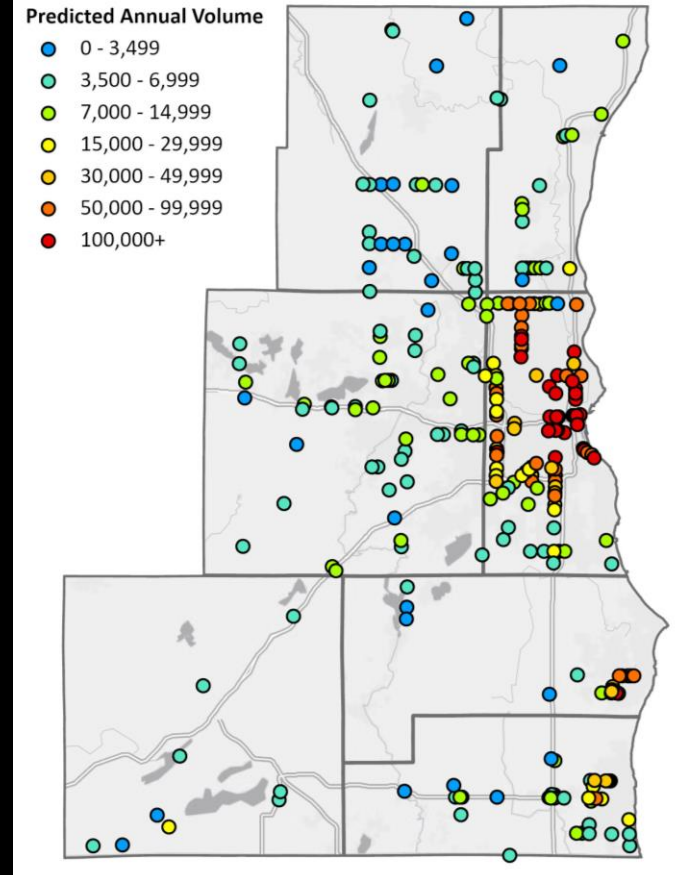


Exposure Data to Improve Pedestrian Safety: WisDOT SE Region Pilot Study



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October 2021

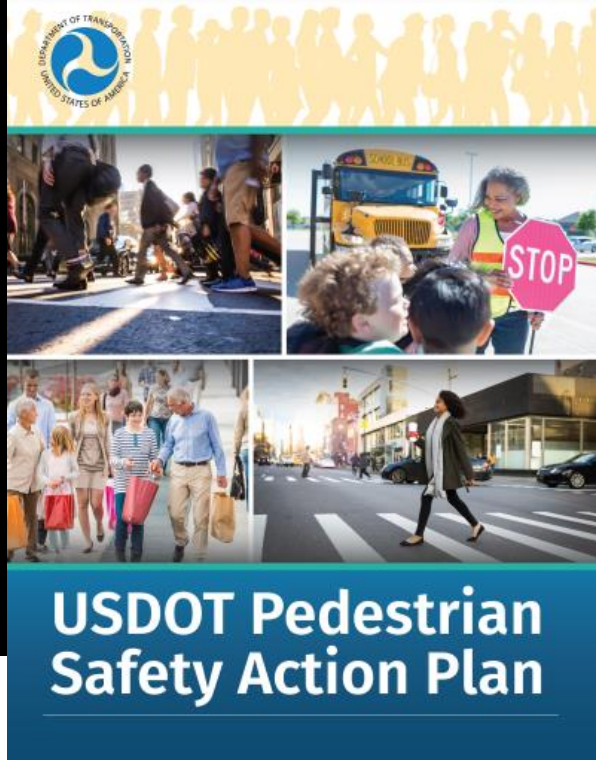
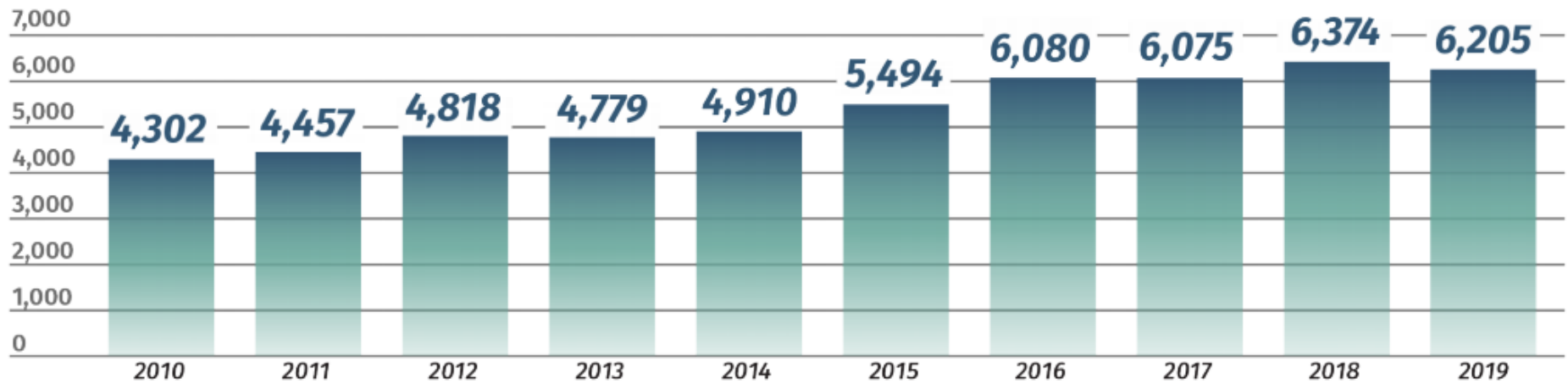


Figure 1. Pedestrian Fatalities, 2010-2019



Source: FARS 2010 to 2018 Final File, NHTSA's Preview of Motor Vehicle Traffic Fatalities in 2019

Source: USDOT Pedestrian Safety Action Plan, https://highways.dot.gov/sites/fhwa.dot.gov/files/2020-11/FHWA_PedSafety_ActionPlan_Nov2020.pdf, 2020.

ADDRESSING THE CHALLENGE

Some factors that are unique to pedestrian safety present challenges when it comes to solutions. Unlike vehicles, there is currently not a consistent way to measure exposure to risk as it relates to pedestrians. Exposure describes the frequency in which pedestrians are exposed to the risk of a crash with a vehicle. The number of person trips is generally not collected. There are some States and localities that are beginning to collect this information, but it is not widespread. In addition to not having a way to measure risk, there are other problems associated with pedestrian safety including urban sprawl which can make it difficult for pedestrians to get around; poor links to transit; problems caused by weather conditions; and a general lack of safe, complete networks for pedestrians to use when they go about their daily travels.

FHWA, NHTSA, and other USDOT agencies are addressing these and other challenges while moving forward with efforts to improve pedestrian safety. The USDOT Pedestrian Safety Action Plan includes actions that will be completed in the near term (December 2020) and those that will be completed by December 2021 and beyond. The plan also identifies those actions that fall under the safe system approach. The safe system approach promotes a more forgiving transportation system that takes human vulnerability into account. It caters to all the modes of transportation, including pedestrians and bicyclists.

**Why do we need pedestrian
exposure data?**

Why do we need pedestrian exposure data?

- Count core users of our transport system
- Prioritize projects
- Inform facility design



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- Prioritize projects
- Inform facility design

*N. 27th Street
Rapid Implementation Project
(City of Milwaukee DPW)*

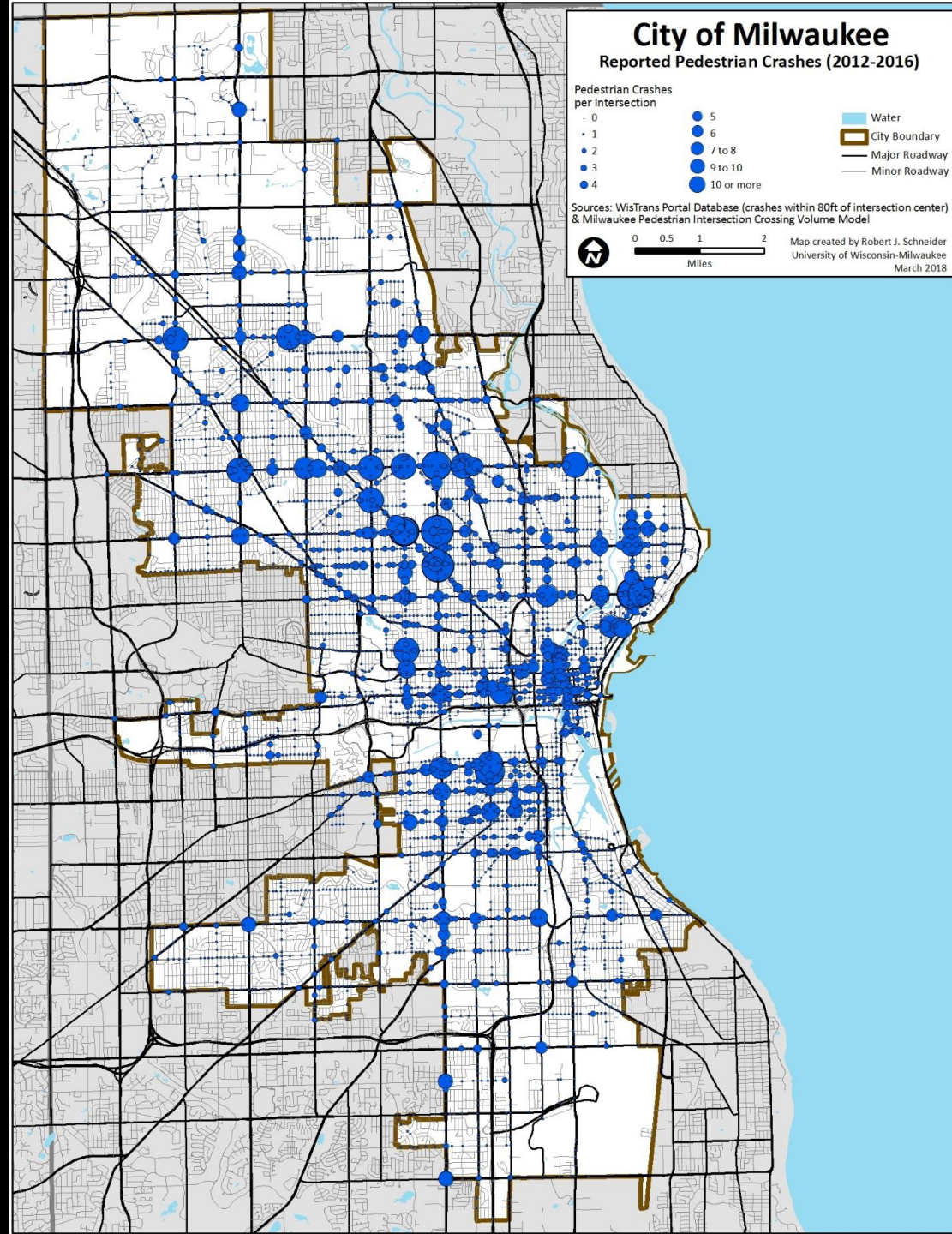


Why do we need pedestrian exposure data?



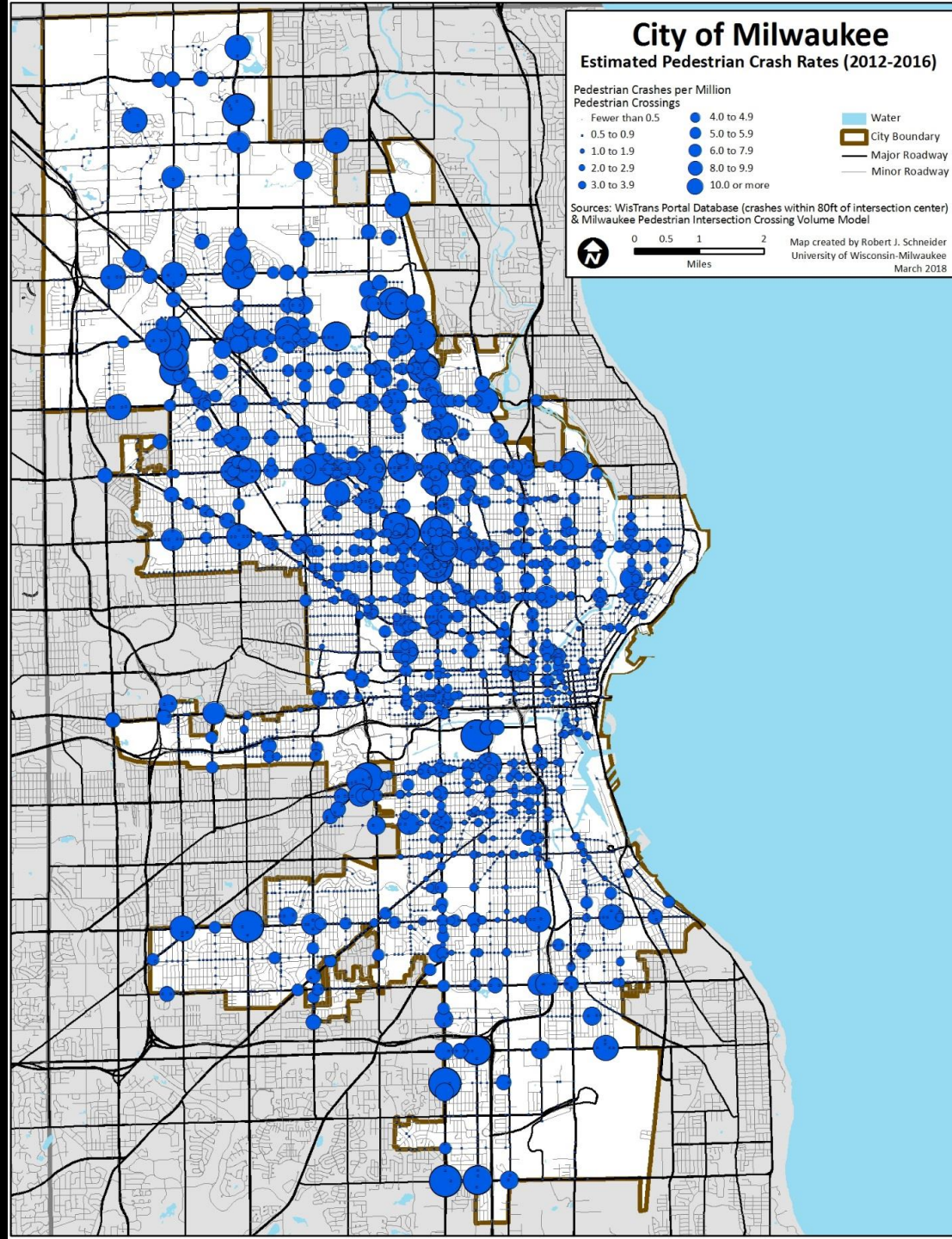
Automobile Volume Counts

Safety Example: Number of Crashes



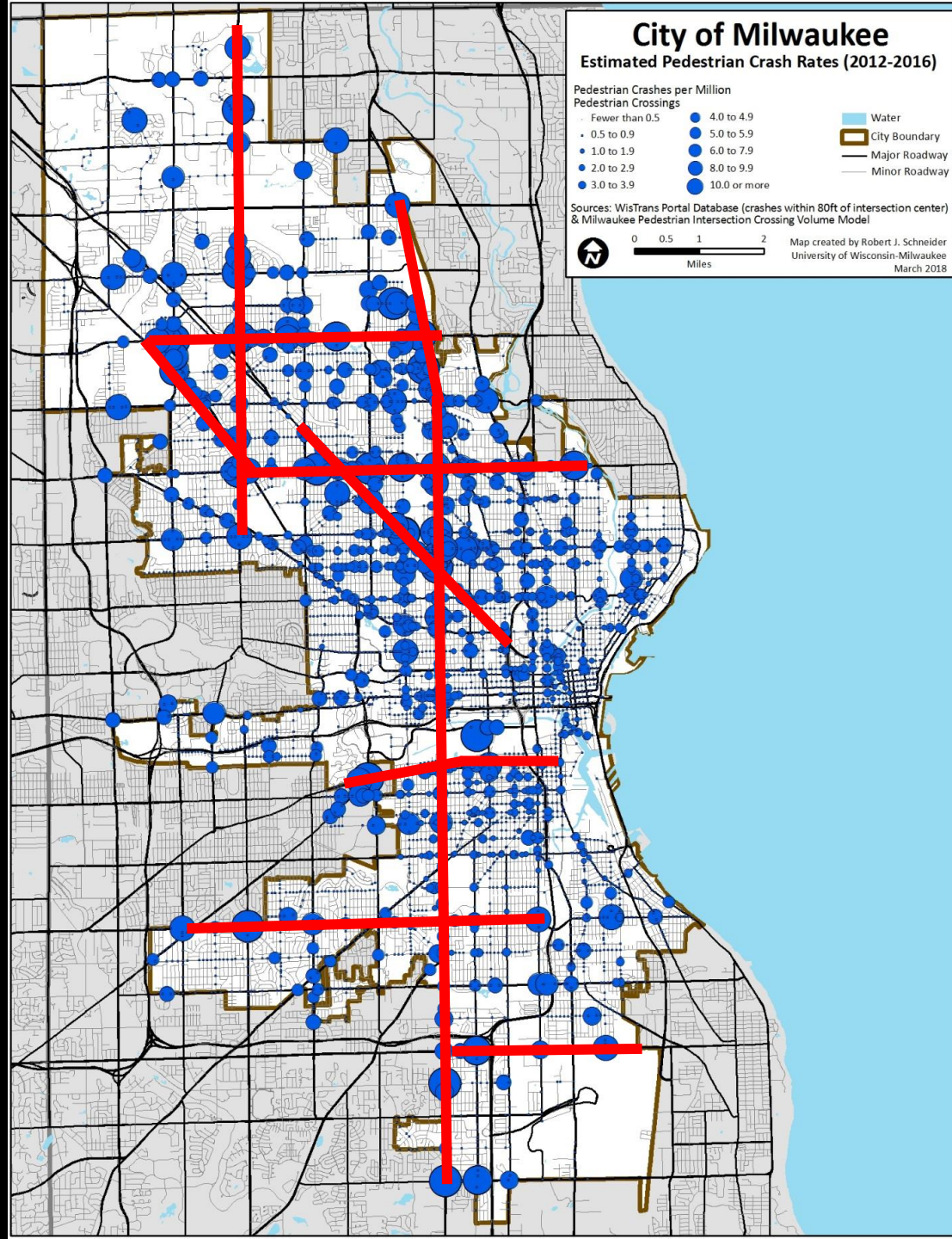
Source: City of Milwaukee,
Milwaukee Pedestrian Plan, 2019

Safety Example: Crash Risk



Source: City of Milwaukee,
Milwaukee Pedestrian Plan, 2019

Safety Example: Crash Risk



Source: City of Milwaukee,
Milwaukee Pedestrian Plan, 2019

1: Regional Pedestrian Volume Model



How many pedestrians cross an intersection with certain characteristics in a year?

Data: Manual Intersection Counts

- Turning counts along SHS & other intersections
- SE Region Office: 1,252 counts from 2013-2018

Intersection Traffic Volume Report		Count Basics		Version 2013 J4.1		Page 1 of 11	
Start Date: Monday, June 16, 2014		Weekday		Schools Not in Session			
Total Number of Hours Counted: 13		Non-Holiday		No Special Events			
Base Information, Observed (13) Hour and Estimated (24) Hour Volume Summaries							
Intersection of: 39th Avenue and STH 158							
Site Information				Count Information			
Municipality: Kenosha		County: Kenosha		WisDOT Region: SE		Print	
Traffic Control: Traffic Signal		Roadway Names: North Direction		North Leg: 39th Avenue		East Leg: STH 158	
South Leg: 39th Avenue		West Leg: STH 158		Hrs Counted: 6:00 AM-7:00 PM		1st Day of Count: Monday, June 16, 2014	
Special Considerations		Schools: Not in Session		Holidays: None		Special Events: None	
Special Pedestrians Observed		Pre-school children: A Few		Elementary school age children: None		Visually impaired (white cane/helper dog): 1 or 2	
Elderly/disabled (except wheelchairs): 1 or 2		Wheelchairs/electric scooters: 1 or 2		Other (describe): None		None	
Count Information		Hrs Counted: 6:00 AM-7:00 PM		1st Day of Count: Monday, June 16, 2014		Weather: Cloudy & Dry	
AM Peak Period: Tuesday, June 17, 2014		Midday Peak Period: Tuesday, June 17, 2014		PM Peak Period: Monday, June 16, 2014		Weather: Cloudy & Dry	
Clear & Dry		Calculated Peak Hours		AM 9:00-10:00am		MD 1:00-2:00pm	
PM 4:15-5:15pm		Peak Hours Selected for Analysis		AM 9:00-10:00am		MD 1:00-2:00pm	
PM 4:15-5:15pm		Daily/Seasonal Adjustment Group: (2) Urban Arterials & Collectors		Count Expansion Group: (2) Urban Arterials & Collectors		Daily/Seasonal Adjustment Factor: 0.898	
Count Expansion Factor: 1.261		Company Name: TADI		Manual Adj.: 1.000		Observers	
AM Peak Period: Jack & Karlyn Bieberitz		Midday Peak Period: Mike Weichmann		PM Peak Period: Ron & Pat Andryk		Observed 13 Hour Volume Summary	

- Supplemented with 38 City of Milwaukee arterial counts

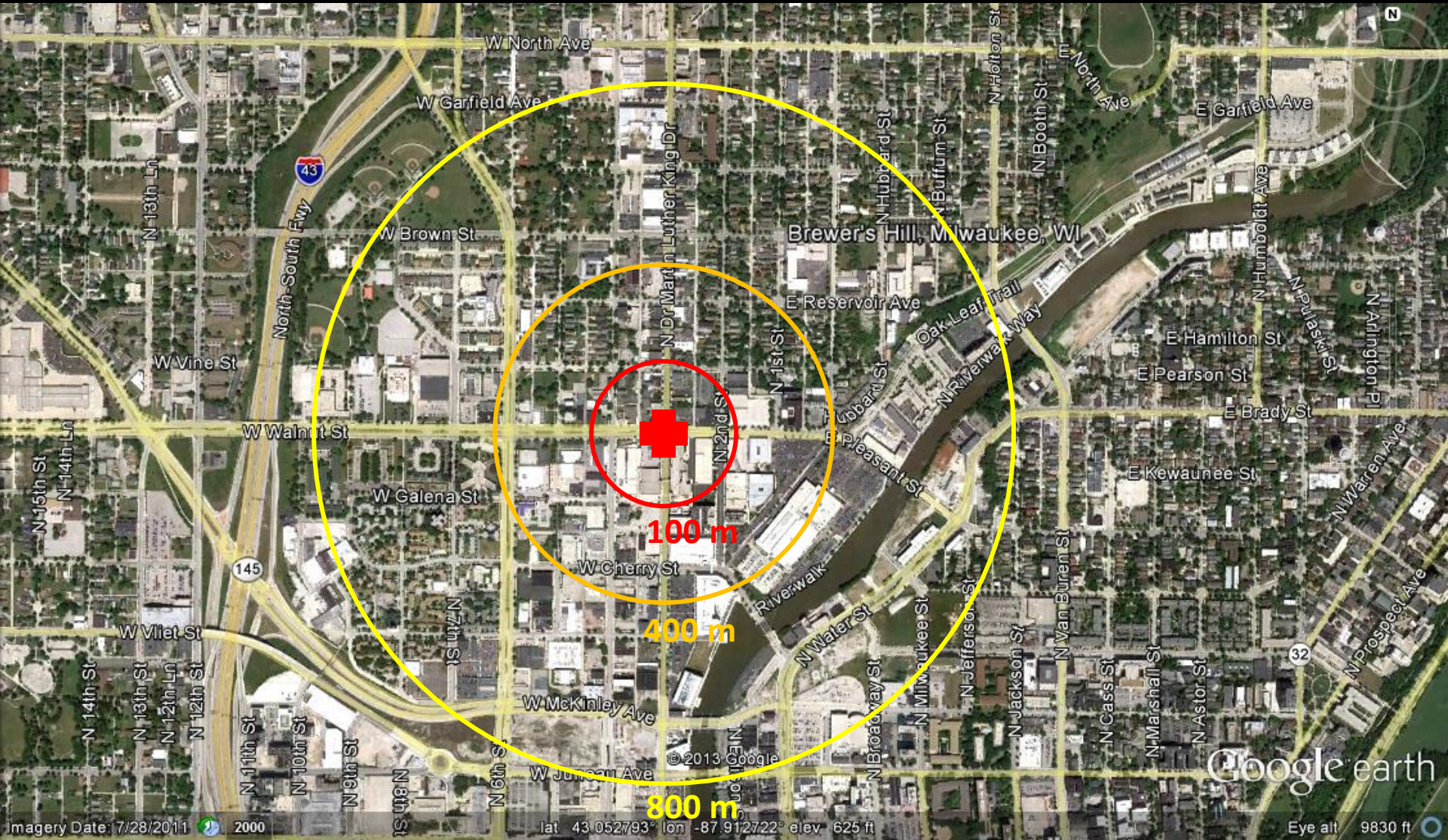
OBSERVED HOUR VOLUMES		39th Avenue		BIKE: 19		TOTAL ENTERING VOLUME	
13		7,257		3539		24,505	
PED: 46		3718		0		281	
728		2457		533		6633	
1		0		0		908	
STH 158		North		STH 158		7822	
PED: 29		8555		8095		15,917	
16,790		0		0		BIKE: 18	
BIKE: 20		5235		726		0	
8235		6558		951		0	
0		4316		0		1194	
0		9,046		4730		2532	
0		39th Avenue		1004		0	
0		BIKE: 8		0		0	

Source: WisDOT, SE Region

Potential Explanatory Variables

- Summarized 14 previous direct demand pedestrian volume models
- Tested variables from previous studies
 - **Built Environment** (Population & employment density, proximity to bus stops, retail, restaurants & bars, parks, schools, college campuses)
 - **Socioeconomic** (Age under 18 & over 64, median income, poverty, renters, zero-vehicle households, blue-collar & white-collar jobs)
 - **Roadway** (Maximum AADT & number of lanes on any approach, signal control)

Explanatory Variable Measurement



Recommended Pedestrian Volume Model

$$Y_i = \exp(7.63 + 0.019X_{1i} + 0.0058X_{2i} + 0.43X_{3i} + 0.38X_{4i} + 0.21X_{5i} + 0.48X_{6i} + 4.18X_{7i})$$

where:

Y_i = estimated annual pedestrian crossing volume at intersection i

X_{1i} = square root of the population density within 400m of intersection i

X_{2i} = square root of the job density within 400m of intersection i

X_{3i} = square root of number of bus stops within 100m of intersection i

X_{4i} = square root of number of retail businesses within 100m of intersection i

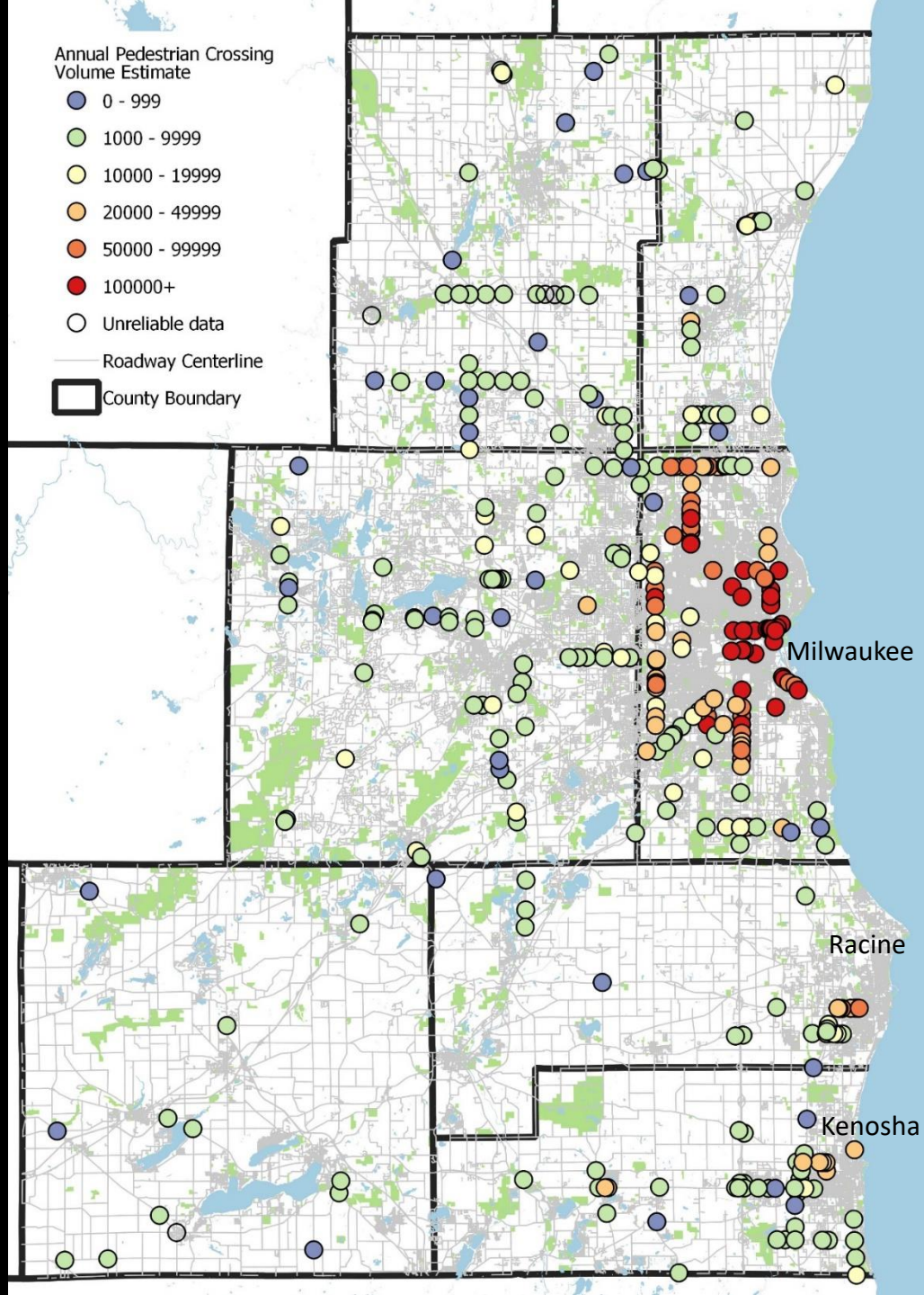
X_{5i} = square root of number of restaurant and bar businesses within 100m of intersection i

X_{6i} = 1 if intersection i is within 400m of a school (0 otherwise)

X_{7i} = Proportion of households without a motor vehicle within 400m of intersection i

Predicted Annual Pedestrian Crossing Volumes at SE Wisconsin Intersections

(Model B, "square root model")



Application: Pedestrian Risk

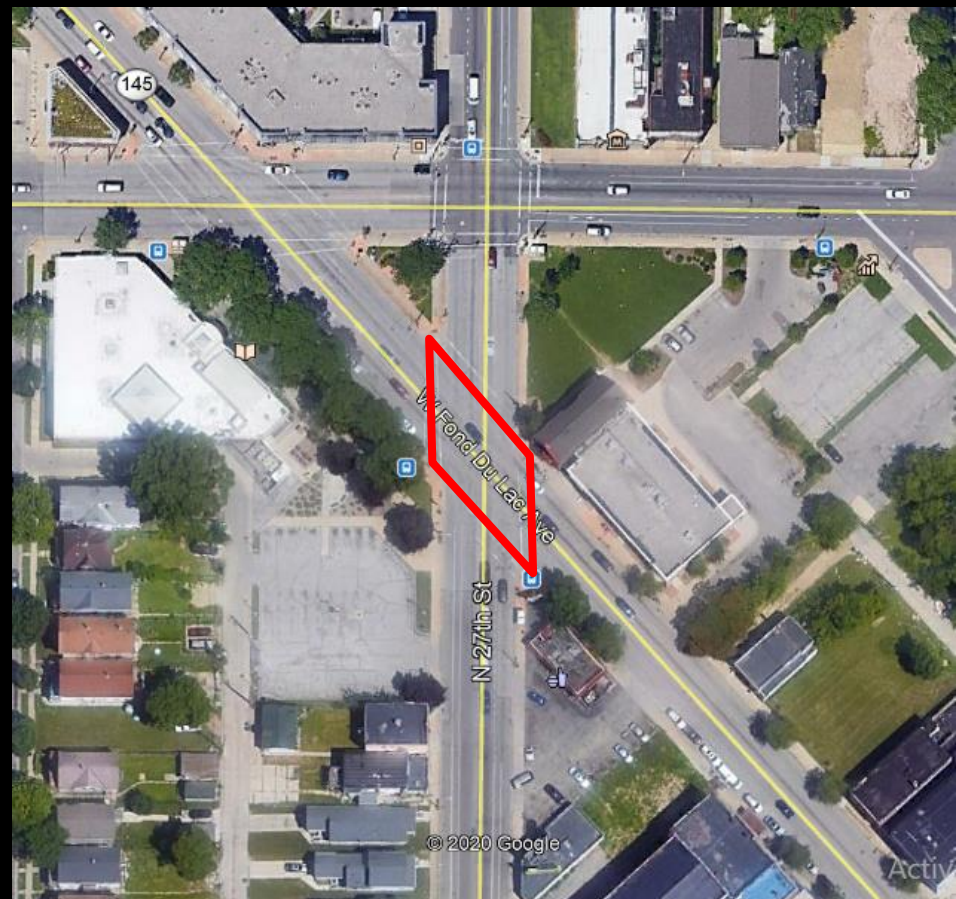
2 crashes in 5 years = 0.4 crash/yr
18,300 crossings/yr

Identical scale (Source: Google Earth, 2018: image height = 1000 feet)

9 crashes in 5 years = 1.8 crash/yr
786,000 crossings/yr

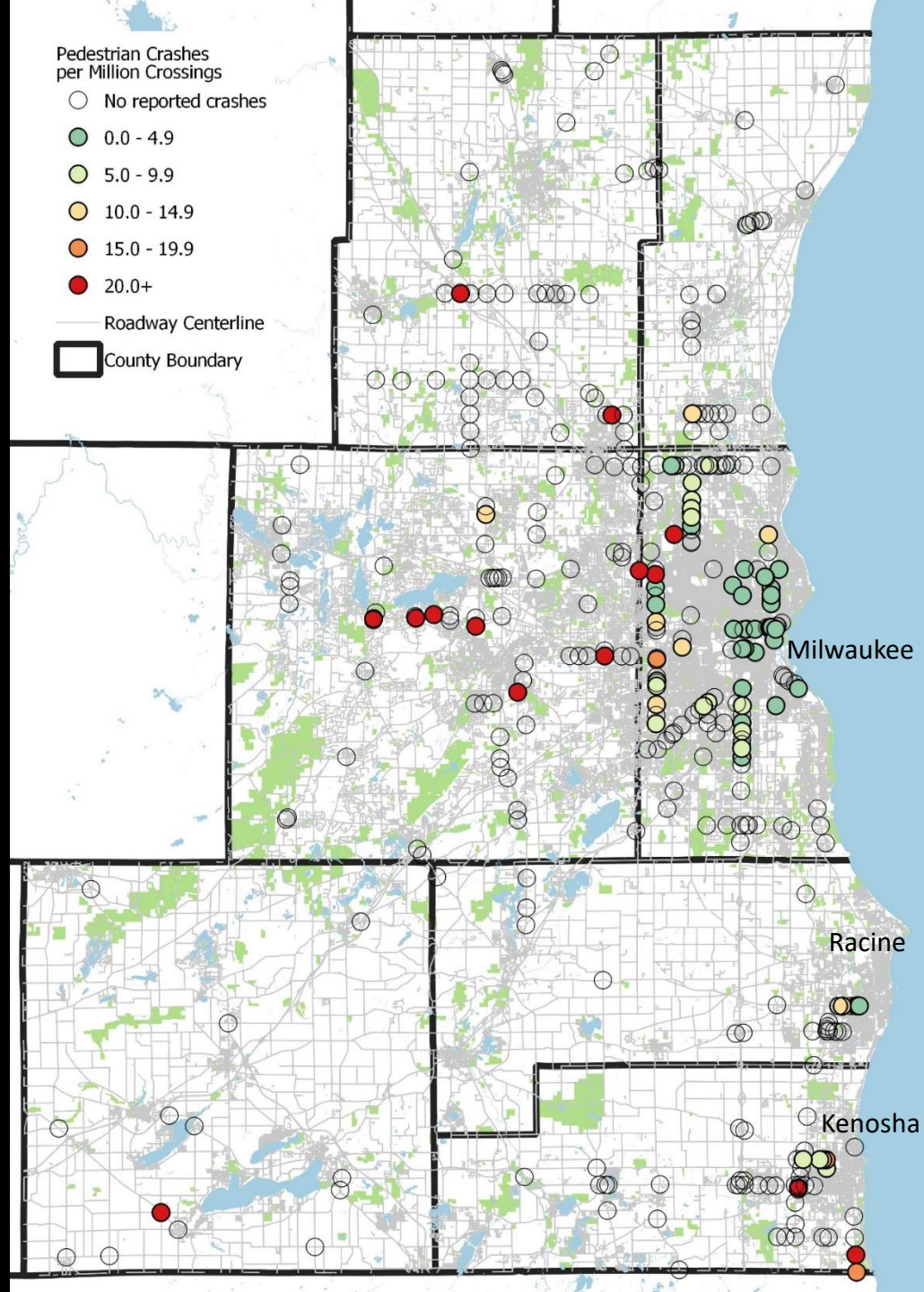


WI 190 & N 124th St, Brookfield
21.9 crashes/million crossings



WI 145 & N 27th St, Milwaukee
2.3 crashes/million crossings

Estimated Pedestrian Crash Risk at SE Wisconsin Intersections (Model B, "square root model")



Putting Research Products to Use

- Interactive statewide pedestrian volume map
- HSP and other safety analysis processes

Development of a Seven-County Regional Pedestrian Volume Model

Robert J. Schneider, PhD; Andrew Schmitz; Xiao Qin, PhD; University of Wisconsin-Milwaukee (TRB Paper 21-01658)



ABSTRACT

This study describes the development and validation of pedestrian intersection crossing volume models for the seven-county Milwaukee metropolitan region. The set of three models, among the first developed at a multi-county scale, can be used to estimate the total number of pedestrian crossings per year at four-leg intersections along state highways and other major thoroughfares. Outputs are appropriate for annual volumes ranging from 1,000 to 650,000. The three models include seven variables that have significant positive associations with annual pedestrian volume: population density within 400m of the intersection, employment density within 400m, number of bus stops within 100m, number of retail businesses within 100m, number of restaurant and bar businesses within 100m, presence of a school within 400m, and proportion of households without a motor vehicle within 400m. Results suggest that square root or cube root transformations of continuous explanatory variables could potentially improve model fit. The models have fair accuracy, with each of the three model formulations predicting 60% or more of validation intersection counts to within half or double the observed value.

COUNT DATA FROM SEVEN COUNTIES, 2013-2018

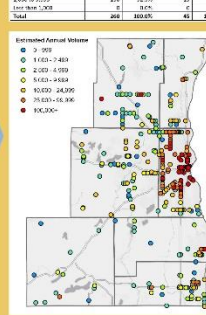
- Pedestrian Counts
 - Intersections along major roadways; each crossing of each leg counted separately
 - 260 intersections for model development; 45 intersections for validation
 - Nearly all counts were 4 or more hours and expanded to annual volume estimates
- Expansion Factors
 - From Milwaukee Pedestrian Plan (2019)

Example of four-to-weekday factors, Weekday-to-weekend week-to-week factors, Weekday-to-weekend

Area	Weekday-to-weekend	Weekday-to-weekend	Weekday-to-weekend	Weekday-to-weekend	Weekday-to-weekend
125th St	0.9100	0.9200	0.9300	0.9400	0.9500
130th St	0.9150	0.9250	0.9350	0.9450	0.9550
135th St	0.9200	0.9300	0.9400	0.9500	0.9600
140th St	0.9250	0.9350	0.9450	0.9550	0.9650
145th St	0.9300	0.9400	0.9500	0.9600	0.9700
150th St	0.9350	0.9450	0.9550	0.9650	0.9750
155th St	0.9400	0.9500	0.9600	0.9700	0.9800
160th St	0.9450	0.9550	0.9650	0.9750	0.9850
165th St	0.9500	0.9600	0.9700	0.9800	0.9900
170th St	0.9550	0.9650	0.9750	0.9850	0.9950
175th St	0.9600	0.9700	0.9800	0.9900	1.0000
180th St	0.9650	0.9750	0.9850	0.9950	1.0000
185th St	0.9700	0.9800	0.9900	1.0000	1.0000
190th St	0.9750	0.9850	0.9950	1.0000	1.0000
195th St	0.9800	0.9900	1.0000	1.0000	1.0000
200th St	0.9850	0.9950	1.0000	1.0000	1.0000
205th St	0.9900	1.0000	1.0000	1.0000	1.0000
210th St	0.9950	1.0000	1.0000	1.0000	1.0000
215th St	1.0000	1.0000	1.0000	1.0000	1.0000

Estimated Annual Volumes at Model and Validation Intersections

Example of four-to-weekday factors, Weekday-to-weekend week-to-week factors, Weekday-to-weekend



MODEL DEVELOPMENT & VALIDATION

We used negative binomial regression to develop models of annual pedestrian volumes at 260 intersections. We applied the best-fit models to predict volumes at the 45 validation intersections.

Potential Explanatory Variables Tested

- **Surrounding built environment/land use:** Population density (per sq. mi.) within 400m/800m, Job density (per sq. mi.) within 400m/800m, Bus stops within 100m/400m, Located within 400m of a park-and-ride lot, Retail properties within 100m/400m, Restaurants and bars within 100m/400m, Located within 100m/400m of a park, Located within 100m/400m of a school, Located within 100m/400m of a college campus
- **Neighborhood socioeconomic characteristics:** % younger than 18 within 400m, % older than 64 within 400m, median income within 400m, % with no vehicle within 400m, % rental housing units within 400m, % workers in construction & manufacturing within 400m, % workers in white collar jobs within 400m
- **Roadway characteristics:** Signalized intersection, 4-lane roadway, Maximum AADT on any approach

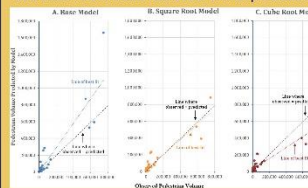
Model Development

The following variables had statistically-significant associations with annual pedestrian volumes. We also tested square root and cube root transformations of the variables in separate models.

- Population density within 400m.
- Employment density within 400m.
- Number of bus stops within 100m.
- Number of retail businesses within 100m.
- Number of restaurant and bar businesses within 100m.
- Presence of a school within 400m.
- Proportion of households without a motor vehicle within 400m.

Model Validation

All three models predicted the observed pedestrian volumes with fair accuracy, though the Square Root and Cube Root models had better overall prediction.

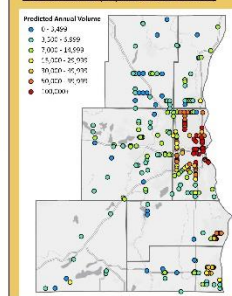


Variable	A. Base Model		B. Square Root Model		C. Cube Root Model	
	Beta	p-value	Beta	p-value	Beta	p-value
Constant	8,454	0.000	7,629	0.000	7,071	0.000
Population density within 400m	0.000140	0.001	0.0019	0.000		
Square root of pop. density					0.100	0.000
Cube root of pop. density						
Employment density within 400m	0.000021	0.040				
Square root of emp. density			0.00081	0.000		
Cube root of emp. density					0.036	0.003
Number of bus stops within 100m	0.0336	0.000	0.434	0.000		
Square root of bus stops					0.477	0.001
Cube root of bus stops						
Number of retail businesses within 100m	0.108	0.025	0.375	0.000		
Square root of retail businesses					0.471	0.000
Cube root of retail businesses						
Number of restaurants/bars within 100m	0.116	0.002	0.208	0.000	0.244	0.000
Square root of restaurants/bars					0.499	0.003
Cube root of restaurants/bars						
School present within 400m	0.515	0.001	0.478	0.000	0.499	0.003
% of households without a motor vehicle within 400m	5,307	0.000	4,164	0.001	4,330	0.000
Sample size (n)	260		260		260	
Log-likelihood	-2792		-2772		-2772	
AIC	5529		5168		5168	
BIC	5529		5193		5188	

1) Examine absolute values of log-likelihood, AIC, and BIC indicate better overall model fit.

IMPLICATIONS

Predicted Annual Volumes at Sample Intersections (Square Root Model)



- Practical Applications
 - Prioritize projects & inform roadway/pedestrian facility design
 - Provide exposure data to estimate pedestrian crash rates (crashes per million crossings) at specific locations
 - Use exposure data as input variable in safety performance functions and systemic safety analyses
 - Add pedestrian volumes to existing state traffic volume databases

Example: Pedestrian Crash Risk

W1100 & N 124th St, Brookfield
2 crashes in 5 years

W1145 & N 27th St, Milwaukee
9 crashes in 5 years



Higher Pedestrian Risk

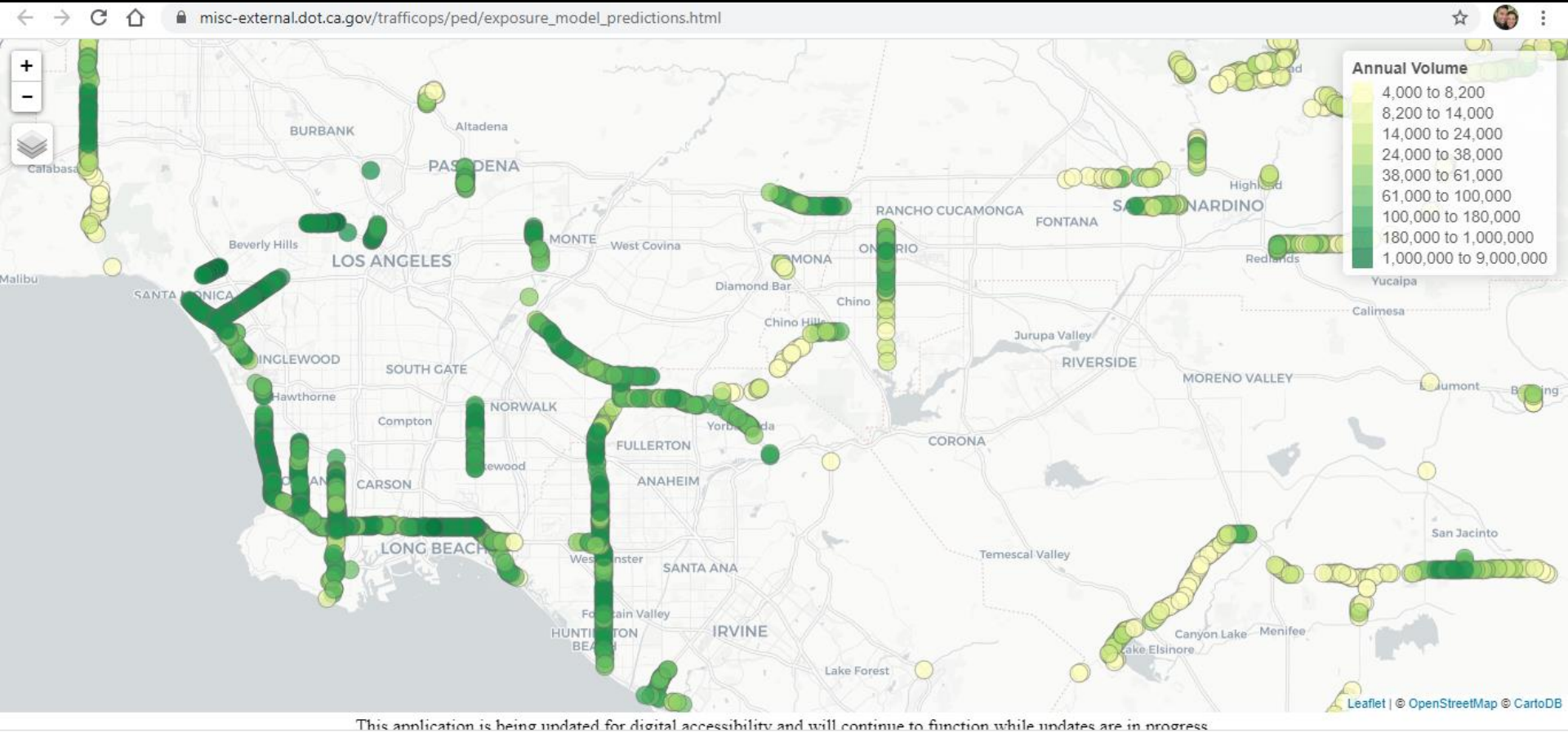
Key info: 18,300 crossings/year
21.9 crashes/million crossings

Key info: 786,000 crossings/year
2.3 crashes/million crossings

CONSIDERATIONS & FUTURE RESEARCH

- California model is one of the only other pedestrian models with a broader range
- Covered a wide range of environments, but model is still only appropriate for annual volumes ranging between 1,000 and 650,000 (not rural or dense urban core)
- Overestimated volumes at intersections with 4+ lanes and in neighborhoods with lower-incomes, more poverty, and more rental housing
 - Try different variables representing number of lanes and socioeconomic status
- Useful for showing broad differences between neighborhoods across many parts of the region, but some specific intersection estimates are imprecise.
- Future research
 - Increase sample size
 - Test more explanatory variables (e.g., performance venues/special attractions, traffic speeds, trash, street trees, crime rates, square footage of businesses)
 - Add 3-leg intersections to model
 - Develop separate models for each crosswalk
 - Collect more continuous counts to improve expansion factors
- Challenge: tradeoff between practicality and accuracy. So also try other methods.

Caltrans Pedestrian Volume Map



Source: California Department of Transportation. State Highway Pedestrian Exposure Estimates, <https://dot.ca.gov/programs/safety-programs/ped-bike/exposure>, 2021.