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The Gouda, the Bad, and the Ugly: Prioritizing Intersections for Pedestrian Safety in
Tillamook, OR with Different Risk Estimation Methods

By

Kelly White

A research project report submitted in partial fulfillment
of the requirement for the degree of

MASTER OF SCIENCE
IN
CIVIL AND ENVIRONMENTAL ENGINEERING

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ABSTRACT

An abstract of the research report of Kelly White for the Master of Science in Civil and Environmental Engineering submitted on June 17th, 2019.

Title: The Gouda, the Bad, and the Ugly: Prioritizing Intersections for Pedestrian Safety in Tillamook, OR with Different Risk Estimation Methods

The following report explores five different pedestrian risk estimation methods at urban intersections. Six study intersections in Tillamook, Oregon were chosen as a case study to analyze each risk estimation method and apply the values to a project prioritization process. Ultimately, risk factors of both exposure and infrastructure contribute to the highest amount of risk for pedestrians. The Oregon Department of Transportation's State Planning and Research Report 779 was identified as the most comprehensive risk estimation method.

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1.0 INTRODUCTION

As agencies across the United States are adopting programs and initiatives to cut down on traffic deaths, pedestrian safety has emerged as a key component for enhancing overall roadway safety. Pedestrians are arguably the road's most vulnerable user, and whether short distance or long distance, at least every single person is a pedestrian on the roadway network at some point in their day. Transportation planning and design efforts have increasingly included pedestrian safety projects as priorities but are often generalized on a corridor level due to the large number of existing low-quality pedestrian facilities that exist in most communities today. When plan implementation rolls around, agencies often struggle to prioritize which facilities require the most need with quantitative justification.

In recent years, local and national agencies have addressed this issue of pedestrian and bicycle project prioritization by developing measures of risk to determine which intersections or segments put pedestrians in the most amount of danger according to specific characteristics of the roadway at each intersection. The following paper will use a case study in Tillamook, Oregon to compare multiple risk calculation methods that have been developed at the state level, national level, and in the private sector to understand how pedestrian projects are being prioritized throughout the world.

1.1 Objectives

The purpose of this research is to conduct a review of pedestrian risk calculation methods developed by agencies at varying levels of jurisdiction. The review will include methods developed by the Oregon Department of Transportation (ODOT), the Federal Highway Administration (FHWA), and the International Roadway Assessment Programme (iRap). These methods will be compared to a risk calculation measured in the field using recently collected pedestrian count data at the study intersections.

1.2 Scope of Work

Risk will be calculated using the methods listed above at six intersections in Tillamook, Oregon where recent pedestrian count data was collected for their 2018 Transportation System Plan. All six intersections are located along US-101 inside of Tillamook city limits. A full analysis of the segment of US-101 through the City will not be included in the scope of this report.

1.3 Organization

The following chapter provides background on the development of each risk assessment method. The methodology chapter describes each risk assessment method in detail, including the necessary data elements for calculation. The analysis section will display the results of each risk calculation, which is followed by a discussion of the results and commentary on the similarities and differences between each method and its output.

2.0 BACKGROUND

The following section provides study area context for this research, background on why risk estimations can be used to quantify pedestrian safety, and brief descriptions of how each risk estimation method used in this research was developed.

2.1 Study Area

The following report will follow a case study of six intersections located in Tillamook, Oregon. The City is located in western Tillamook County, on the southeast end of Tillamook Bay, and west of the Tillamook State Forest. Tillamook is located about 60 miles west of Portland and less than 10 miles from the Oregon coast. All six intersections are located along the US-101 couplet, which travels north-south through the City and provide connections from Tillamook to the communities of Garibaldi and Bay City to the north and Lincoln City to the south. The study intersections are shown in Figure 1 below, and are listed below:

- 3rd Street / US 101 SB
- 3rd Street / US 101 NB
- 4th Street / US 101 SB
- 4th Street / US 101 NB
- 11th Street / US 101 SB
- 11th Street / US 101 NB

Figure 1. Study Intersections in Tillamook, Oregon along US-101

Study intersections for this research were chosen based upon available pedestrian and vehicle count data collected during the development of the recent update to Tillamook’s Transportation System Plan, (TSP). As part of the project identification in the TSP update, a number of pedestrian crossings were evaluated and prioritized as a bundle for both basic and advanced crossing improvements. The purpose of this research is to provide a framework for how to prioritize crossings within these bundles to allocate funding to intersections that are experiencing the highest pedestrian risk. Notably, the intersections selected for this project were not necessarily identified by the TSP for improvement, but rather were chosen because of their differing infrastructure and exposure characteristics to show how risk estimation methods scoring impacts a variety of intersections.

The intersections on 3rd Street and 4th Street are located in what is known as “downtown” Tillamook, and are surrounded by grocery stores, restaurants, and shops. Each of these

intersections is four-way stop controlled, with marked crosswalks on each leg. Importantly, during the time of the development of the TSP when pedestrian and vehicle counts were taken as well as the available crash data that was analyzed, the intersection of 4th Street and US 101 SB was under construction. To account for the construction's impact on data collected, the intersection was analyzed with only two marked crosswalks as the other two were under construction.

The intersections on 11th Street are surrounded by single-family homes. Each intersection is four-leg stop controlled and may experience different crossing patterns and characteristics. Crosswalks are marked on at least two of the legs at each intersection, however the crosswalks are not clearly marked.

2.2 Pedestrian Counts and Factoring Method

Four-hour pedestrian counts were collected during the PM peak hours at each of the study intersections during the development of the City's TSP.¹ According to methodology developed by the National Bicycle and Pedestrian Documentation Project, the peak hour was calculated at each intersection and counts were extrapolated to daily, monthly, and annual pedestrians.² Table 1 summarizes each step that was taken to factor the peak hour counts at each intersection. Table 2 provides a summary of the peak hour pedestrian counts at each intersection and the AADT values that were calculated.

Table 1. Peak Hour Count Factoring Process

Step	Name	Description	Factor Applied
1	Adjustment Factor	Reflection of non-peak pedestrians	1.05 * peak hour counts
2	Average Weekday	Hourly Adjustment Factor for weekday pedestrian environment (4-5pm)	Factored peak / 0.08
3	Average Weekly	Daily Adjustment Factors for Tuesday	Average Weekday / 0.13
4	Average Monthly	Average number of weeks in a month	Average Weekly * 4.33
5	Annual Totals	Monthly Adjustment by Climate Area (June, Moderate Climate)	Average Monthly / 0.08
6	Daily Averages (AADT)	365 days in a year	Annual totals / 365

Table 2. Study Intersection Peak Hour Pedestrian Volumes

Intersection	Pedestrian Peak Hour Count	Pedestrian AADT Value
3rd Street / US 101 SB	220	793
3rd Street / US 101 NB	193	793
4th Street / US 101 SB	193	958
4th Street / US 101 NB	126	719
11th Street / US 101 SB	23	90
11th Street / US 101 NB	24	150

¹ Counts were collected August 29, 2017 from 2-6pm.

² Count Adjustment Factors, National Bicycle & Pedestrian Documentation Project, March 2009.

These factors may not accurately represent pedestrian AADT in Tillamook, OR because pedestrian variations throughout the country are unknown and lack year-long automatic count data for adjustments. To control for this potential over or under-estimation, the same factored pedestrian counts will be used in each of the risk estimation methods.

2.3 Brief Crash Data Analysis

To understand the current state of pedestrian safety in Tillamook, the most recent available crash data (2013-2017) was obtained from ODOT's Crash Database. Eleven (11) pedestrian crashes occurred in Tillamook during the analysis period with five occurring at the study intersections excluding 4th Street and US 101 NB. One serious injury occurred at 4th Street and US 101 SB, and all crashes included at least one injured pedestrian. Although so few crashes occurred in the five-year analysis period, crashes that involve pedestrians are particularly concerning because of how vulnerable pedestrians are and how severe vehicle-pedestrian crashes can be. Because of this concern, other methods have been developed to quantify the safety of pedestrians besides crashes.

2.4 Quantifying Pedestrian Risk

As mentioned in the previous section, using crash data and frequency-based methods alone may not reveal where true pedestrian safety issues lie within the transportation system. As an alternative, risk-based methods may provide additional pedestrian safety context by incorporating additional explanatory variables.

Contextually, risk is defined as a probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through preemptive action. As shown by the risk matrix in Figure 2, the amount of risk can be interpreted as the probability of the outcome and potential severity of the outcome if the event occurs, (Berdica, 2002).

Figure 2. Risk Matrix, Darker Shading Indicates Higher Risk (Berdica, 2002)

For pedestrians, the probability of a crash is a function of exposure and the consequence is a function of the infrastructure or operating conditions. As the remainder of this report describes, risk-based scoring models include many different factors that increase risk levels for pedestrians that include elements of exposure and expectations of the severity of the outcome.

2.5 ODOT SPR 779

In an effort to mitigate both the rising number of pedestrian and bicycle fatalities and injuries throughout Oregon and the high social cost of these events, the Oregon Department of Transportation (ODOT) has identified pedestrian and bicycle crashes as a primary focus area for investing infrastructure funding, and subsequently has allocated approximately \$4 million annually in the All Roads Transportation Safety Program (ARTS) to help address this key need. Due to the low frequency of bicycle and pedestrian crashes, selecting and scheduling projects to address necessary safety concerns is challenging.

In conjunction with research teams from Portland State University (PSU), ODOT's State Planning and Research Program (SPR) developed pedestrian and bicycle risk-scoring methods with weights derived from data analysis in ODOT SPR 779. Prior risk-scoring methods at ODOT were developed using limited supplemental data and therefore risk scores were based on best judgement. This research greatly expanded the previous dataset by merging data elements that were collected on segments and intersections, and later developed into logistic models resulting in an easy to use tool. Inputs for the tool and a brief discussion on the methodology behind the tool will be described in the following chapter. The scope of this report limits discussion of ODOT's SPR 779 tool to only pedestrian risk-scoring methods at intersections.

2.6 FHWA SCRAM

Similar to the motivation behind ODOT SPR 779, the FHWA recognizes that many transportation agencies are placing more emphasis on improving bicycle and pedestrian safety but are lacking a methodological approach to assess pedestrian and bicyclist risk for the purposes of identifying high-priority areas and transportation facilities for safety improvement. In conjunction with researchers from Texas A&M Transportation Institute, University of Michigan Transportation Research Institute, and Kimley-Horn and Associates, Inc, the Federal Highway Administration (FHWA) developed a guide describing a scalable risk assessment method (SCRAM) for pedestrians and bicyclists which achieves the following items:

- Outlines eight sequential steps to develop risk values at various desired geographic scales.
- Describes the scope and nature of each step, including any guiding principles.
- Provides information on the analytic methods to estimate pedestrian and bicyclist exposure.
- Identifies other relevant guides and resources that provide supplemental information.

The guide is organized based on eight steps that can be followed to develop bicycle and pedestrian risk values at various geographic scales, shown in Figure 3.

Figure 3. Eight Steps for Scalable Risk Assessment for Pedestrians and Bicyclists (SCRAM)

The methodology chapter will discuss each step in greater detail. Notably, the scope of this research is limited to evaluation of pedestrian risk only.

2.7 iRAP

The International Road Assessment Programme (iRAP) is a United Kingdom based charity dedicated to saving lives through safer roads. Of particular interest for this research, iRAP works in partnership with government and non-government organizations throughout the world to inspect high-risk roads and develop star ratings and safer roads investment plans. Agencies across the world have adopted this program, including EuroRAP (European countries, mainly Sweden, Germany and the UK), AusRAP (Australia), usRAP (United States), and in New Zealand (KiwiRAP).

The program assigns star ratings and road safety scores to each road segment, which are based on the presence or absence of design and traffic control features known to be related to safety for both roadways and intersections. The star ratings range from one star to five stars, where one-star roads have the fewest safety-related design and traffic operational features and five-star roads have many safety-related design and traffic control features. Particularly applicable for this research, separate star ratings are assigned for vehicle occupants, motorcyclists, bicyclists, and pedestrians because the features that affect crash frequencies for the various travel modes differ substantially.

Via iRAP's website, free software and a global body of research that supports the predictive risk modeling program is available. Further details on the development of pedestrian specific risk models using iRAP will be discussed in the Methodology section of this report.

2.8 HSM Predictive Models and Field Measured Exposure

The Highway Safety Manual provides a predictive method for calculating the predicted and/or expected average crash frequency of a network, facility, or individual site through the concept of safety performance functions (SPFs).³ The resulting predictions of average crash frequency as a function of traffic volume and roadway characteristics can be used for making decisions related to designing, planning, operating, and maintaining roadway networks. The predictive method can be used to assess crashes for existing conditions, alternatives to existing conditions, or proposed new roadways.

For the purposes of this research, the predictive method was used to assess pedestrian type crashes for existing conditions at each of the study intersections. To relate the predictive model to the other risk assessment methods described in this report, the expected crash frequency determined by the HSM predictive models will be used with available exposure data to calculate pedestrian risk at each study intersection. Further details on the use of the HSM predictive model in this research will be provided in the Methodology section of this report.

³ Highway Safety Manual, Part C: Predictive Method.

2.9 Field Measured Risk

Historical crash data was used in conjunction with available exposure data to calculate a field measured risk value for each study intersection. Further detail on the calculation of exposure will be provided in the methodology section of this report.

3.0 METHODOLOGY

The following chapter describes the methodology behind each risk estimation method and how it will be interpreted for this research.

3.1 ODOT SPR 779

In order to develop a useful risk-scoring tool with weights based on a detailed data analysis, the research team for ODOT SPR 779 identified a number of key risk factors for bicycle and pedestrian crashes. The risk factors are shown in Table 3.

Table 3. Summary of Identified Risk Factors for Pedestrian Crashes

Roadway: <ul style="list-style-type: none"> • Average sidewalk width • Distance to the closest marked crosswalk or intersections • Lane widths • Maximum number of crossing stages • Number of driveways • Number of traffic directions • Number of traffic lanes • Paved shoulder • Presence of bus stop • Presence of marked crosswalk • Presence of median • Presence of paved sidewalk • Total road width 	Traffic Characteristics: <ul style="list-style-type: none"> • Average daily traffic • Functional class • Number of left- and right-turning vehicles • Operating vehicle speed • Pedestrian crossing volumes • Percent heavy vehicles • Percentage of public transit vehicles • Posted speed limit • Time of day • Weekend/weekday 	Demographic and Behavior: <ul style="list-style-type: none"> • Age <18 and Age >65 • Driver drug/alcohol use • Employee population • Gender • Household size • Mean household income • Pedestrian drug/alcohol use • Proportion of people of working age • Race • Resident population • Single-family residential • Vehicle number in housing unit
Intersections: <ul style="list-style-type: none"> • Horizontal curve on opposing approach • Midblock location • Number of lanes • Number of left-turn lanes • Number of right-turn lanes • Number of through lanes being crossed • Pedestrian delay (cycle length) • Presence of enhanced crossing • Presence of intersection • Presence of median (major or minor) • Type of traffic control 	Land Use: <ul style="list-style-type: none"> • Block size • Natural resources inventory net density • Neighborhood business • Neighborhood service district • Residential-neighborhood commercial • Urban/rural areas 	Lighting and Weather: <ul style="list-style-type: none"> • Lighting (Dark/daylight) • Lighting adequacy data • Visibility • Weather (Clear/other/raining)

Multiple crash occurrence models were developed and tested, and the research team ultimately selected a logit occurrence model (crash/no crash) to develop risk scores. As risk is defined by a probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities that may be avoided through preemptive actions, risk scores include both elements of exposure and likely outcomes. The maximum risk score is set to 100 for the scoring matrix. Model results were converted to a risk score using the odds ratio, where a higher odds ratio indicates that there is a higher probability of having crashes. The base condition was transformed to the minimum odds ratio to make all scores positive, and each variable was assigned a component of the risk score based on the overall contribution.

Six variables were determined significant in calculations for risk scores for pedestrians at intersections, as shown in Table 4. The largest contributing variable to the risk score was assigned to the number of transit routes running through the intersection (maximum weight = 25). Population density in the census block received the next highest weight (maximum weight = 21), followed by traffic volume with respect to major road AADT (maximum weight = 18), medians on the major roads (maximum weight = 13), right-turn lanes on the minor roads (maximum weight = 15), and right-turn lanes on the minor roads (maximum weight = 8).

Table 4. Pedestrian Intersection Risk Scores

Variable	Levels	Internal Weight	Risk Score
Number of transit lines with routes through intersection	0 (base)	1.00	0
	1	1.47	6
	2	2.15	8
	3	3.16	12
	>3	6.79	25
Total Population Density (per square mile)	<=1000	1.00	0
	(1001, 3000)	1.44	5
	(3001, 5000)	2.30	8
	(5001, 7000)	3.77	13
	>7000	6.03	21
Major AADT (2014)	<=5000	1.00	0
	(5001, 10000)	1.37	5
	(10001, 15000)	1.88	7
	(15001, 20000)	2.57	10
	(20001, 25000)	3.52	13
	>25000	4.82	18
Minor road, presence of right-turn lanes	Yes	1.00	0
	No	3.71	15
Presence of median on major road	Yes	1.00	0
	No	3.52	13
Major road, presence of right-turn lanes	No	1.00	0
	Yes	2.19	8

An Excel spreadsheet was constructed to aid the implementation of the risk scoring table. Notably, the risk scores are only intended to be evaluated within each context (i.e., the risk scores for pedestrians at intersections are not comparable for the risk scores for pedestrians on segments).

3.2 FHWA SCRAM

The following section will discuss each step of the SCRAM process for pedestrians and how it was interpreted for the purposes of this research.

Step 1. Determine Use of Risk Values

The first step in developing risk values for pedestrians is to clearly define the use of the risk values. The use of the risk values provides direction throughout the remaining steps of the SCRAM process, and the guide provides several questions to help clarify the use and objective of each risk value. Typical uses of pedestrian risk values include:

- Safety Performance Measures
- Network Screening, both area-based and facility-based
- Countermeasure evaluation
- Site evaluation
- ***Project Prioritization***

Figure 4 describes how determination of the use of risk values will impact the remaining steps in the SCRAM process.

Step 1. Define Use(s) of Risk Values	Step 2. Select Geographic Scale				Step 3. Select Risk Definition			Step 4. Select Exposure Measure					Step 5. Select Analytic Method		
	Point	Segment	Network	Regional	Observed Crash Rate	Expected Crashes	Risk Indicators	Distance Traveled	Time Traveled	Volume/Counts	Trips Made	Population	Site Count	Estimation Model	Travel Survey
Safety performance measures: Track changes in risk over time	X	X	✓	✓	✓	X	X	✓	✓	X	O	O	O	X	✓
Network screening: area-based: Identify high-risk areas for possible improvement	NA	NA	✓	✓	✓	O	O	✓	✓	X	O	O	X	O	✓
Network screening: facility-based: Identify high-risk facilities for possible improvement	✓	✓	NA	NA	✓	O	O	O	O	✓	O	O	✓	✓	X
Project prioritization: Rank projects based on existing risk or expected risk reduction	✓	✓	O	O	✓	O	✓	O	O	✓	X	X	✓	✓	X
Countermeasure evaluation: Evaluate if a specific countermeasure reduces risk (and by how much)	✓	✓	NA	NA	✓	O	O	O	O	✓	X	X	✓	O	X
Site evaluation: Evaluate if risk was reduced after site improvements (and by how much)	✓	✓	NA	NA	✓	✓	O	O	O	✓	X	X	✓	O	X

Legend: ✓ = Yes, preferred; O = yes, as a secondary preference; X = Not likely; NA = Not applicable

Figure 4. Selecting Key Parameters Based on Use(s) of Risk Values

This research will estimate risk values for the purposes of project prioritization, so that it can easily be compared to other risk estimation methods that are geared towards similar outputs. The result of the SCRAM method will be a ranking of intersections based on their risk estimations.

Step 2. Select Geographic Scale

Step 2 in the SCRAM process is to select the geographic scale at which risk and exposure values are desired. As mentioned previously, the use of the risk value will often help define the geographic scale. Subsequently, the selection of geographic scale will impact the remainder of the steps in this process. The four scale categories in the Scalable Risk Assessment process are shown in Table 5.

Table 5. Four Scale Categories in the Scalable Risk Assessment Process

Scale Group	Scale Category	Description	Examples
<i>Facility-Specific</i>	<i>Point</i>	<i>Specific location where conflicting traffic streams cross, merge, or diverge.</i>	<ul style="list-style-type: none">• <i>Single intersection or mid-block crossing</i>• <i>All crossings at an intersection</i>• <i>Conflict zone (e.g., merge area)</i>
	Segment	Length of street or roadway between two points. Traffic volumes and physical characteristics generally remain the same along the length of a segment, although very small variations occur.	<ul style="list-style-type: none">• Street segment between major intersections• Multiple street segments along a single facility, or on parallel facilities (e.g., corridor)• Street segment of defined length (e.g., one mile)
Areawide	Network	A mid-sized geographic area that includes an interconnected set of transportation facilities.	<ul style="list-style-type: none">• Census tracts• Census block groups• Traffic analysis zones
	Regional	A large geographic area that includes all transportation facilities within a defined political boundary. Because of the large geographic size, land use at this scale can be heterogeneous within a defined area.	<ul style="list-style-type: none">• City• County• Metropolitan Statistical Area• State

This research will analyze the six study intersections as facility-specific points.

Step 3. Select Risk Definition

Step 3 in the SCRAM process is to select a specific definition of risk that will be used to calculate quantitative risk values. Table 6 describes the possible definitions for pedestrian risk.

Table 6. Possible Definitions of Pedestrian Risk

	1. Observed Crash Rate	2. Expected Crashes	3. Additional Risk Indicators
Description	<ul style="list-style-type: none">• Risk = Observed crashes divided by exposure• Obtain observed crashes from available crash database(s).• Estimate exposure with the guide.	<ul style="list-style-type: none">• Risk = Expected crashes• Estimate expected crashes with HSM or other statistical modeling, using exposure as input variables• Estimate exposure with the guide.	<ul style="list-style-type: none">• <i>Risk = function of one or more risk indicators: observed crashes, facility type or condition, motor vehicle speed and volume, adjacent land use, exposure, etc.</i>• <i>Estimate exposure with the guide.</i>
Strengths	<ul style="list-style-type: none">• Common use among many practitioners.• Use with other crash analysis tools.	<ul style="list-style-type: none">• Use of expected crashes overcomes issues with low (or no) observed crash frequency. Permits evaluation of implemented countermeasures.	<ul style="list-style-type: none">• <i>Compatible with FHWA Systemic Safety Analysis.</i>• <i>Approach geared towards practitioners.</i>
Limitations	<ul style="list-style-type: none">• Low exposure or low (or no) frequency of observed crashes may not accurately represent risk	<ul style="list-style-type: none">• Requires advanced statistical methods to estimate expected crashes.	<ul style="list-style-type: none">• <i>Risk is a dimensionless numeric score or rating, not a crash frequency or crash value.</i>

This research will define risk within the SCRAM process by using more than one risk indicator combined into a composite risk score. Additional risk factors will be determined through a Systemic Safety Analysis and discussed in further detail in the analysis section of this report. The limitations of this method will be addressed by the other risk estimation methods within this research.

Step 4. Select Exposure Measure

Step 4 in the SCRAM process is to select a specific exposure measure to be used in the calculation of risk values. There are several different categories of exposure measures that attempt to quantify the level of contact that pedestrians have with potentially harmful safety outcomes; however, the following five exposure measures are included in the SCRAM guidance:

- Distance Traveled – cumulative distance traveled by all pedestrians at the specified geographic scale, most commonly measured as pedestrian miles traveled (PMT).
- Time Traveled – cumulative time traveled by all pedestrians at the specified geographic scale, most commonly measured as pedestrian hours traveled.

- **Volume/Count** – number of pedestrians for a specified time period and geographic scale, which sometimes may be annualized for a typical day.
- **Trips Made** – cumulative number of trips made by all pedestrians at the specified geographic scale.
- **Population** – number of people (or specified sub-population) at the specified geographic scale, most commonly measured as the number of people (or percent of the population) that walk.

Figure 5 shows the selection matrix provided by the SCRAM guide, which recommends exposure measures based on the appropriate geographic scale that was selected in Step 3.

Category of Exposure Measure	Typical measures	Typical scale				Typical data sources
		Point	Segment	Network	Region	
Distance Traveled	Miles of travel	○	●	●	●	<ul style="list-style-type: none"> • Site counts or demand estimation models, multiplied by segment length • Sometimes travel surveys
	Miles crossed per entering vehicle	◐				
Time Traveled	Hours of travel	○	○	●	●	<ul style="list-style-type: none"> • Travel surveys • Sometimes site counts combined with crossing time or average travel speed data.
	Product of crossing time and vehicle volume	○	○			
Volume/Count	Volume/count	●	●			<ul style="list-style-type: none"> • Site counts • Demand estimation models
	Product of pedestrian /bicyclist volumes and motor vehicle volumes	◐	◐			
Trips Made	Number of trips			●	●	<ul style="list-style-type: none"> • Travel surveys
Population	Number of people that walk or cycle on regular basis			●	●	<ul style="list-style-type: none"> • U.S. Census data products
	Percent of the population that walk or cycle on regular basis			●	●	

Legend: ○ = to a small extent; ◐ = to a moderate extent; ● = to a great extent.

Note: Each exposure measure will be for a defined time period that matches the risk definition.

Figure 5. Selection Matrix for Exposure Measures

This research selected pedestrian volume/counts as the exposure method for the Scalable Risk Assessment. The strength of this selection aside from it matching with the appropriate geographic scale, is that no assumptions will be made about distance or time traveled that are required in the other recommended exposure measures for a point scale.

In the development of the recently adopted Tillamook Transportation System Plan (TSP), four-hour weekday PM peak hour (2-6pm) intersection counts were collected at the identified study intersections.⁴ Counts were then factored to average daily numbers following methodology developed by the National Bicycle and Pedestrian Documentation Project.⁵ The pedestrian average daily numbers were then multiplied by vehicle AADT⁶ to estimate exposure at each intersection with the following equation:

$$\text{Pedestrian Volume} * \text{Motor Vehicle Volume} = \text{Pedestrian Exposure}$$

Documentation of pedestrian count factoring and exposure calculations can be found in the Background section of this report.

Step 5. Select Analytic Method to Estimate Exposure

Step 5 in the SCRAM process is to select an analytic method to exposure. There are numerous analytic methods that can be used to estimate exposure that depend on the desired geographic scale, scope, data availability, and available analysis resources. The analytic methods outlined in the guide include:

- **Site counts**
- Demand estimation models
 - Direct demand models
 - Regional TDM
 - Trip generation and flow models
 - GIS-based models
 - Discrete choice models
 - Simulation-based traffic models
 - Data fusion
- Travel Surveys
 - ACS
 - NHTS
 - Regional household travel survey

For this research, site counts were selected to estimate exposure. Other analytic methods require additional steps for estimating exposure, however the methodology used to translate individual site counts to pedestrian exposure at each intersection was described in the previous step.

Step 6. Use Analytic Method to Estimate Selected Exposure Measure

Step 6 in the SCRAM process is to use the analytic method selected in step 5 to estimate the desired exposure measure. Within the SCRAM guide, step 6 provides an overview of the manual

⁴ Counts collected on August 29, 2017 from 2-6pm.

⁵ Count Adjustment Factors, National Bicycle and Pedestrian Documentation Project, March 2009.

⁶ Major roadway AADT obtained from the ODOT TransGIS Database, Minor Roadway AADT calculated from intersection turning movement counts collected for the Tillamook TSP on August 29, 2017.

and automated counting procedures that could be used to estimate selected exposure. These methods were not used in this research, as recent count data was available.

Step 7. Compile Other Required Data

Step 7 in the SCRAM process consists of compiling other data besides exposure that is required based upon the risk definition selected in Step 3. Where this research had less involvement in step 5 and step 6 of the SCRAM process, step 7 involved a much more detailed analysis.

A Systemic Safety Approach was used to develop a list of additional risk factors.⁷ A review of the attributes from the crash data analysis and roadway inventory to determine which risk factors were present at one or more of the study intersections. Table 7 describes the risk indicators that were identified, and the appropriate thresholds based on the conditions of intersections throughout the City of Tillamook.

Table 7. Identified Risk Indicators

Risk Indicator	Risk Threshold
Minor Approach Functional Class	Urban Collector and above
Traffic Control	Presence of a traffic signal
Presence/Proximity of a Transit Stop	Bus stop within 500 feet of intersection
Volume	Major Roadway AADT over 6500
Exposure	Exposure value within top 50% of intersections with available data in Tillamook

Outputs of each risk indicator at the study intersections are documented in the analysis section of this report.

Step 8. Calculate Risk Values

Step 8 in the SCRAM process is to calculate risk values based on the outputs from the previous steps. For project prioritization purposes, this research used the defined risk thresholds to assign one “star” to an intersection if it exhibited conditions above the risk threshold. Therefore, intersections with a higher number of stars are presumably more risky intersections and should be prioritized for safety improvements. Star ratings and risk values are documented in the analysis section of this report.

3.3 iRAP

The iRAP methodology involves combining a decided upon number of risk factors to develop an overall risk score. These risk factors are equitable to crash modification factors (CMFs), which are used to compute the expected number of crashes after implementing a given countermeasure at a specific site. In general, iRAP follows a multiplicative model for each of its factors:

$$\text{Risk Score} = \text{likelihood factor} * \text{likelihood factor} * \text{likelihood factor}$$

⁷ Methodology provided by the Systemic Safety Project Selection Tool promoted by the FHWA.

Agencies may choose to include other factors such as protection actors or area accident type factors, however this research only included likelihood factors based on available data.

Risk factor definitions and scores that are used in iRAP products are available on their website in the form of fact sheets, however the selection of criteria for a specific crash type is dependent on the agency. For the purposes of this research, framework for determining which risk factors should be included in the pedestrian risk models was chosen based on the EuroRAP rating process to provide an additional layer of context outside of the United States for comparing risk estimation methods. The factors included in the EuroRAP pedestrian model are shown in Table 8.

Table 8. Factors included in the EuroRAP Pedestrian Model

Mode	Accident Type	Likelihood Factor
Pedestrian	Along Road	Speed Sidewalk Side Friction
	<i>Crossing</i>	<i>Speed</i> <i>Number of Lanes</i> <i>Median Type</i> <i>Pedestrian Crossing Facilities</i> <i>Quality of Crossing</i>

For the purposes of this research, the likelihood factors for the Crossing accident type were selected for the risk estimation model. After consideration of the EuroRAP factors and a review of the remaining factors applicable to pedestrians, the following attributes were selected for the iRAP risk estimation model:

- Speed (mph)
- Number of Lanes
- Pedestrian Crossing Facilities
- Quality of Crossing
- Intersection Type
- Vehicle Parking

Notably, “Median Type” was removed from the final list of likelihood factors because all study intersections are located on one-way roadways with no presence of a median. Table 9 describes each road attribute risk and its associated likelihood factor. Notably, only relevant categories for the study intersections were included in this table, and additional categories can be found on the iRAP fact sheets available on their website. The assumption was made that all study intersections are located in an urban area.

Table 9. iRAP Risk Factor Key

Road Attribute	Category	Risk Factor (Urban)
Operating Speed (mph)	<20	0.01
	25	0.019
Number of Lanes	One	1
	Two	0.02
Pedestrian Crossing Facility	Signalized without refuge	1.25
	Unsignalized marked crossing without refuge	4.8
Quality of Crossing⁸	Poor	1.5
	Adequate	1
	Not Applicable	1
Intersection Type	4-leg unsignalized without protected turn lane	70
	4-leg signalized without protected turn lane	45
	4-leg signalized with protected turn lane	35
Vehicle Parking	One side	1.2
	Two sides	1.33

All data necessary to assign each risk factor was obtained via Google Streetview. Risk score results for each intersection according to the iRAP scoring system are found in the Analysis section of this report. Noticeably, a likelihood factor of exposure has been excluded from the risk estimation with the iRAP method in this report. The iRAP methodology includes two likelihood factors related to pedestrian risk: pedestrian external flow and pedestrian observed flow.

Pedestrian external flow reflects risk to pedestrians increasing with the flow of heavier mass vehicles and motorcyclists at the location. The road attribute factors would be used to reflect the likelihood that a pedestrian would be struck by a vehicle. As shown in Figure 6 below, for the purposes of the iRAP model where the highest side road volume category is >15,000 (7,500 vehicles per lane assuming a two-lane road) the peak value of 0.5 has been adopted for any intersecting road with lane flows greater than 7,500.⁹

⁸ Quality of Crossing categories determined by iRAP handbook. Description of this road attribute can be found in iRAP Coding Manual as described in Reference List.

⁹ iRAP Model Factsheet 5 – External Flow.

Figure 6. Pedestrian (crossing side road at intersection) external flow risk factors

Due to the location of the study intersections on US-101 in this research, each study intersection received the same risk factor value for pedestrian external flow. Therefore, this likelihood factor was not included in the iRAP risk estimation for this report.

The pedestrian observed flow likelihood factor is expected to have had an impact on the overall risk estimation for the iRAP method. However, due to the proprietary nature of the iRAP methodology, not all risk factor values are available without full purchase of the program. For that reason, the pedestrian observed flow likelihood factor was not included in the iRAP risk estimation for this report.

3.4 HSM Predictive Models and Field Measured Exposure

The HSM Predictive Method can be used to assess crash frequencies of a network, facility, or individual site under existing conditions. The method focuses on the use of statistical models to address the inherent randomness of crashes and calculates expected and/or predicted crash frequencies based on roadway characteristics and traffic volume. There are three crash frequencies that can be used in the predictive method:

- Observed crash frequency – historical crash data observed/reported at the site during the period of analysis.
- Predicted average crash frequency – can be modeled with the geometric design, traffic control features, and traffic volumes of a site.
- Expected average crash frequency – the long-term average crash frequency that would be expected from the site, only used when observed crash frequency is available.

The predictive models in HSM Part C are composed of three basic elements:

- Safety Performance Functions (SPFs)
- Crash Modification Factors (CMFs)
- Local calibration factors

The following formula shows how expected average crashes are estimated at signalized intersections¹⁰:

$$N_{ped} = N_{pedbase} \times CMF_{1p} \times CMF_{2p} \times CMF_{3p}$$

Where:

N_{ped} = Estimated Number of Crashes

$N_{pedbase}$ = Number of Predicted Crashes according to SPF for Vehicle
– Pedestrian Collisions

$CMF_{p1}, CMF_{p2}, CMF_{p3}$ = CMFs for Vehicle – Pedestrian Collisions

For pedestrian collisions that occur at stop-controlled intersections, overall crashes are multiplied by a Pedestrian Crash Adjustment Factor using the following equation and Table 10:

$$N_{ped} = N_{total} \times f_{pedi}$$

Table 10. Pedestrian Crash Adjustment Factors

Intersection Type	Pedestrian Crash Adjustment Factor (f_{pedi})
3ST	0.021
4ST	0.022

To calculate expected crash frequency, an additional step is added to incorporate the observed crash frequency by weighting with Empirical Bayes (EB). Table 11 describes the data requirements that are needed to complete the spreadsheet, which requires inputs for the SPFs, CMFs, Local Calibration Factors, and necessary elements for the EB Method.

Table 11. Pedestrian Data Needed for SPF Calculation

Data Element
Vehicle AADT
Number of Lanes
Pedestrian Volume
Bus Stops within 1,000 ft
Number of Alcohol Sales Establishments within 1,000 ft
Schools within 1,000 ft

¹⁰ Equation 12-28, Highway Safety Manual Urban-Suburban Equations.

The remainder of this section will provide further detail for calculating the expected average number of pedestrian-vehicle crashes at signalized intersections.

Safety performance functions (SPFs) are used to estimate the predicted average crash frequency of an individual roadway segment or intersection. They are developed through statistical regression techniques using historical crash data collected over a number of years at “base” sites with similar characteristics. Particularly of interest for this research, for intersections the dependent variable is the predicted average crash frequency for a facility type under base conditions, and the independent variables are AADT on the major and minor roads. The SPFs are developed for total crash frequency including all crash severity levels and collision types, however SPFs for specific collision types and/or crash severity levels are also developed. Table 12 shows the appropriate SPFs for a given crash frequency at a specific site.

Table 12. List of SPFs by Facility Type

Facility Types (HSM Chapter)	Facility Type	SPF for Collision Type	SPF for Crash Severity Level
Rural Two-Lane, Two-Way Roads (Chapter 10)	Roadway Segment	All collision types	All severity levels
	Intersection	All collision types	All severity levels
Rural Multilane Highways (Chapter 11)	Roadway Segment	All collision types	- All severity levels - Fatal-and-injury crashes
	Intersection	All collision types	- All severity levels - Fatal-and-injury crashes
<i>Urban and Suburban Arterials (Chapter 12)</i>	Roadway Segment	Single-vehicle collision	- All severity levels - Fatal-and-injury crashes - PDO crashes
		Multiple-vehicle non-driveway collision	- All severity levels - Fatal-and-injury crashes - PDO crashes
		Single-vehicle collision	All severity levels
		Multiple-vehicle driveway- related collision	All severity levels
		Vehicle-pedestrian collision	All severity levels
		Vehicle-bicycle collision	All severity levels
	<i>Intersection</i>	Multiple-vehicle collision	- All severity levels - Fatal-and-injury crashes - PDO crashes
		Single-vehicle collision	- All severity levels - Fatal-and-injury crashes - PDO crashes
		<i>Vehicle-pedestrian collision</i>	<i>All severity levels</i>
		Vehicle-bicycle collision	All severity levels

The SPFs that will be used in this research are at Intersections on Urban and Suburban Arterials for vehicle-pedestrian collisions at all severity levels¹¹:

$$N_{pedbase} = \exp(a + b \times \ln(AADT_{total}) + c \times \ln\left(\frac{AADT_{min}}{AADT_{maj}}\right) + d \times \ln(PedVol) + e \times n_{lanes})$$

Where:

a, b, c, d, e = references from HCM Table 12 – 14

$AADT_{total}$ = total Annual Average Daily Traffic of both major and minor roadways

$AADT_{min}$ = total Annual Average Daily Traffic of minor roadway

$AADT_{maj}$ = total Annual Average Daily Traffic of major roadway

$PedVol$ = total Annual Average Daily Pedestrian Volume

n_{lanes} = number of lanes

Table 13. SPFs for Vehicle-Pedestrian Collisions at Signalized Intersections (Table 12-14, HSM)

Intersection Type	Coefficients Used in Equation 12-29					Overdispersion Parameter (k)
	Intercept (a)	AADT _{total} (b)	AADT _{min} / AADT _{max} (c)	PedVol	N _{lanes}	
Total Crashes						
3SG	-6.60	0.05	0.24	0.41	0.09	0.52
4SG	-9.53	0.40	0.26	0.45	0.04	0.24

While the base models are calculated using a given set of site characteristics to calculate the predicted average crash frequency, *Crash Modification Factors (CMFs)* are used to adjust the base model to local conditions. A CMF represents the relative change in estimated average crash frequency due to differences for each specific condition. The following set of tables represent each CMF included in the vehicle-pedestrian collisions at signalized intersections where Table 14 describes CMF_{1p} , Table 15 describes CMF_{2p} , and Table 16 describes CMF_{3p} .

¹¹ Equation 12-29, Highway Safety Manual Urban-Suburban Equations.

Table 14. Crash Modification Factor (CMF_{1p}) for the Presence of Bus Stops near the Intersection

Number of Bus Stops within 1,000 ft of the Intersection	CMF_{1p}
0	1.00
1 or 2	2.78
3 or more	4.15

Table 15. Crash Modification Factor (CMF_{2p}) for the Presence of Schools near the Intersection

Number of Schools within 1,000 ft of the Intersection	CMF_{2p}
No school present	1.00
School present	1.35

Table 16. Crash Modification Factor (CMF_{3p}) for the Number of Alcohol Sales Establishments near the Intersection

Number of Alcohol Sales Establishments within 1,000 ft of the Intersection	CMF_{3p}
0	1.00
1 – 8	1.12
9 or more	1.56

The third element of the predictive model is the *Local Calibration Factor*. Because the HSM SPFs were developed using data from a subset of states, difference in crash data quality, roadway inventory, traffic counts, traffic reporting thresholds, and weather conditions may affect the prediction of the number and severity of crashes among states. For the predictive method to provide reliable results for each jurisdiction that uses them, several agencies have developed calibration factors. Figure 7 shows the Oregon DOT's local calibration factors.

Figure 7. Local Calibration Factors developed for Oregon by ODOT for HSM Predictive Models

Once the appropriate predicted average crash frequency is calculated, the Empirical Bayes Method (EB method) can be used to calculate the expected average crash frequency for past and future periods at the site. This adjustment is only applied when observed crash data for a minimum of 2 years are available for the specific site. The EB method can reduce the effect of the regression-to-the-mean, which recognizes the fact that crashes are random events and over time an intersection with given characteristics will achieve the same amount of crashes on average. The EB method can be described as follows:

1. Combines actual site crash history with predicted average crash frequency.
2. Weights the two values based on the strength of the model (SPF), where the measure of the model's strength is referred to as the overdispersion parameter (k).

$$N_{expected} = w * N_{predicted} + (1.00 - w) * N_{observed}$$

Where:

$$w = \frac{1}{[1 + k * (\sum N_{predicted})]}$$

And:

k = overdispersion parameter

$\sum N_{predicted}$ = predictive model estimate for all study years

As the result of ODOT SPR 684, an intuitive spreadsheet can be used to calculate the predicted number of crashes per year at a given intersection.

The analysis section of this report will describe in further detail how the predicted number of crashes per year at each intersection were combined with observed crash frequency within the

last five years of available crash data to generate the expected average crash frequencies, in addition to the calculation of risk estimations using exposure from pedestrian and vehicle counts.

3.5 Field Measured Risk

To calculate risk values according to observed historical crash and count data, vehicle and pedestrian AADT values and crash data will be combined using the following fundamental risk equation:

$$risk = \frac{crashes}{exposure}$$

In the development of the recently adopted Tillamook Transportation System Plan (TSP), two-hour weekday PM peak hour (4-6pm) intersection counts were collected at the identified study intersections.¹² Counts were then factored to average daily numbers following methodology developed by the National Bicycle and Pedestrian Documentation Project.¹³ The pedestrian average daily numbers were then multiplied by vehicle AADT¹⁴ to estimate exposure at each intersection with the following equation:

$$Pedestrian\ Volume * Motor\ Vehicle\ Volume = Pedestrian\ Exposure$$

Documentation of pedestrian count factoring can be found in the Background section of this report.

¹² Counts collected on August 29, 2017 from 2-6pm.

¹³ Count Adjustment Factors, National Bicycle and Pedestrian Documentation Project, March 2009.

¹⁴ Major roadway AADT obtained from the ODOT TransGIS Database, Minor Roadway AADT calculated from intersection turning movement counts collected for the Tillamook TSP on August 29, 2017.

4.0 ANALYSIS

The following section provides a table for each risk estimation method that describes the risk at each study intersection.

4.1 ODOT SPR 779

Risk values were determined for each study intersection according to the risk factors identified by ODOT SPR 779. Table 17 shows the resulting risk scores.

Table 17. ODOT SPR 779 Risk Scores

Intersection	Total Pop. Density in Census Block	Transit Routes through Int.	Major AADT	Presence of Median on Major Road	Minor Road, Presence of RT lanes	Major Road, Presence of RT lanes	Total Risk Score
3rd Street / US 101 SB	>7000	>2	5000 – 10000	No Presence	No Presence	No Presence	62
3rd Street / US 101 NB	>7000	>3	5000 – 10000	No Presence	No Presence	No Presence	79
4th Street / US 101 SB	5000-7000	2	5000 – 10000	No Presence	No Presence	No Presence	54
4th Street / US 101 NB	1000-3000	3	5000 – 10000	No Presence	No Presence	No Presence	50
11th Street / US 101 SB	>7000	2	5000 – 10000	No Presence	No Presence	No Presence	62
11th Street / US 101 NB	>7000	2	5000 – 10000	No Presence	No Presence	No Presence	62

The intersection of 3rd Street / US 101 NB was identified as the most risky intersection with the ODOT SPR 779 risk estimation method. As shown in the table above, it is the only intersection with more than three transit lines through the intersection and a higher ADT category.

4.2 FHWA SCRAM

Following the 8-step method provided in FHWA's Scalable Risk Assessment Guide, risk values were determined for each of the study intersections as "star" ratings. A higher star rating indicates a riskier intersection which should be prioritized for pedestrian safety improvements. Table 18 shows the star ratings for each intersection.

Table 18. SCRAM Risk Scores

Intersection	Minor Approach FC	Traffic Control	Proximity of Transit Stop	Volume	Exposure	Total Stars
3rd Street / US 101 SB	*	*		*		***
3rd Street / US 101 NB	*	*		*		***
4th Street / US 101 SB		*	*	*		***
4th Street / US 101 NB		*	*	*		***
11th Street / US 101 SB			*	*	*	***
11th Street / US 101 NB			*		*	**

Five of the six study intersections received the same risk score using the SCRAM method, though notably the risk attributes that received stars for each intersection varied. There were similarities between intersections on the same minor roadway in terms of the factors that met a risky threshold.

4.3 iRAP

Risk values were determined for each study intersection according to the risk factors identified in the iRAP Methodology section of this report. Table 19 shows the resulting risk scores.

Table 19. iRAP Risk Scores

Intersection	Likelihood Factors						Risk Score
	Speed	Number of Lanes	Intersection Type	Pedestrian Crossing Facilities	Quality of Crossing	Vehicle Parking	
3rd Street / US 101 SB	0.01	0.02	45	1.25	1	1.2	0.014
3rd Street / US 101 NB	0.01	0.02	45	1.25	1	1.2	0.014
4th Street / US 101 SB	0.01	0.02	35	1.25	1	1.33	0.012
4th Street / US 101 NB	0.01	0.02	45	1.25	1	1.33	0.015
11th Street / US 101 SB	0.019	0.02	70	4.8	1	1.33	0.170
11th Street / US 101 NB	0.019	0.02	70	4.8	1	1.33	0.170

As the only method that did not use exposure data in the risk estimation process, both intersections on 11th Street were identified as the most risky according to the iRAP methodology. These intersections have less protection from vehicles for pedestrians in terms of actual pedestrian infrastructure, though pedestrian counts were so much lower at this intersection that other methods inclusion of exposure minimized the risk calculations on 11th Street. The results of the iRAP method could suggest that though there are fewer pedestrians on 11th Street, they are experiencing higher levels of risk and potential for crashes with motor-vehicles.

4.4 HSM Predictive Models and Field Measured Exposure

Risk values were determined for each study intersection according to the predictive method described in the HSM in conjunction with field measured exposure via vehicle and pedestrian AADT values.¹⁵ Table 20 shows the resulting risk scores and ranking of intersections. An additional column for ranking is provided for clearer determination of which intersections have higher pedestrian risk.

Table 20. HSM Predictive Model and Field Measured Exposure Risk Scores

Intersection	Predicted Average Crash Frequency	Observed Crash Frequency	Expected Average Crash Frequency	Exposure	Risk (crashes / exposure)	Ranking
3rd Street / US 101 SB	0.324	1	0.51	5475023	9.37E-08	2
3rd Street / US 101 NB	0.35	1	0.54	4760890	1.14E-07	1
4th Street / US 101 SB	0.275	1	0.46	6611349	6.88E-08	3
4th Street / US 101 NB	0.242	0	0.19	4958512	3.78E-08	4
11th Street / US 101 SB	0.007	1	0.02	619814	2.46E-08	5
11th Street / US 101 NB	0.007	1	0.02	898281	1.70E-08	6

Similar to the ODOT SPR 779 risk estimation method, 3rd Street / US 101 NB was identified as the most risky study intersection. The HSM Predictive Method uses CMFs that account for pedestrian generators such as transit stops and convenience stores that sell alcohol therefore placing additional weight on exposure rates at each intersection, which likely explains the similar result to the ODOT method.

4.5 Field Measured Risk

Risk values were determined for each study intersection according to the risk equation described previously in the Methodology section. Table 21 shows the resulting risk scores and ranking of intersections. An additional column for ranking is provided for clearer determination of which intersections have higher pedestrian risk.

Table 21. Field Measured Risk Scores

Intersection	Exposure	Crashes	Risk (crashes / exposure)	ranking
3rd Street / US 101 SB	5475023	1	1.83E-07	2
3rd Street / US 101 NB	4760890	1	2.10E-07	1
4th Street / US 101 SB	6611349	1	1.51E-07	3
4th Street / US 101 NB	4958512	0	0.00E+00	6
11th Street / US 101 SB	619814	1	1.61E-06	5
11th Street / US 101 NB	898281	1	1.11E-06	4

¹⁵ Vehicle AADT on major roadways estimated using the ODOT TransGIS database. Vehicle AADT on minor roadways and Pedestrian AADT estimated using traffic counts taken for the adopted Tillamook TSP on August 29, 2017.

Due to the low number of crashes at the study intersections during the analysis period, the simplified field measured risk is also placing higher weight on exposure values, resulting in similar risk estimations to the HSM Predictive Method and the ODOT SPR 779 report.

5.0 RESULTS AND DISCUSSION

Table 22 provides a summary of the comprehensive risk values for all six study intersections' according to the five risk estimation methods analyzed. Lower rankings indicate intersections that should be prioritized for pedestrian safety improvements, where a ranking of 1 indicates the highest amount of risk.

Table 22. Comparison of Risk Estimation Models at each Study Intersection

Intersection	ODOT SPR 779	FHWA SCRAM	iRAP	HSM Predictive	Field Measured	Final Ranking
3rd Street / US 101 SB	2	1	4	2	2	11
3rd Street / US 101 NB	1	1	4	1	1	8
4th Street / US 101 SB	5	1	6	3	3	18
4th Street / US 101 NB	6	1	3	4	6	20
11th Street / US 101 SB	2	1	1	5	5	15
11th Street / US 101 NB	2	2	1	6	4	15

With the lowest final ranking of 8 points, 3rd Street and US 101 NB was identified as the most-risky study intersection. As one of the intersections with the highest vehicle and pedestrian AADT values, this ranking seems to be logical in terms of exposure alone. Its proximity to transit lines and transit stops also likely contribute to pedestrian volumes and increases exposure-related risk factors included in many of the estimation methods.

The intersection of 4th Street and US 101 NB received the highest final ranking of 20 points, indicating that it should have the lowest priority for pedestrian safety improvement projects. This intersection was the only intersection that did not have a crash in the last five years of available crash data.

Potentially as a result of risk factor inputs, intersections located on the same minor roadways were grouped together in the final ranking. Table 23 describes this observation. This trend may also be attributed to the short block distance between the northbound and southbound legs of the couplet, resulting in fewer differences between intersections on either direction of US 101.

Table 23. Minor Roadway Trend among Study Intersection Risk Ranks

Minor Roadway	Intersection (Rankings)
3 rd Street	US 101 SB (8), US 101 NB (11)
11 th Street	US 101 SB (15), US 101 NB (15)
4 th Street	US 101 SB (18), US 101 NB (20)

5.1 Frequently used Inputs/Data Requirements

Though each pedestrian risk estimation model had its own risk factors, common inputs and data requirements emerged after completing analyses for all methods. The following list of risk factors occurred in more than one risk estimation method:

- Presence/Proximity of Transit Lines or Stops
- Motor Vehicle Volume
- Pedestrian Volume
- Presence of Vehicle Turn Lanes
- Number of Vehicle Lanes

Following the definition of risk for pedestrians that exposure and infrastructure quality (probability) are related to the consequence, the mixture of exposure variables and infrastructure quality variables that were common among the methods analyzed in this report is logical. In addition, risk factors for the ODOT SPR 779 report and the FHWA SCRAM analysis were developed by looking at other risk estimation methods and what may contribute most to a lack of pedestrian safety. The following subsection will discuss an overall review of the risk estimation methods used in this report.

5.2 The Gouda, the Bad, and the Ugly

The Gouda

The risk estimation model developed by ODOT SPR 779 seemed to have the most risk factors in common with other estimation models and would be recommended for use in future project prioritization analyses. The methodology behind the ODOT SPR 779 model was developed through a comprehensive literature review of multiple methods, including the iRAP and HSM Predictive methodologies. In addition, its risk estimation was most similar to the cumulative risk estimations for all of the methodologies.

The Bad

As mentioned previously in this report, using a simplified definition of risk that only includes exposure and crashes is an incomplete way to prioritize intersections for pedestrian safety. As identified by using a combination of risk estimation methods, pedestrian volumes were not as high at the study intersections on 11th Street but including infrastructure elements in risk scoring allows the analysis to quantify poor quality that is experienced in the field. Without quantification of infrastructure conditions, unsafe intersections could go overlooked if pedestrians are not crossing there.

The Ugly

Arguably, any pedestrian on the roadway should be protected whether they are a part of a larger group of pedestrians or not. Pedestrian risk estimation methods that place a heavy weight on exposure values may be oversimplifying the nature of pedestrian traffic and how the attractiveness and safety of a crossing may impact how many pedestrians cross there. The

ultimate goal of identifying pedestrian projects within a TSP process is to make the overall pedestrian system better throughout a city or region, therefore building out a safe network can promote pedestrian activity at intersections that currently experience lower crossing volumes. It is the job of transportation engineers and planners to analyze a network holistically, which a number of the risk estimation methods analyzed in this report do. “The Ugly” can only happen when pedestrians are overlooked.

6.0 REFERENCES

Berdica, K. “An Introduction to Road Vulnerability: What Has Been Done, Is Done and Should be Done. *Transport Policy*, Vol. 9 No. 2, 2002.

City of Tillamook, Transportation System Plan Update, 2018.

Count Adjustment Factors, National Bicycle & Pedestrian Documentation Project, March 2009.

International Roadway Assessment Programme, iRAP Model Fact Sheets:

- Full Reference List
- Operating Speed
- Pedestrian Crossing Facilities
- Vehicle Parking
- External Flow
- Star Rating Score Worked Example
- Coding Manual

Updated 2013.

Kolody, K., Perez-Bravo, D., Zhao, J., Neuman, T.R. “Highway Safety Manual User Guide,” FHWA/AASHTO, NCHRP 17-50, 2014.

Lynam, D. “Development of Risk Models for the Road Assessment Programme,” EuroRAP, 2012.

Monsere, Chris, H. Wang, Y. Wang, and C. Chen. “Risk Factors for Pedestrian and Bicycle Crashes,” ODOT Research Section, May 2017.

Turner, Shawn, et. Al. “Guide for Scalable Risk Assessment Methods for Pedestrians and Bicyclists,” United States Department of Transportation, Federal Highway Administration. 2018.

United States Department of Transportation, Federal Highway Administration. Highway Safety Manual, 2010.