-lane	Appropriate for high frequency of head-on, left turn and rear-end crashes.

CM ID	Countermeasure Name	CM Group	Crash Types Addressed	CMF	Overall Efficacy (High, Medium, Low)	Complexity	Cost	Unit Price	Cost Unit	Cost Notes	CMF Source	Notes
	way left-turn and bicycle lanes)										roadways with center turn lane (road diet))	
B1	**Install bicycle lanes**	New Bicycle Facilities	Ped & Bike	0.51	High	Low	$	$ 40,000	Mile			Standard, non-protected bike lanes may not be comfortable for cyclists of all ages and abilities.
B2	**Create neighborhood greenways on low volume, low speed streets**	New Bicycle Facilities	Ped & Bike		Medium	Medium	$	$ 80,000	Mile	Cost is highly variable. Includes wayfinding sharrows, signage, speed bumps, and crossing treatments. Major crossings requiring signalization changes or other interventions often account for a large percentage of the costs of a bike boulevard. Source: "Cost Analysis of Bicycle Facilities: Cases from cities in the Portland, OR region".		With the right traffic calming, volume control, and intersection crossing treatments, bicycle boulevards can provide an all ages and abilities bicycle facility.
P1	**Install pedestrian crossing at signalized intersection**	New Pedestrian Facilities	Ped & Bike		Medium	Medium	$	$ 8,200	Crossing	Cost assumes use of high visibility crosswalk markings and appropriate signage.		
P2	**Install pedestrian crossing at uncontrolled locations**	New Pedestrian Facilities	Ped & Bike		Low	Medium	$	$ 3,000	Crossing	New signs and markings only		Detectable Warning Surfaces at curb ramps should be considered as an accessibility and safety feature.
P3	**Install Pedestrian Signal (including Pedestrian Hybrid Beacon (HAWK))**	New Pedestrian Facilities	Ped & Bike		High	Medium	$$$	$ 150,000	Each	Source: "Cost Analysis of Bicycle Facilities: Cases from cities in the Portland, OR region"		
P4	**Construct sidewalk**	New Pedestrian Facilities	Ped & Bike		High	High	$$$	$ 200	LF	100 LF of 6' sidewalk, 2' Curb and gutter over existing pavement, 4' landscaping		To prevent pedestrians walking in the roadway. Cost is highly variable, and complexity depends on space available.
P5	**Install "paint and post" walkway using temporary materials**	New Pedestrian Facilities	Ped & Bike		Medium	Medium	$$	$ 50	LF			
O1	**Install edgeline rumble strips/stripes**	Operation / Warning	All		Medium	Low	$$	$ 10	LF		TORBIC ET AL., 2009 via cmfclearinghouse.org (Install edgeline rumble strips)	Consider impact to bicyclists of rumble strips.
O2	**Install dynamic/variable**	Operation / Warning	All	0.95	Low	Low	$$	$ 7,500	Each		HALLMARK ET AL., 2015 via cmfclearinghouse.org (Install dynamic speed feedback sign)	Curved roadways -- Consider appropriate combinations with other CMs.

CM ID	Countermeasure Name	CM Group	Crash Types Addressed	CMF	Overall Efficacy (High, Medium, Low)	Complexity	Cost	Unit Price	Cost Unit	Cost Notes	CMF Source	Notes
	speed warning signs											
O3	**Install Flashing Beacons at Stop-Controlled Intersections**	Operation / Warning	All	0.95	Low	Low	$$	$ 25,000	Intersection	Assume 4-leg intersection.	SRINIVASAN ET AL., 2008 via cmfclearinghouse.org (Provide flashing beacons at stop controlled intersections)	Look for turning collisions -- or PCF of "traffic signals and signs".
O4	**Install curve advance warning signs**	Operation / Warning	All	0.7	Medium	Low	$	$ 300	Sign	Cost is to manufacture and install sign. Assume one post per sign.	ELVIK, R. AND VAA, T., 2004 via cmfclearinghouse.org (Advance static curve warning signs)	Consider appropriate combinations with other CMs.
O5	**Improve pavement friction (High Friction Surface Treatments)**	Operation / Warning	All		Low	Low	$	$ 1	SF	Based on Caltrans Cost Data for Sand Cover (Seal).		Wet-pavement condition crashes or "failure to stop" crashes.
O6	**Install reflective object markers**	Operation / Warning	All		Low	Low	$	$ 50	Each			Curved roadways and roadways with fixed object crashes -- consider combining with other appropriate CMs.
O7	**Install raised pavement markers and striping through intersection**	Operation / Warning	All		Low	Low	$	$ 1,600	Intersection	Assume 100' wide intersection, 8 stripes with markers at $2/ft.		Beneficial for intersections with large footprints and/or multiple turn lanes on an approach.
O8	**Install/upgrade larger or additional stop signs or other intersection warning/regulatory signs**	Operation / Warning	All		Low	Low	$	$ 600	Sign	Cost is to manufacture and install sign. Assume one post per sign.		Rear-end, right angle, or turning collisions -- indicating visibility of stop presence.
O9	**Lower speed limit by 10 mph**	Operation / Warning	All		Medium	Low	$	$ 600	Sign			Lowering speed limits should be accompanied by other mitigation measures to lower design speed.
U5	**Install in-street pedestrian crossing sign**	Pedestrian Crossing Upgrades	Ped & Bike		Low	Low	$	$ 400	Sign			
U1	**Construct pedestrian refuge island**	Pedestrian Crossing Upgrades	Ped & Bike	0.44	High	Medium	$$	$ 20,000	Approach		TOOLBOX OF COUNTERMEASURES AND THEIR POTENTIAL EFFECTIVENESS TO MAKE INTERSECTIONS SAFER, ITE, 2004	Can also be installed using less expensive materials such as paint and plastic bollards.

CM ID	Countermeasure Name	CM Group	Crash Types Addressed	CMF	Overall Efficacy (High, Medium, Low)	Complexity	Cost	Unit Price	Cost Unit	Cost Notes	CMF Source	Notes
U2	**Install Rectangular Rapid Flashing Beacon (RRFB)**	Pedestrian Crossing Upgrades	Ped & Bike	0.53	High	Medium	$$	$ 20,000	Beacon		ZEGEER ET AL., 2017 via cmfclearinghouse.org (Install rectangular rapid flashing beacon (RRFB)	
U3	**Construct raised pedestrian crossing**	Pedestrian Crossing Upgrades	Ped & Bike	0.64	High	High	$$$	$ 600	SY		ELVIK, R. AND VAA, T., 2004	Typically used for midblock crossings or across free right turns.
U4	**Install pedestrian countdown signal heads**	Pedestrian Crossing Upgrades	Ped & Bike	0.91	Low	Low	$$	$ 12,000	Intersection	Assume 8 signal heads	KITALI ET AL., 2017 via cmfclearinghouse.org (Install pedestrian countdown timer)	
M1	**Modify signal phasing to implement a Leading Pedestrian Interval (LPI)**	Signal Modifications	Ped & Bike	0.9	Low	Low	$	$ 600	Intersection		GOUGHNOUR ET AL., 2018 via cmfclearinghouse.org (Modify signal phasing (implement a leading pedestrian interval)	
M2	**Provide protected left turn phase (left turn lane already exists)**	Signal Modifications	All	0.58	High	Low	$$	Varies	Approach	Depends what modifications are required; May require installation of vehicle detectors, signal equipment, and signal programing.	DAVIS AND AUL, 2007 via cmfclearinghouse.org (Change from permitted-protected to protected on major approach)	Applicable to crashes involving left-turning vehicles -- may be angle, head-on, sideswipe or rear end. Also may include pedestrian crashes.
M3	**Modify signal phasing to implement pedestrian signal recall**	Signal Modifications	Ped & Bike		Low	Low	$	$ 500	Intersection	Assume existing signal		Pedestrian recall should be considered when pedestrian demand is great enough that there is a pedestrian call in most cycles.
T1	**Hardened centerline for left turn traffic calming**	Traffic Calming	Ped & Bike		Medium	Low	$	$ 800	Approach	28' rubber speed bump (21' along double yellow and 7' in intersection)		Install on centerline of receiving roadway to modify the angle of motorists turning left. Expands the field of vision for drivers and increases the visibility of pedestrians.
T2	**Install truck aprons**	Traffic Calming	Ped & Bike		Low	Medium	$$	$ 2,500	Corner	Includes pavement markings, flex posts, and pillow apron		
			Key / notes:	Crash Modification	High: CMF < .7 Med: CMF < .9 Low: CMF > .9 N/A: Inconclusive evidence			Unit price includes construction materials and			Text in parentheses identifies the countermeasure name used on cmfclearinghouse.org	