Pedestrian Exposure Data for the Wisconsin State Highway System: WisDOT Southeast Region Pilot Study

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1. Introduction

Pedestrian travel, including people walking and using wheelchairs to get from place to place, is the universal form of human movement.[1] Pedestrians travel in cities, suburbs, small villages, and rural areas. A transportation system that is safe, comfortable, and convenient for pedestrians truly serves all people, regardless of age, gender, race, ability to afford a car, ability to drive, or other characteristic. Pedestrian needs are at the core of an equitable transportation system.

Since everyone is a pedestrian, reducing the impact of pedestrian crashes is important for the health and vitality of every resident in Wisconsin. Recognizing the importance of this issue, the Wisconsin Department of Transportation (WisDOT) emphasized “Improve Non-Motorist Safety” as one of ten “Highest Priority Issue Areas” in the Wisconsin Strategic Highway Safety Plan (SHSP), 2017-2020.[2] The SHSP Action Plan for “Improve Non-Motorist Safety” recommended engineering, education, and enforcement countermeasures to achieve its goals.

1.1. Project Purpose

Identifying effective strategies to improve pedestrian safety requires better data, particularly information about pedestrian exposure (i.e., pedestrian activity levels). Pedestrian exposure is often represented by pedestrian counts along sidewalks or pedestrian counts at intersections. Compared to motor vehicle volumes, which are available for most state highways and local arterial streets throughout the state, pedestrian counts are only available in a few locations in a small number of communities. Therefore, the purpose of this report is to pilot test new methods to improve the process of documenting and analyzing pedestrian exposure in the seven-county WisDOT Southeast Region and identify promising approaches that could be applied statewide.

The lack of pedestrian exposure data available to integrate with Wisconsin’s traffic crash database creates several obstacles for analyzing pedestrian safety:

- First, analysts may attempt to identify pedestrian safety problems simply using absolute numbers of pedestrian crashes. These crashes tend to cluster in locations with the most pedestrians, such as downtown areas and near major activity centers. These locations do not necessarily have the most significant safety problems, measured in terms of risk (e.g., pedestrian crashes per million crossings).
- Second, when comparing crash data before and after a pedestrian safety improvement project absolute numbers of pedestrian crashes are likely to mask the true reduction in pedestrian risk. This is because pedestrian volumes are likely to increase after a safety improvement project.
- Third, along with motor vehicle volumes, roadway design attributes, and pedestrian crossing facilities, pedestrian volumes are a critical predictive variable to include in safety performance functions (SPFs). SPFs are a central component of the systemic approach to improving transportation safety, which allows agencies to make improvements proactively by quantifying underlying risk throughout a highway system.

Better pedestrian exposure data is critical for better pedestrian safety analysis and ultimately better pedestrian safety outcomes in Wisconsin.

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[1] Schneider, R.J., S. Kothuri, L. Blackburn, K. Manaugh, L. Sandt, and J. Fish. 2020. Pedestrian Transportation Research: Past and Future, Transportation Research Board Centennial Paper, http://onlinepubs.trb.org/onlinepubs/centennial/papers/ANF10-Final.pdf.

[2] Wisconsin Department of Transportation. 2017. Wisconsin Strategic Highway Safety Plan (SHSP), 2017-2020, https://wisconsindot.gov/Documents/safety/education/frms-pubs/strategichwy-17-20.pdf.

1.2. Project Components

This study was conducted in the WisDOT Southeast Region, which includes Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties. The region has a population of approximately 2 million residents, or about 35% of the statewide population.[3]

We pursued three main tasks, which are described briefly below.

- *Task 1. Explore existing and new pedestrian exposure data sources.* We compiled a database of pedestrian crossing counts at more than 300 intersections along major roadways. It also included collecting continuous counts using automated sensors at three sidewalk locations to document different patterns of pedestrian activity and collecting pedestrian and vehicle counts and movements using automated analysis of WisDOT traffic camera video at four intersections.
- *Task 2. Develop and validate a seven-county regional pedestrian volume model.* We used the pedestrian crossing counts from 260 of the major roadway intersections to estimate a set of three models that predict annual pedestrian crossing volumes at intersections along most major roadways in the Southeast Region (intersections with annual volumes ranging from 1,000 to 650,000). The models include seven statistically-significant land use and socioeconomic variables. Each of the models predict 60% or more of validation intersection counts to within half or double the observed value.
- *Task 3. Create exposure-based models of trail user crashes at roadway crossings.* We analyzed trail user crashes reported at 197 crossings in the Southeast Region and City of Minneapolis, MN between 2011 and 2018 to develop one of the first trail crossing crash models. Data required to develop this model included continuous trail counts and historic aerial and street-level imagery. We used a Poisson-lognormal (PLN) model structure to overcome the challenge that many crossings have small numbers of crashes. After controlling for trail user and motor vehicle volumes, trail user crashes were associated roadway crossing design characteristics.

The following sections of the report provide more details about results from these three tasks. Note that the methods used to develop these findings in the seven-county WisDOT Southeast Region could potentially be used throughout Wisconsin. The final section of the report presents recommendations for how to implement the results of this study.

[3] United States Census Bureau. American Community Survey, 5-year population estimates, 2014-2018.

2. Existing and New Pedestrian Exposure Data Sources

Prior to this study, pedestrian counts had not been compiled formally in the WisDOT Southeast Region. The City of Milwaukee conducted 72 intersection counts over the decade prior to producing the Milwaukee Pedestrian Plan in 2019.[4] WisDOT had collected pedestrian crossing counts at hundreds of intersections as a part of routine intersection counting procedures across the region during the 2010s, but they were only available on individual spreadsheets. The Southeastern Regional Planning Commission (SEWRPC), with support from WisDOT, collected trail user counts at 115 locations in the Southeast Region between 2015 and 2018 (these counts included pedestrians as well as bicyclists and other trail users).[5] There may have been other ad hoc pedestrian counts collected in other jurisdictions, but the vast majority of roadway locations throughout the Southeast Region did not have any pedestrian counts. For comparison, motor vehicle counts were available on nearly all highways throughout the entire State Highway System and on most locally-maintained arterial roadways.[6,7]

As a part of this project, we compiled three types of pedestrian exposure data in the Southeast Region: 1) short-duration pedestrian crossing counts at intersections along major roadways, 2) long-duration pedestrian screenline counts at locations along multi-use trails and sidewalks, and 3) short-duration pedestrian and vehicle counts and movements at intersections with WisDOT traffic cameras (Figure 1). These data sources are described below.

2.1. Pedestrian Crossing Counts at Intersections

We gathered existing intersection pedestrian crossing counts from two primary sources.

- The WisDOT Southeast Region office contracts with consultants to conduct hundreds of manual intersection counts each year. Each of these intersection counts is recorded in a separate spreadsheet. We compiled all 1,252 spreadsheets that were created between 2013 and 2018. Some spreadsheets covered the same intersection at different times during these six years. In addition to motor vehicle and bicycle counts, each spreadsheet included the number of times pedestrians crossed each leg of an intersection in 15-minute increments during a given study period. The most common type of study period covered 13 hours from 6 am to 7 pm. There were a variety of other study period durations, and 99% of the 1,252 counts were at least four-hours long.
- The second intersection count data source was the City of Milwaukee Pedestrian Plan pedestrian count database.[8] The City of Milwaukee uses a similar method as WisDOT to collect intersection pedestrian counts. These counts were important to include because WisDOT's counts do not cover many areas of central Milwaukee County. While the City of Milwaukee database includes counts at 72 intersections, 38 were chosen as examples of intersections along state highways or major thoroughfares.

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[4] City of Milwaukee, Department of Public Works. 2019. *Milwaukee Pedestrian Plan*, https://city.milwaukee.gov/dpw/infrastructure/multimodal/Milwaukee-Pedestrian-Plan.

[5] Southeastern Wisconsin Regional Planning Commission (SEWRPC). 2021. "Regional Nonmotorized Count Program," https://www.sewrpc.org/SEWRPC/Transportation/nmcounts.htm.

[6] Wisconsin Department of Transportation. 2021. "Traffic Counts," https://wisconsindot.gov/Pages/projects/data-plan/traf-counts/default.aspx.

[7] Wisconsin Traffic Operations and Safety Laboratory. 2021. "Wisconsin Hourly Traffic Data Web Access Portal," The WisTransPortal System, https://transportal.cee.wisc.edu/products/hourly-traffic-data/.

[8] City of Milwaukee. Milwaukee Pedestrian Intersection Crossing Volume Model, White Paper, prepared for the City of Milwaukee Pedestrian Master Plan, https://city.milwaukee.gov/ImageLibrary/Groups/cityBikePed/2019-Images/Pedestrian-Plan/MKEPedPlan_WhitePaper_PedVolumeModel-20190422.pdf, April 2019.

Between the two data sources, 1,290 unique counts were considered. We geocoded these counts based on the intersecting streets recorded in a master spreadsheet. Then we removed the following counts from consideration:

- Counts without geocoded locations.
- Counts taken on days with rain or snow, as indicated by field data collectors.
- Counts taken between November and March. Pedestrian counts are often low and highly variable from day to day during winter months.
- Counts for which the quality was suspect. This included counts that were very different from other counts at the same location and counts at five-leg intersections (since the form only included four legs).
- Counts with zero pedestrians. These counts were either erroneous counts (e.g., a count of zero in a location with dense population and activities) or were in locations with such low pedestrian activity levels that they would have too much day-to-day variability for statistical analyses.
- Counts not on a major roadway (e.g., intersections of two local roadways).
- Counts at locations that were labeled as freeway ramps or minor driveways (e.g., driveways to single-family homes). Some major driveways (e.g., driveways from a major street to a shopping center or apartment complex) operate like street legs and have formal crosswalks, so these were kept for analysis.
- Counts at three-leg intersections. These were removed because pedestrian activity is likely to be distributed differently across the three crosswalks than it would be across four crosswalks.

After applying these criteria, 520 counts remained. However, some of these counts were collected at the same intersections. To identify unique locations with counts, we grouped all counts that were located within 50 meters of another count. This produced 348 intersections that had at least one count. Of the 348 intersections, 223 had one count, 97 had two counts, 18 had three counts, 9 had four counts, and 1 had six counts. Table 1 shows the distribution of the pedestrian intersection count locations by county.

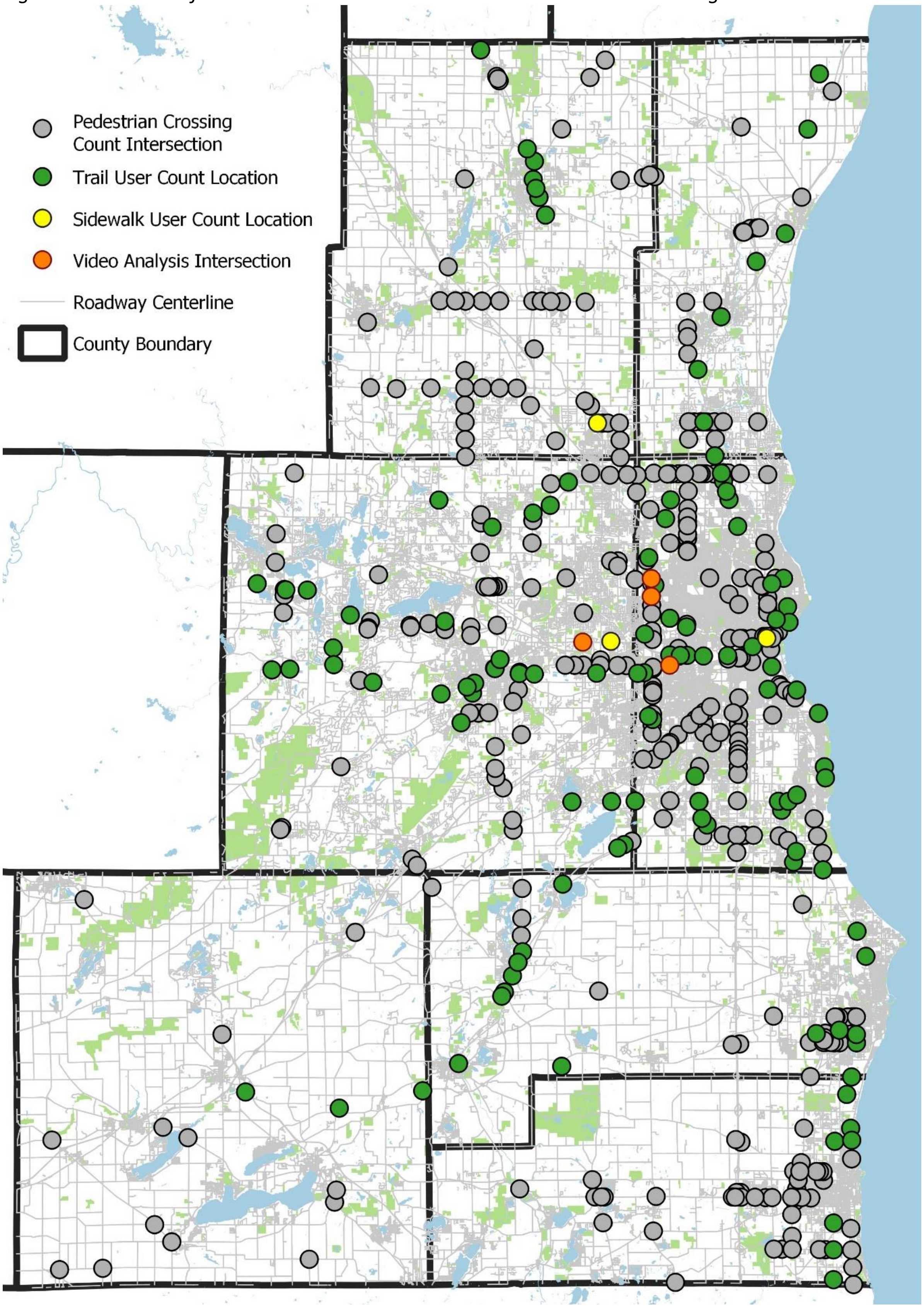
Table 1. Pedestrian Intersection Count Locations by County

County	Number of Count Locations	% of Count Locations	Population[1]	% of Population	State & National Highway Centerline Miles[2]	% of State & National Highway Centerline Miles
Kenosha County	48	13.8%	168,330	8.2%	705.27	14.7%
Milwaukee County	128	36.8%	954,209	46.7%	537.92	11.2%
Ozaukee County	25	7.2%	88,284	4.3%	413.92	8.6%
Racine County	25	7.2%	195,398	9.6%	573.41	12.0%
Walworth County	12	3.4%	103,013	5.0%	751.11	15.7%
Washington County	42	12.1%	134,535	6.6%	657.92	13.7%
Waukesha County	68	19.5%	398,879	19.5%	1151.85	24.0%
SE Region Total	**348**	**100.0%**	**2,042,648**	**100.0%**	**4791.39**	**100.0%**

1) Population data are from the American Community Survey 5-year population estimates (2014-2018).

2) Roadway centerline miles were calculated from the WISLR GIS database (2019). The mileage includes state and national highways and excludes interstate and county highways. Divided roadways are represented with two lines in the WISLR GIS database, so one mile of divided roadway is counted as two centerline miles.

Figure 1. Locations of Pedestrian-Related Counts in the WisDOT Southeast Region



2.2. Screenline Counts along Multi-Use Trails and Sidewalks

Screenline counts register when a person or vehicle passes a specific location along a transportation facility. These locations are typically between intersections. One advantage of using screenline counts to quantify pedestrian activity is that they can be collected with automated counters that became widely-available in the 2010s. This makes it possible to record long-term activity patterns of pedestrians and other multi-use trail and sidewalk users.

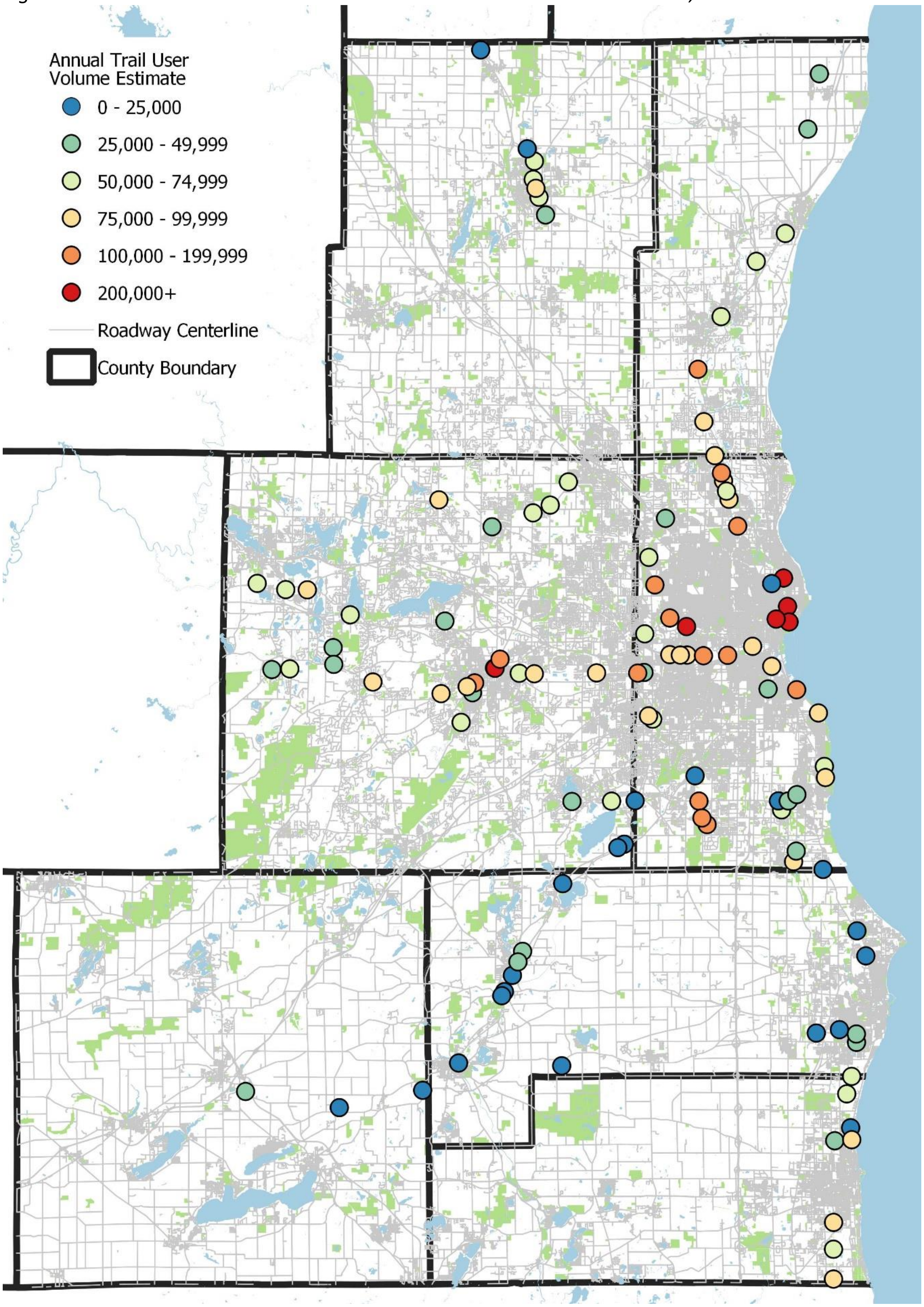
2.2.1. Multi-Use Trail User Counts

SEWRPC and WisDOT started counting multi-use trail users with automated infrared sensors at screenline locations in 2015. Counts of each person (more specifically, each source of body-level heat) passing the sensor were registered and summarized by 15-minute or one-hour periods. For this study, we compiled trail user counts at 115 locations in the Southeast Region that had been collected between 2015 and 2018. These counts did not differentiate between pedestrians, bicyclists, or other trail users.

Of the 115 multi-use trail screenline count locations, 17 were permanent and had continuous counts available for longer than one year. Average volumes at these locations ranged from approximately 490,000 users per year (1,300 per day) on the Oak Leaf Trail near Brady Street/Veterans Memorial Park to 13,000 users per year (35 per day) on a short segment of the Beerline Trail near Abert Place.

The other 98 screenline count locations had infrared sensors installed temporarily, most for approximately two weeks during the year. Of these 98 locations, 50 had data from three different years, 17 had data from two different years, and 31 had data from one year. We used the seasonal count patterns over the entire year from the 17 permanent count locations to expand the two-week counts to and create an annual volume estimate for the 98 temporary count locations. For example, the August 14th through August 27th period represented about 6% of the total annual trail volume. Therefore, a count of approximately 5,600 users during that two-week period was expanded to a total annual trail volume of approximately 93,000 (5,600 divided by 0.06). Figure 2 shows annual trail user volume estimates for all 115 count locations.

Figure 2. Annual Multi-Use Trail User Volume Estimates at Count Locations, 2015-2018



2.2.2. Sidewalk User Counts

Prior to this study, no long-term, continuous sidewalk user counts had been collected in the Southeast Region. For this study, we worked with WisDOT, SEWRPC, and the City of Milwaukee to install automated infrared sensors at three sidewalk locations. Each location was selected to represent different nearby land use characteristics. We expected that these different types of locations would each have different patterns of pedestrian activity.

- North side of US 18 (Bluemound Road), east of Crystal Lane, Elm Grove. This location is in a suburban residential corridor. The counter was installed by the WisDOT Southeast Region office in October 2019.
- South side of Wisconsin Avenue, east of Vel R. Phillips Avenue, Milwaukee. This location is in a central business district corridor. The counter was installed by the City of Milwaukee Department of Public Works in November 2019.
- North side of WI 167 (Mequon Road), west of Pilgrim Road, Germantown. This location is in a suburban, mixed-use retail and residential corridor. The counter was installed for approximately four months from November 18, 2019 to March 22, 2020; for two weeks from October 13, 2020 to October 26, 2020; and for several weeks in May 2021.

Note that the automated sensors counted any person who used a sidewalk, which could have included bicyclists, scooter riders, or people using other forms of transportation. However, the majority of sidewalk users in all three locations were likely to be pedestrians.

To demonstrate the value of automated counts, we summarized weekly sidewalk user count patterns with data from the Wisconsin Avenue (Downtown Milwaukee) and WI 167 (suburban mixed-use corridor) sensor locations. This summary was done using data from a four-week period, February 10, 2020 to March 8, 2020 (prior to major changes in travel due to the COVID-19 pandemic). Therefore, it represents a typical late winter weekly activity pattern.

Figure 3 shows the average hourly volume across all 168 hours of the week during the four-week period. At the Wisconsin Avenue site, there were generally between 50 and 90 sidewalk users per hour during regular weekday work hours, with Friday typically having the highest volumes. However, the highest volumes during the entire week were during the mid-day period on Saturdays, ranging between 100 to 120 sidewalk users per hour. At the WI 167 site, there were generally five to 10 sidewalk users per hour during regular weekday work hours, with the exception of Fridays around lunch time. Mid-day periods on Fridays, Saturdays, and Sundays had the highest activity levels, reaching 10 to 20 users per hour.

Continuous sidewalk user volume data are useful for understanding how activity levels are distributed across a typical week. Figure 4 shows the percentage of total weekly sidewalk counts that occur within each hour of the week. At the Wisconsin Avenue site, regular weekday work hours each typically represent around 1.0% of the total weekly volume, with slightly higher percentages on Friday. Saturday mid-day hours each represent 1.5% to 2.0% of the total weekly volume. Compared to the Wisconsin Avenue site, the weekday work hours at the WI 167 site generally represent less of the total weekly volume and mid-day weekend hours represent more of the total weekly volume. However, the pattern has more variation, likely due to the smaller number of sidewalk users at the suburban site. Data from more weeks would likely show a smoother trend.

The percentage of weekly sidewalk user volume per hour is useful for expanding short-term counts (e.g., two to four hours) to weekly volume estimates. For example, if a short-term count is collected manually at a different location in Downtown Milwaukee, it is likely to have a similar weekly pattern of pedestrian activity (assuming that adjacent land use characteristics are similar). A count that is taken over four hours from 12 pm to 4 pm on a Tuesday can be assumed to represent 3.8% of the weekly volume. If 200 sidewalk users are counted during this time, the weekly volume estimate would be approximately 5,300 (200 divided by 0.038).

This concept of expanding shorter-duration counts to daily, weekly, and yearly volume estimates is described more in the next section.

Figure 3. Average Count of Sidewalk Users Per Hour, 2/10/20 to 3/8/20

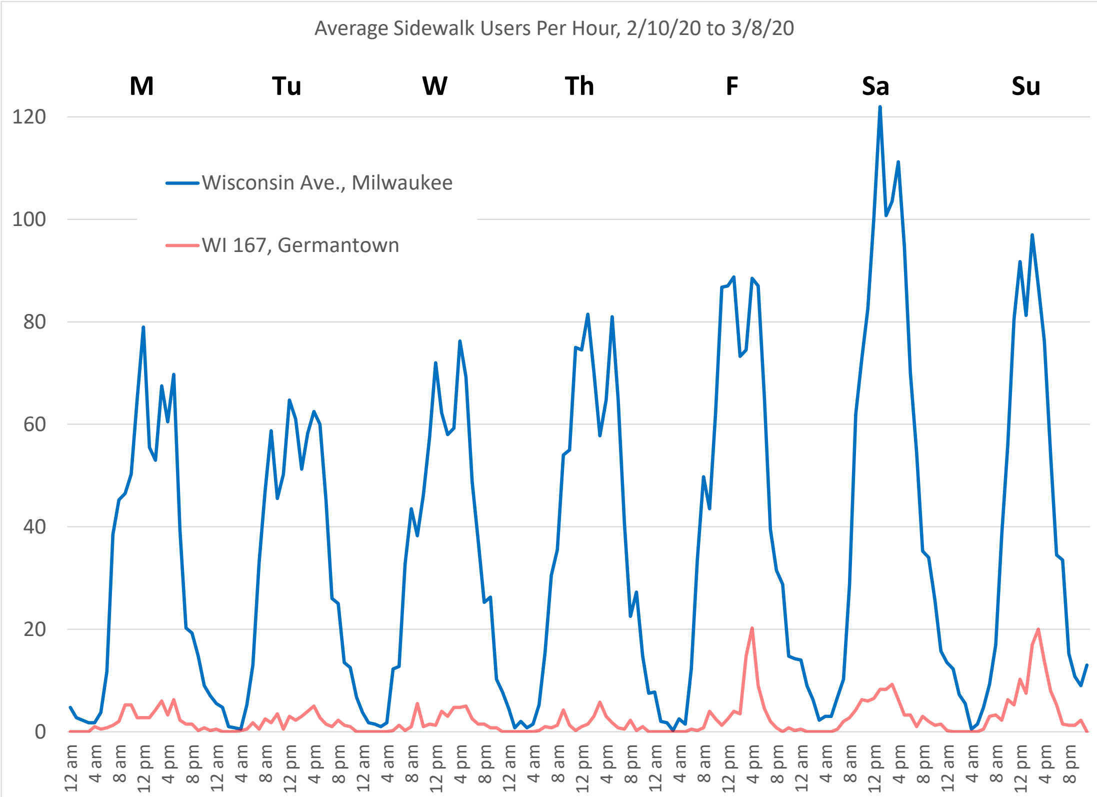
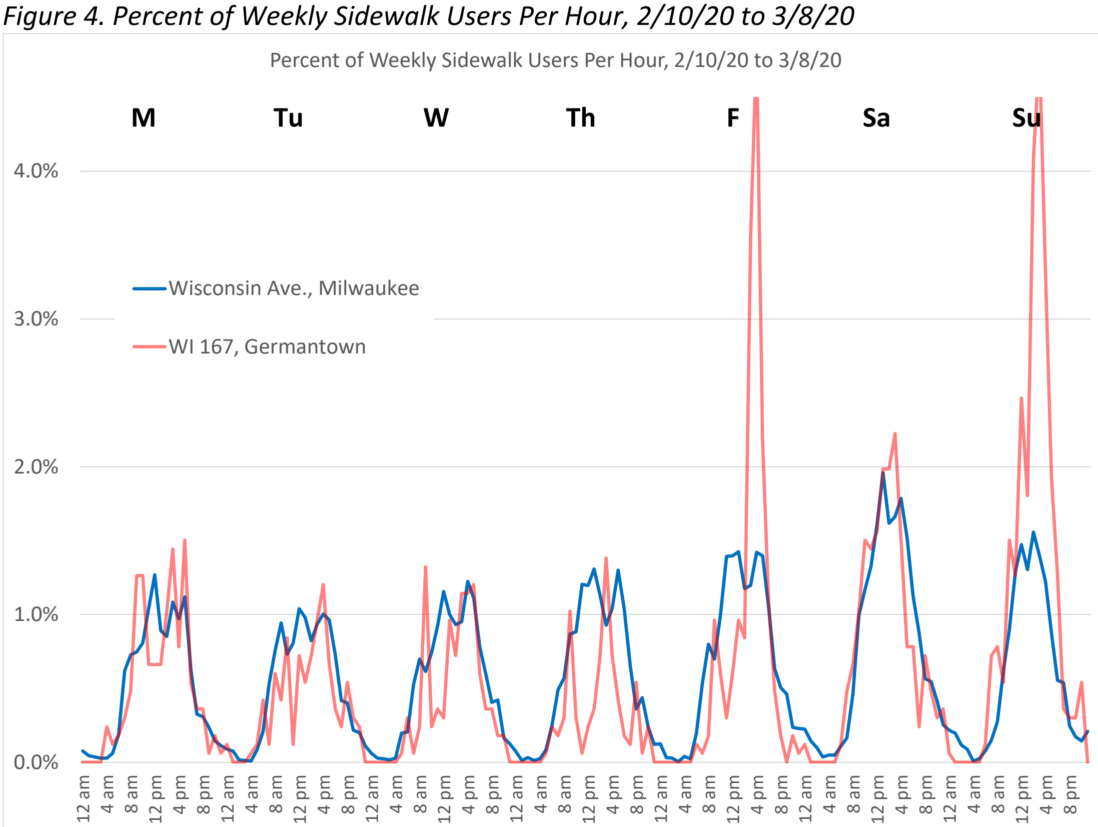


Figure 4. Percent of Weekly Sidewalk Users Per Hour, 2/10/20 to 3/8/20



2.2.3. Use of Automated Count Data to Estimate Annual Volumes

This section describes the process that we followed to expand the 348 available short-duration intersection pedestrian crossing counts from WisDOT and the City of Milwaukee to annual pedestrian volume estimates.

Initially, we intended to base our expansion calculations on data from the Milwaukee central business district, the suburban mixed-use, and the suburban residential automated count sites described above. However, travel behavior changed significantly starting in March 2020 due to the COVID-19 pandemic. We did not think that sidewalk user volume patterns that were collected during the pandemic would be appropriate to apply to previous pedestrian counts in order to estimate the total annual pedestrian volumes that occurred between 2014 and 2018. Therefore, we used pedestrian expansion factors established through other research to conduct our analysis. As more automated count data is collected from the three sites described above and from other sites across the state in the future, WisDOT can establish locally-specific pedestrian volume patterns for various types of locations of Wisconsin.

2.2.3.1. Overview of Annual Volume Estimation Process

The counts at each of the 348 study intersections were collected at different times of day, week, and year, so we applied expansion factors to estimate comparable annual volumes at each intersection. Annualization is important because pedestrian activity peaks at different times. For example, the effects of season are particularly strong in Wisconsin, so it is important to treat April and July counts differently.

We used three factors to expand the short-duration counts to annual pedestrian volume estimates: hour-to-weekday (hourly factor, or HF), weekday-to-week (daily factor, or DF), and week-to-year (weekly factor, or WF). Note that the three factors are applied to the average hourly count for the full count period, regardless of its duration (e.g., 13 hours, 9 hours).

The annual volume at an intersection was estimated using the following equation:

Annual volume estimate = Average hourly count * 1/HF * 1/DF * 1/WF

At intersections with multiple counts, annual estimates were generated from each count, and then these annual estimates were averaged to give a composite annual estimate.

The three expansion factors are described below.

2.2.3.2 Hour to Weekday Factors (HF)

We used the factors listed in Table 2 to estimate the weekday volume from the available hourly counts. These factors were applied to intersections based on five mutually-exclusive land use categories. Each land use category has a distinct daily pedestrian activity pattern.

Table 2. Hour to Weekday Factors

Hour	CBD Location in the central business district	School Non-CBD location with a school within 200m	Trail Non-CBD & Non-School location with a trail access point within 200m	Commercial Non-CBD, Non-School, & Non-Trail location with 2 or more retail, restaurant, or bar businesses within 200m	Other Location in none of the other categories (these locations tend to be residential)
12:00 AM	0.0108	0.0034	0.0008	0.0091	0.0099
1:00 AM	0.0089	0.0021	0.0007	0.0063	0.0057
2:00 AM	0.0062	0.0014	0.0004	0.0047	0.0057
3:00 AM	0.0058	0.0016	0.0006	0.0037	0.0037
4:00 AM	0.0046	0.0030	0.0005	0.0056	0.0041
5:00 AM	0.0095	0.0123	0.0299	0.0098	0.0126
6:00 AM	0.0199	0.0234	0.0609	0.0222	0.0278
7:00 AM	0.0435	0.1176	0.0844	0.0522	0.0613
8:00 AM	0.0540	0.0803	0.0977	0.0558	0.0654
9:00 AM	0.0599	0.0467	0.0984	0.0513	0.0563
10:00 AM	0.0697	0.0458	0.0701	0.0556	0.0556
11:00 AM	0.0769	0.0533	0.0444	0.0604	0.0577
12:00 PM	0.0806	0.0583	0.0311	0.0630	0.0592
1:00 PM	0.0758	0.0741	0.0336	0.0643	0.0618
2:00 PM	0.0702	0.0879	0.0342	0.0712	0.0678
3:00 PM	0.0702	0.1098	0.0637	0.0820	0.0837
4:00 PM	0.0618	0.0606	0.0676	0.0730	0.0754
5:00 PM	0.0595	0.0597	0.0841	0.0715	0.0761
6:00 PM	0.0524	0.0502	0.1144	0.0648	0.0663
7:00 PM	0.0492	0.0463	0.0486	0.0564	0.0515
8:00 PM	0.0367	0.0254	0.0156	0.0436	0.0351
9:00 PM	0.0314	0.0180	0.0080	0.0341	0.0260
10:00 PM	0.0235	0.0115	0.0069	0.0244	0.0173
11:00 PM	0.0190	0.0070	0.0033	0.0150	0.0142
	Based on 25 counter locations	*Based on 15 counter locations*	*Based on 7 counter locations*	*Based on 55 counter locations*	*Based on 30 counter locations*

Information source: Griswold, et al. 2018.

These factors are based on a total of 132 locations with long-term pedestrian and bicycle counts from automated counters in California (San Francisco, Fresno, and Los Angeles regions).[9] Since most of the California count locations were on sidewalks, the majority of counts represent pedestrians. The California study is the most extensive analysis available to date on how pedestrian volume patterns relate to nearby land uses.

[9] Griswold, J.B., A. Medury, R.J. Schneider, and O. Grembek. "Comparison of Pedestrian Count Expansion Methods: Land Use Groups versus Empirical Clusters," Transportation Research Record: Journal of the Transportation Research Board, DOI: 10.1177/0361198118793006, 2018

Currently, there are no local long-term, pedestrian-only count data currently available for sidewalk or other street locations in Wisconsin. The only available counts are from trail locations, which may represent different hourly activity patterns than sidewalks and intersection street crossings). Without local data to use, it is reasonable to assume that hourly pedestrian activity patterns have a similar relationship to general land use categories in both California and Wisconsin. For comparison, the City of Minneapolis has assumed that 16% to 18% of weekday pedestrian activity occurs between 4 pm and 6 pm at all locations, but this is based on multi-use trail counts and does not make important distinctions between land use categories.[10]

Future development of pedestrian expansion factors in Wisconsin should also include hour to weekday factors that differentiate between hourly pedestrian patterns on weekdays and weekend days. Relative to weekdays, Saturdays and Sundays often have more pedestrian activity concentrated in the late morning and early afternoon hours. Therefore, having different hour to weekday factors will make it possible to expand weekend counts more accurately. Another approach to do this would be to establish hour-to-week factors rather than have separate hour-to-day and day-to-week factors.[11] This is not a serious issue in this particular study because only three of the counts were taken on a Saturday or Sunday. Two of these counts covered 6 am to 2 pm and one covered 6 am to 9 pm, so the difference between weekday and weekend pedestrian activity patterns over these periods is likely to be small.

2.2.3.3. Weekday to Week Factors (DF)

The factors listed in Table 3 were used to estimate the weekly volume from the weekday estimate. These factors were applied to intersections based on two mutually-exclusive land use categories. Locations near schools were the only land use category considered to have a substantially different weekly activity pattern than other locations in the California study (described above).

Table 3. Weekday to Week Factors

	School	**Other**
Weekday	Location with a school on an adjacent block	Non-School location
Monday	0.1537	0.1461
Tuesday	0.1545	0.1486
Wednesday	0.1562	0.1486
Thursday	0.1693	0.1481
Friday	0.1544	0.1494
Saturday	0.1138	0.1381
Sunday	0.0983	0.1212
	Based on 20 counter locations	*Based on 83 counter locations*

Information source: Griswold, et al. 2018.

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[10] City of Minneapolis. *Minneapolis Non-Motorized Traffic Counts: Operations and Methodology*, Available online, http://www.minneapolismn.gov/www/groups/public/@publicworks/documents/images/wcms1p-104840.pdf, February 2013.

[11] Schneider, R.J., T. Henry, M.F. Mitman, L. Stonehill, and J. Koehler. "Development and Application of the San Francisco Pedestrian Intersection Volume Model," Transportation Research Record: Journal of the Transportation Research Board, Volume 2299, pp. 65-78, 2012.

These factors are based on a total of 103 locations used in the California study that had sufficient data to analyze volume patterns across all weekdays. It is reasonable to assume that daily pedestrian activity patterns have a similar relationship to general land use categories in both California and Milwaukee.

2.2.3.4. Week to Year Factors (WF)

The factors listed in Table 4 were used to estimate the annual volume from the weekly estimate within any given month. These factors were applied to all data regardless of land use category, which assumes that seasonal patterns do not vary by land use. This assumption should be tested through future research. These factors also assume that all weeks in the same month represent the same proportion of annual volume, which should also be tested. Note that the factor values do not sum to one because they apply to any given week within a month (on average, they represent roughly 1/52nd of the year rather than 1/12th of the year).

Table 4. Week to Year Factors

	All
Month	All locations
January	0.0113
February	0.0126
March	0.0142
April	0.0179
May	0.0233
June	0.0263
July	0.0299
August	0.0248
September	0.0226
October	0.0197
November	0.0150
December	0.0124
	Based on analysis in Table 5

It is not reasonable to assume that California week to year factors apply to Milwaukee because the areas have very different climates. Therefore, the week to year factors for Southeastern Wisconsin were based on two local sources of annual data: reported pedestrian crashes by month and multi-use trail volumes within the City of Milwaukee. Table 5 shows how these two sources were combined to create the week to year factors.

We used an average monthly distribution between the two sources to produce a better estimate than using either source alone. Monthly numbers of reported pedestrian crashes may not match monthly pedestrian intersection crossing volumes because the risk of pedestrian crashes per pedestrian crossing may vary by seasonal condition (e.g., snow and ice, hours of darkness) or because pedestrian crashes are not reported consistently to police throughout the year. Multi-use trail volumes may not match pedestrian intersection crossing volumes because pedestrian activity on trails may be more recreational (i.e., more discretionary) than at intersections of city streets, meaning that these volumes are likely to be impacted more by adverse weather conditions. In addition, trail counts include bicyclists, who may also be more affected by winter weather than pedestrians crossing at city street intersections.

Table 5. Derivation of Week to Year Factors

Month	**Police-reported pedestrian crashes in Milwaukee**	**Multi-use trail volumes at 6 continuous counter locations[1]**	**Average of crash and trail volume data sources**	**Typical month**	**Ratio of two-source average to typical month**	**Final weekly factors calculated from average of other two sources**
January	7.61%	2.20%	4.90%	8.33%	0.59	0.0113
February	7.20%	3.75%	5.47%	8.33%	0.66	0.0126
March	7.38%	5.00%	6.19%	8.33%	0.74	0.0142
April	7.93%	7.65%	7.79%	8.33%	0.93	0.0179
May	9.76%	10.50%	10.13%	8.33%	1.22	0.0233
June	8.66%	14.18%	11.42%	8.33%	1.37	0.0263
July	9.13%	16.90%	13.01%	8.33%	1.56	0.0299
August	8.77%	12.77%	10.77%	8.33%	1.29	0.0248
September	8.73%	10.93%	9.83%	8.33%	1.18	0.0226
October	8.98%	8.14%	8.56%	8.33%	1.03	0.0197
November	8.10%	4.97%	6.53%	8.33%	0.78	0.0150
December	7.75%	3.03%	5.39%	8.33%	0.65	0.0124
Total	100.00%	100.00%	100.00%	100.00%		
Source	*11,040 crashes reported from 1997 to 2016, WisTransPortal Database*	*2,042,000 trail users, City of Milwaukee and Milwaukee County automated counters*				*Month ratio divided by 52.18 weeks per year*

1) The distribution of multi-use trail volumes per month is an average from the following six trail counter locations: Kinnickinnic River Trail at Maple (July 2015 to June 2016), Kinnickinnic River Trail at Rosedale (January 2017 to December 2017), Marsupial Bridge under Holton Viaduct (January 2017 to December 2017), Oak Leaf Trail at Brady Street Bridge (January 2016 to December 2017), Oak Leaf Trail at South Shore Park (January 2016 to December 2017), and Oak Leaf Trail at Hartung Park (January 2016 to December 2017).

The total annual pedestrian crossing estimates at our 348 study intersections are shown in Figure 5. These annual pedestrian crossing volumes make it possible to calculate a pedestrian crash rate. We counted the total number of police-reported pedestrian crashes within 50 feet of each study intersection between 2014 and 2018 and then divided this by the estimated number of pedestrian crossings during this five-year period. This provided an estimate of the number of pedestrian crashes per million crossings. In general, Figure 6 shows that the highest pedestrian crash rates are in suburban roadway corridors that tend to have high motor vehicle volumes, multiple lanes, and relatively low pedestrian volumes. Pedestrian crash rates tend to be lower in urban communities with older development patterns and relatively high pedestrian volumes. Note that pedestrian crash rates were only calculated for intersections that experienced at least one crash during the study period.

Figure 5. Annual Pedestrian Crossing Estimates at Intersections with Short-Term Counts, 2014-2018

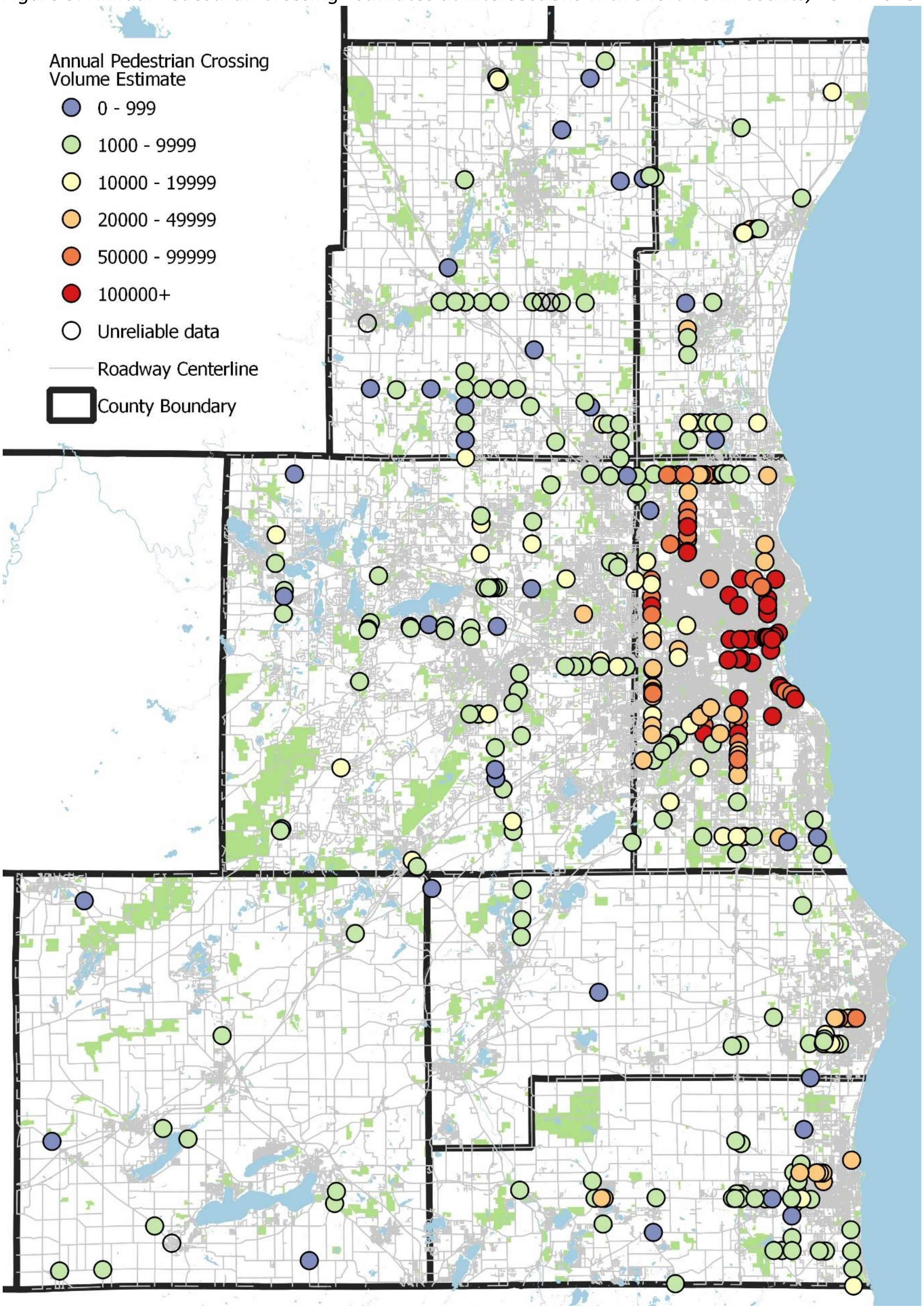
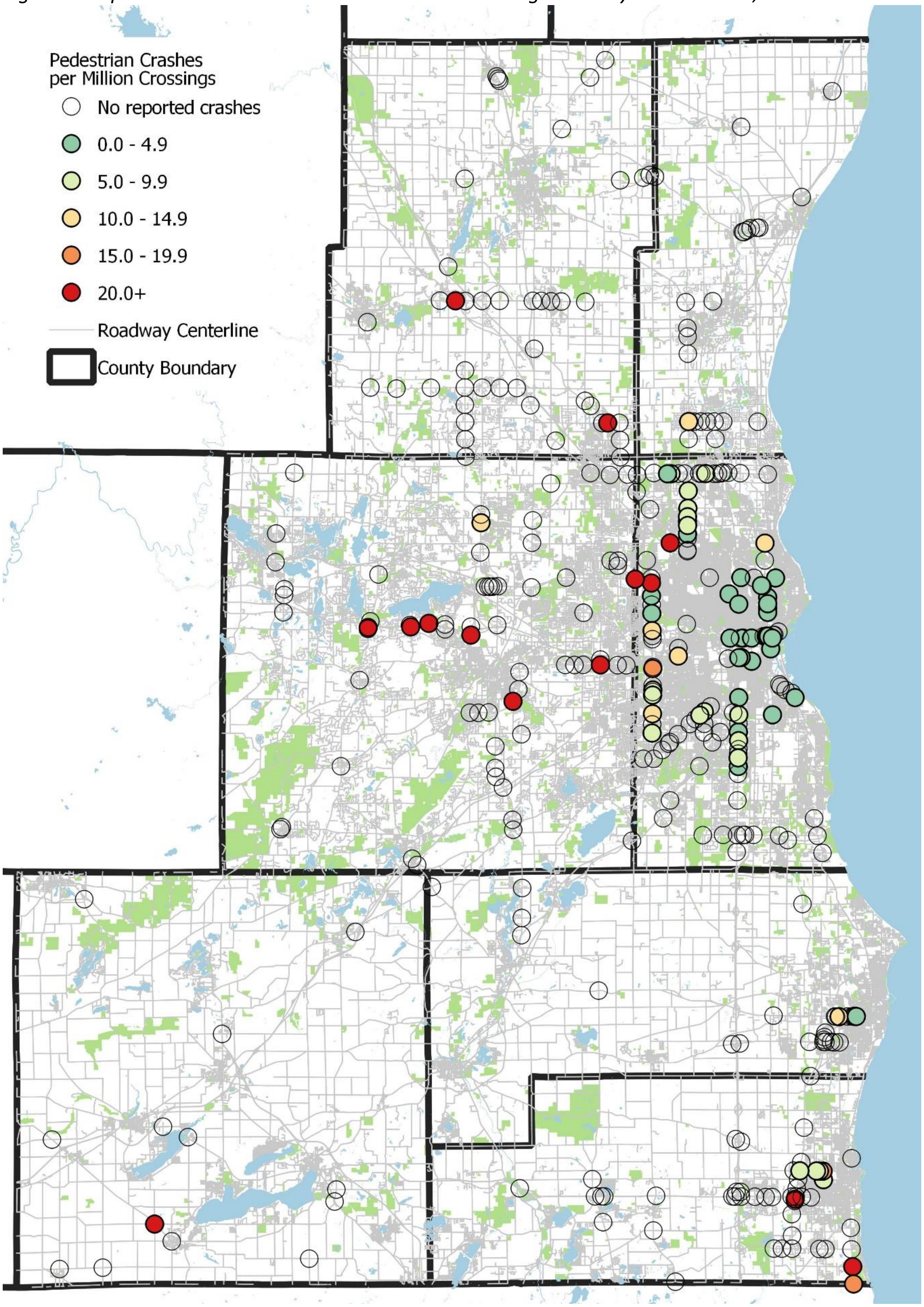


Figure 6. Reported Crashes Per Million Pedestrian Crossings at Study Intersections, 2014-2018



2.3. Pedestrian and Vehicle Counts and Movements at Intersections with Traffic Cameras

Our third type of pedestrian exposure data included both pedestrian and vehicle counts and movements, as well as potential conflicts between roadway users. We contracted with Transoft Solutions to conduct a pilot analysis of 30 hours of video data from WisDOT traffic cameras at four state highway intersections. The WisDOT Traffic Management Center recorded the videos in September 2020. We chose to use existing traffic camera video rather than install new cameras to see if useful exposure data could be gathered from this available resource.

<u>2.3.1. Automated Video Analysis Locations</u>

We focused on the four specific intersections listed below. Each had an existing WisDOT traffic camera. They appeared to have some pedestrian activity, and the camera angles were sufficient to clearly observe at least two crosswalks or one crosswalk and midblock crossings of one roadway leg approaching the intersection. However, none of these locations had particularly high pedestrian volumes, so they demonstrate how the technology handles low-volume situations.

- US 18 (Bluemound Rd.) & Calhoun Rd. (the observations would include counts of pedestrians crossing the east leg (US 18) away from the intersection). The speed limits were 45 mph on both legs of US 18 and 35 mph on both legs of Calhoun Rd.
- WI 59 (Greenfield Ave.) & 92nd St. The speed limits were 30 mph on both legs of WI 59, 30 mph on the north leg of 92nd St., and 25 mph on the south leg of 92nd St.
- WI 100 (Mayfair Rd.) & Burleigh St. (the observations would include counts of pedestrians crossing the north leg (WI 100) away from the intersection). The speed limits were 40 mph on both legs of WI 100 and 35 mph on both legs of Burleigh St.
- WI 100 (Mayfair Rd.) & WI 190 (Capitol Dr.). The speed limits were 40 mph on both legs of WI 100, 35 mph on the east leg of WI 190, and 45 mph on the west leg of WI 190.

<u>2.3.2. Automated Video Analysis Times[12]</u>

Transoft Solutions analyzed 30 hours of video at each intersection. We provided seven separate video files covering the following times at each of the four intersections.

- Period 1: Tuesday, September 15th, 2020, 7 am to 9 am (2 hours)
- Period 2: Tuesday, September 15th, 2020, 11 am to 6 pm (7 hours)
- Period 3: Wednesday, September 16th, 2020, 7 am to 9 am (2 hours)
- Period 4: Wednesday, September 16th, 2020, 11 am to 6 pm (7 hours)
- Period 5: Friday, September 18th, 2020, 8 pm to 11 pm (3 hours)
- Period 6: Saturday, September 19th, 2020, 11 am to 5 pm (6 hours)
- Period 7: Saturday, September 19th, 2020, 8 pm to 11 pm (3 hours)

<u>2.3.3. Automated Video Analysis Measures</u>

Transoft Solutions used automated video analysis to produce the following measures for each movement at each intersection:

- Counts for different roadway users (pedestrian, bicyclist, car, bus, motorcycle, pickup, truck), including time stamps
- Speeds of roadway users, including time stamps
- Prevalence of Speeding (5 or more mph over speed limit)
- Surrogate safety measures, including post-encroachment time (PET) and time-to-collision (TTC), including time stamps

[12] Periods 5, 6, and 7 for US 18 & Calhoun Rd. were done the following week (Friday, September 25th and Saturday, September 26th) because the camera angle moved on 9/18 and 9/19.

Transoft Solutions provided a dashboard that allows users to summarize data in a variety of ways at each location (Figure 6, Figure 7, Figure 8, and Figure 9). Many of the data that were provided could be useful for a variety of traffic safety analyses beyond the scope of this project.

2.3.4. Automated Video Analysis Findings

This analysis helped us develop a better understanding of what types of pedestrian exposure data can be collected from automated video processing. We were particularly interested in observations of pedestrian crossings within crosswalks at intersections, near crosswalks at intersections, and at mid-block locations on the approaches to intersections.

Overall, the pedestrian counts produced by the automated video analysis appeared to be reasonable (Table 6). For example, the three visible legs of the Greenfield and 92nd Street intersection averaged approximately six to eight pedestrian crossings per hour on September weekdays between 11 am and 6 pm. Pedestrian counts were higher during the day than at night at all locations. Transoft Solutions confirmed that the lighting should have been sufficient to detect pedestrians in the crosswalks at night.

Table 6. Mid-Day Pedestrian Crossing Counts

Intersection	Tuesday, 9/15, 11 am-6 pm	Wednesday, 9/16 11 am-6 pm	Friday, 9/18 8 pm-11 pm	Saturday, 9/19 8 pm-11 pm
WI 59 & 92nd St. (S, E, W crosswalks & mid-block crossings of S, E, W legs)	57	41	2	2
WI 100 & Burleigh St. (N, E crosswalks & mid-block crossings of N leg)	18	36	3	4
WI 100 & WI 190 (S, W crosswalks & mid-block crossings of S, W legs)	50	36	3	5
US 18 & Calhoun Rd. (N, S, E, W crosswalks & mid-block crossings of E leg)	41	38	N/A	N/A

However, there were some challenges with the automated video analysis, so the results should be considered carefully.

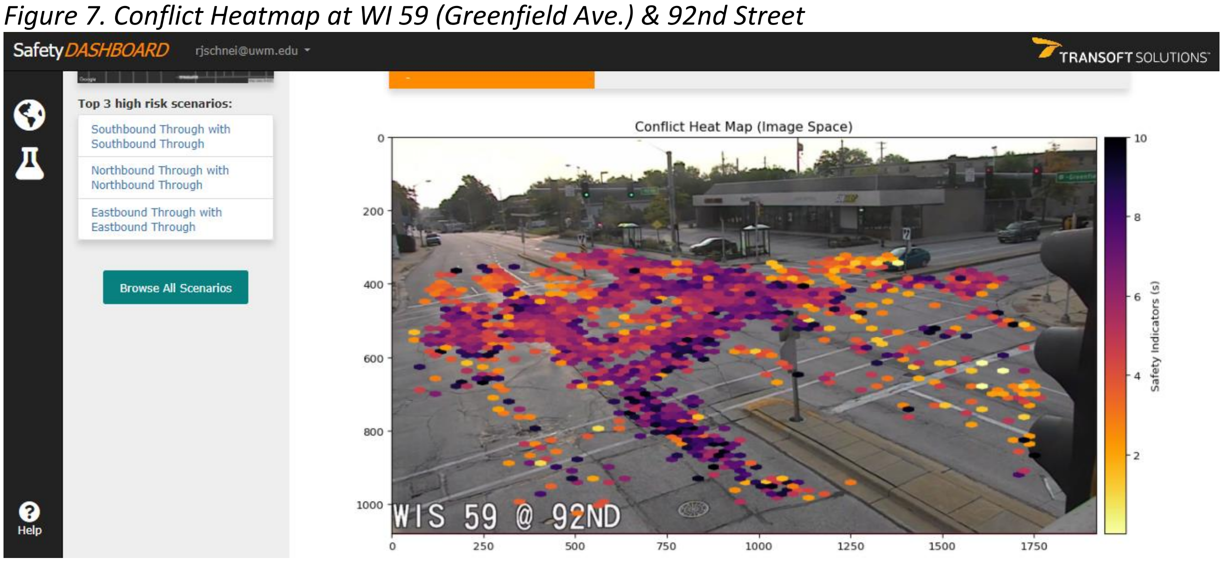
- Transoft Solutions performed follow-up manual checks and found several types of false positive pedestrian counts. These included signs being detected as pedestrians and pedestrians walking in the grass along the roadway being counted as crossing mid-block.
- The night crossings of US 18 and Calhoun Road were unreliable. Nearly all counts during this time period were recorded as mid-block crossings of the east leg, which was inconsistent with daytime counts. Several signs were repeatedly being detected as pedestrians.
- Mid-block crossings were recorded by the automated video analysis. We had hoped that the mid-block crossings could be detected as far as 200 feet from the intersection crosswalk. However, Transoft Solutions found that the camera views generally made it possible to detect pedestrians up to 60 feet from the crosswalk. Further, given the camera height and image resolution, the results may not be completely reliable. To study mid-block pedestrian crossings in the future, it would be desirable to set up cameras specifically for that purpose.
- Some of the automated results produced duplicate counts, so these required cleaning.

While we identified some limitations to automated video analysis, this technology continues to develop and improve. It is an important tool to collect data for pedestrian exposure and other safety analyses.

Figure 6. Intersection User Trajectories at WI 59 (Greenfield Ave.) & 92nd Street

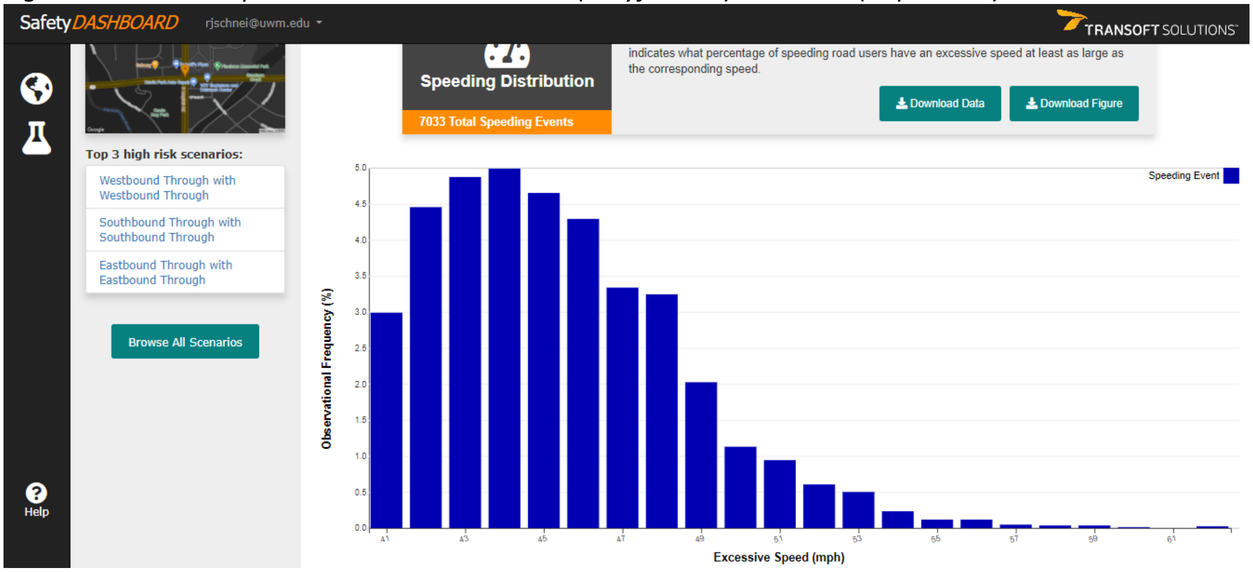
Source: Transoft Solutions, 2021.

Figure 7. Conflict Heatmap at WI 59 (Greenfield Ave.) & 92nd Street



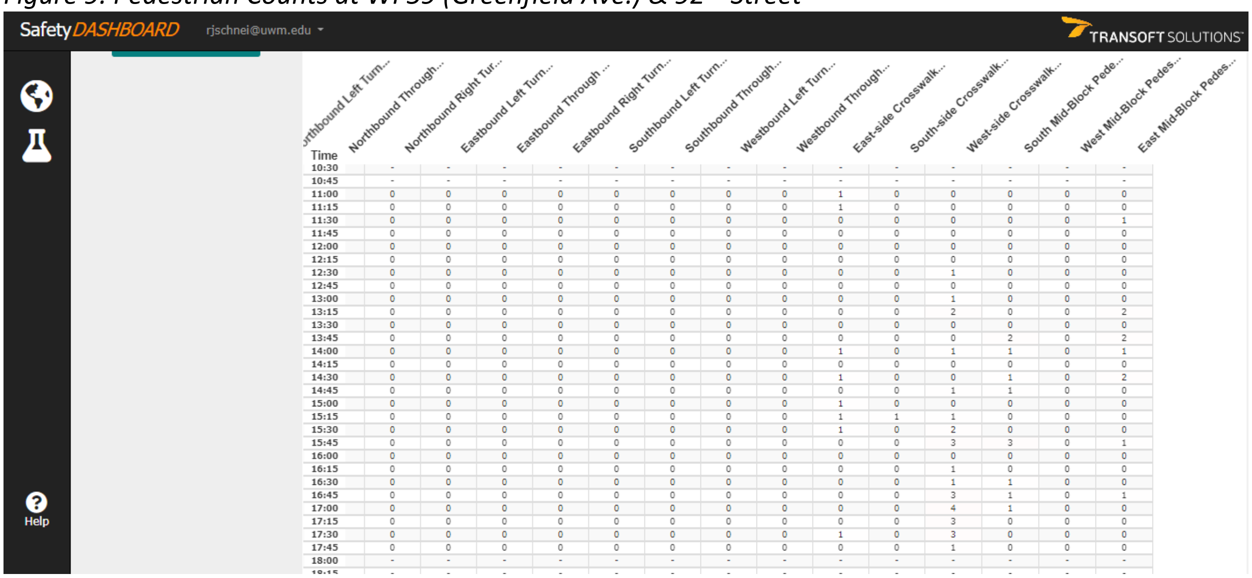
Source: Transoft Solutions, 2021.

Figure 8. Excessive Speed Distribution at WI 100 (Mayfair Rd.) & WI 190 (Capitol Dr.)



Source: Transoft Solutions, 2021.

Figure 9. Pedestrian Counts at WI 59 (Greenfield Ave.) & 92nd Street



Time	rthbound Left Turn...	Northbound Through...	Northbound Right Tur...	Eastbound Left Turn...	Eastbound Through ...	Eastbound Right Turn...	Southbound Left Turn...	Southbound Through...	Westbound Left Turn...	Westbound Through...	East-side Crosswalk...	South-side Crosswalk...	West-side Crosswalk...	South Mid-Block Pede...	West Mid-Block Pedes...	East Mid-Block Pedes...
10:30			-	-	-	-	-	-	-	-	-	-	-	-	-	-
10:45			-	-	-	-	-	-	-	-	-	-	-	-	-	-
11:00			0	0	0	0	0	0	0	0	1	0	0	0	0	0
11:15			0	0	0	0	0	0	0	0	1	0	0	0	0	0
11:30			0	0	0	0	0	0	0	0	0	0	0	0	0	1
11:45			0	0	0	0	0	0	0	0	0	0	0	0	0	0
12:00			0	0	0	0	0	0	0	0	0	0	0	0	0	0
12:15			0	0	0	0	0	0	0	0	0	0	0	0	0	0
12:30			0	0	0	0	0	0	0	0	0	0	1	0	0	0
12:45			0	0	0	0	0	0	0	0	0	0	0	0	0	0
13:00			0	0	0	0	0	0	0	0	0	0	1	0	0	0
13:15			0	0	0	0	0	0	0	0	0	0	2	0	0	2
13:30			0	0	0	0	0	0	0	0	0	0	0	0	0	0
13:45			0	0	0	0	0	0	0	0	0	0	0	2	0	2
14:00			0	0	0	0	0	0	0	0	1	0	1	1	0	1
14:15			0	0	0	0	0	0	0	0	0	0	0	0	0	0
14:30			0	0	0	0	0	0	0	0	1	0	0	1	0	2
14:45			0	0	0	0	0	0	0	0	0	0	1	1	0	0
15:00			0	0	0	0	0	0	0	0	1	0	0	0	0	0
15:15			0	0	0	0	0	0	0	0	1	1	1	0	0	0
15:30			0	0	0	0	0	0	0	0	1	0	2	0	0	0
15:45			0	0	0	0	0	0	0	0	0	0	3	3	0	1
16:00			0	0	0	0	0	0	0	0	0	0	0	0	0	0
16:15			0	0	0	0	0	0	0	0	0	0	1	0	0	0
16:30			0	0	0	0	0	0	0	0	0	0	1	1	0	0
16:45			0	0	0	0	0	0	0	0	0	0	3	1	0	1
17:00			0	0	0	0	0	0	0	0	0	0	4	1	0	0
17:15			0	0	0	0	0	0	0	0	0	0	3	0	0	0
17:30			0	0	0	0	0	0	0	0	1	0	3	0	0	0
17:45			0	0	0	0	0	0	0	0	0	0	1	0	0	0
18:00			-	-	-	-	-	-	-	-	-	-	-	-	-	-
18:15			-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Transoft Solutions, 2021.

Note that pedestrians were only counted in the crosswalk columns at the right side of the table.

3. Seven-County Regional Pedestrian Volume Model

As communities throughout the state establish goals to increase pedestrian activity and reduce pedestrian injuries, pedestrian volume models can provide useful information for planners and engineers. These models can generate estimates of pedestrian activity levels at thousands of locations, a task that would be highly impractical to do through field data collection. The pedestrian volume estimates can be used in pedestrian safety analysis, especially for representing exposure when assessing pedestrian crash risk. Pedestrian volume estimates can also help inform project prioritization, facility design, and development impact assessment.

Pedestrian travel occurs in urban, suburban, small town, and rural communities. Yet, pedestrian activity levels vary greatly across these different types of communities and even within different parts of the same jurisdiction. Therefore, pedestrian volume models must be sensitive to a variety of variables that influence pedestrian activity. Yet, for practical application, it is helpful if these models are relatively easy to run and understand.

This section provides a brief overview the development of a pedestrian volume model for the seven-county WisDOT Southeast Region (Milwaukee region). Our effort builds on previous pedestrian volume models developed in communities such as San Francisco, Montreal, and Minneapolis, but it is one of the first to be created for such a large, multi-county area, with a wide range of urban, suburban, and rural development patterns.

The model was developed using pedestrian intersection crossing volumes at 260 study intersections. We started with short-term counts (in most cases, 13-hours on a single day) and expanded them to annual pedestrian volume estimates using continuous pedestrian volume data from a sample of locations. We then compared these annual pedestrian volumes to surrounding land use, roadway, and neighborhood socioeconomic variables. Using negative binomial regression models, we identified seven variables to be significant predictors of annual pedestrian volumes: population density within 400 m of the intersection; employment density within 400 m; number of bus stops within 100 m; number of retail businesses within 100 m; number of restaurant and bar businesses within 100 m; presence of a school within 400 m; and proportion of households without a motor vehicle within 400 m (Table 7).

Based on the range of data used to create the model, we suggest that the outputs are appropriate for annual pedestrian volumes ranging from 1,000 to 650,000. This includes most intersections in the Southeast region, except for those in very-low-density rural areas, on university campuses, and in the highest-density areas of Downtown Milwaukee.

We evaluated the accuracy of the pedestrian volume model outputs at 45 separate validation intersections. Our three potential models had fair accuracy, predicting 60% or more of validation intersection counts to within half or double the observed value. We identified one model formulation—the one that used square-root transformations of the explanatory variables—to be the most accurate, and we recommend that this model be used by WisDOT and other agencies. Still, there are opportunities to improve the modeling process, such as adding new variables to better represent the number of lanes on each intersection leg and low socioeconomic status of adjacent neighborhoods.

Table 7. Final Annual Pedestrian Crossing Volume Models

	A. Base Model		B. Square Root Model		C. Cube Root Model	
Variable	Beta	p-value	Beta	p-value	Beta	p-value
Constant	8.334	0.000	7.629	0.000	7.071	0.000
Average population density (per square mile) for census tracts that have any overlap with a 400m buffer around the intersection (PopDen400)	0.000140	0.001				
Square root of PopDen400			0.019	0.000		
Cube root of PopDen400					0.100	0.000
Average job density (per square mile) for census tracts that have any overlap with a 400m buffer around the intersection (EmpDen400)	0.000021	0.046				
Square root of EmpDen400			0.00581	0.005		
Cube root of EmpDen400					0.036	0.003
Number of bus stops within 100m of the intersection (BusStp100)	0.336	0.000				
Square root of BusStp100			0.434	0.000		
Cube root of BusStp100					0.477	0.001
Number of retail properties (NAICS codes 44, 45) within 100m of the intersection (Retail100)	0.108	0.026				
Square root of Retail100			0.375	0.000		
Cube root of Retail100					0.471	0.000
Number of restaurants and bars (NAICS codes 7224, 7225) within 100m of the intersection (RestBar100)	0.116	0.062				
Square root of RestBar100			0.208	0.050		
Cube root of RestBar100					0.244	0.044
Intersection is within 100m of a public or private school (1 = yes; 0 = no) (SchDum400)	0.515	0.001	0.478	0.003	0.499	0.002
Average proportion of households with zero vehicles for census tracts that have any overlap with a 400m buffer around the intersection (Pct0Veh400)	5.307	0.000	4.184	0.001	4.330	0.000
Sample size (n)	260		260		260	
Log-likelihood[1]	-2792		-2774		-2772	
AIC[1]	5601		5565		5560	
BIC[1]	5629		5593		5588	

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

More details about the data, analysis methods, results, validation, and considerations related to the seven-county regional pedestrian volume model is provided in the reference listed below. We do not copy all information from that publication here due to copyright considerations.

Schneider, R.J., A. Schmitz, and X. Qin. “Development and Validation of a Seven-County Regional Pedestrian Volume Model,” Transportation Research Record: Journal of the Transportation Research Board, https://doi.org/10.1177/0361198121992360, 2021.

https://journals.sagepub.com/doi/abs/10.1177/0361198121992360

4. Exposure-Based Models of Trail User Crashes at Roadway Crossings

Multi-use trails are popular for pedestrian and bicyclist transportation and recreation in many parts of Wisconsin and throughout the world. While these trail facilities typically prohibit motor vehicle traffic, users are exposed to the risk of motor vehicle crashes at locations where the trails cross roadways (i.e., "trail crossings"). Existing pedestrian and bicycle design guidelines generally suggest that trail crossings are safer when they have lower automobile traffic volumes and speeds, fewer lanes, shorter trail-user crossing distances, and better visibility between drivers and trail users. A variety of crossing treatments, such as median islands, curb extensions, and flashing beacons can also be added to improve safety. However, there is little information about which trail crossing design changes might have the best safety outcomes and which specific crossing locations throughout the state should be prioritized for improvements. Further, while police crash data are available for many trail crossing crashes, there is rarely information about trail user volumes, or exposure, which prevents understanding where the highest trail crossing crash rates might be.

This section describes the development of one of the first safety performance functions in the United States for trail crossings. It is a statistical model that relates specific trail crossing characteristics with police-reported trail user crashes. The model can be used as a part of a systemic safety analysis process to estimate the expected number of crashes per year at a crossing with a particular set of characteristics. This makes it possible to prioritize safety improvements proactively at locations with the highest potential risk in the future (rather than highest number of crashes reported in the past). The statistical model can also help inform the trail design process by identifying specific crossing characteristics that have the strongest association with trail crossing crashes. Ultimately, this can lead to improved trail crossing design guidance. Outputs from the model can also be used to prioritize safety improvement resources.

We developed the model using trail user crash data and design characteristics from 197 trail crossings. Eighty-nine of the trail crossings were in the WisDOT Southeast Region, most of which were in suburban and rural areas. We supplemented these trail crossings with 108 urban locations in the City of Minneapolis, MN. We used Minneapolis data because it has a similar climate to Wisconsin, and the City of Minneapolis has been counting pedestrians and bicyclists on their trail system for more than a decade. It was essential for all trail crossings used in the study to have an estimated trail user crossing volume. As described in Section 2.2.1, SEWRPC has worked closely with WisDOT and other local agencies to collect counts at many locations on the trail system using automated counters since 2015. Note that these trail user counts did not differentiate between pedestrians and bicyclists, so the model applies to pedestrian and bicyclist crashes, combined. However, across our study locations, 85% of crashes involved bicyclists.

We used historic aerial and street-level imagery to collect more than 30 trail crossing variables at each study location. Categories of variables included exposure (motor vehicle and trail user volumes), crossing type (midblock and type of intersection crossing), geometric (e.g., crossing distance, presence of median, curb extensions), control and flow (e.g., type of traffic control, speed limit), sign and marking (e.g., type of crosswalk marking, warning signs, flashing beacons), visibility (e.g., clear distance, lighting presence), and study area (Milwaukee region versus Minneapolis). We tested all of these variables to identify which ones had significant associations with trail crossing crashes.

One key challenge of the modeling process was that many crossings had small numbers of crashes (or zero crashes) during the study period. The standard approach to modeling the number of crashes at a particular location is using a Poisson-gamma, or negative binomial model, but these can have problems when there are many locations with zero crashes. We addressed this issue by also estimating a Poisson-lognormal model, which provided more precise parameter estimates for variables in the model. The recommended Poisson-lognormal model shows that trail crossing crashes are a function of trail traffic volume, roadway motor vehicle volume, three-way intersections where the trail crosses perpendicular to the mainline roadway, and total crossing length. While they were not statistically-significant in the model, signalized intersections and limited sight lines between drivers and trail users near crossings may also be associated with more crashes, so these variables should be tested through future studies.

Table 8. Trail Crossing Crash Models

	Poisson-Gamma Model (Negative Binomial)			**Poisson-Lognormal Model[1]**		
Variable	**Beta**	**Std. Err.**	**Sig.[2]**	**Mean**	**Std. Dev.**	**Sig.[2,3]**
Constant	-9.482	1.547	**	-10.17	1.502	**
Natural log of AADTT (trail users)	0.703	0.138	**	0.735	0.130	**
Natural log of AADT (motor vehicles)	0.472	0.162	**	0.495	0.148	**
Mid-block crossing (base)	n/a	n/a	n/a	n/a	n/a	n/a
Crossing one 4-way intersection leg (1 = yes; 0 = no)	0.117	0.463	ns	0.167	0.418	Ns
Crossing leg parallel to mainline at 3-way intersection (1 = yes; 0 = no)	-0.683	0.866	ns	-1.022	0.899	Ns
Crossing leg perpendicular to mainline at 3-way intersection (1 = yes; 0 = no)	0.938	0.471	**	0.930	0.437	**
Traffic signal control (1 = yes; 0 = no)	0.561	0.448	ns	0.492	0.409	Ns
Crosswalk length (m)	0.038	0.021	*	0.040	0.018	**
Clear distance: driver ~50m from the crossing can see less than 5m of the trail on at least one side of the roadway (1 = yes; 0 = no)	0.274	0.349	ns	0.333	0.325	Ns
Clear distance: driver ~50m from the crossing can see more than 20m of the trail on both sides of the roadway (1 = yes; 0 = no)	-0.422	0.334	ns	-0.452	0.304	Ns
sigma[4]	n/a	n/a	n/a	0.689	0.195	**
Sample size (n)	197			197		
Log-likelihood[5]	-164.0			n/a		
AIC[5]	348.0			n/a		
BIC[5]	380.8			n/a		

1) Poisson-lognormal model parameter estimates are based on a simulation using 100,000 iterations.
2) ** indicates $p < 0.05$; * indicates $p < 0.10$; ns = indicates not significant.
3) Significance for the Poisson-lognormal model parameter estimates is determined by their percentile values (** indicates that the 2.5% and 97.5% parameter signs are the same; * indicates that the 5% and 95% parameter signs are the same).
4) sigma is the parameter associated with the variance in the Poisson-lognormal model: variance = sigma squared.
5) Lower absolute values of log-likelihood, AIC, and BIC indicate better overall model fit.
n/a = not applicable

WisDOT can use this model to improve trail crossing safety as it expands its systemic safety efforts. More details about the data, analysis methods, results, validation, and considerations related to the trail crossing crash model is provided in the reference listed below. We do not copy all information from that publication here due to copyright considerations.

Schneider, R.J., A. Schmitz, G. Lindsey, and X. Qin. “Exposure-Based Models of Trail User Crashes at Roadway Crossings,” Transportation Research Record: Journal of the Transportation Research Board, https://doi.org/10.1177/0361198121998692, 2021.

https://journals.sagepub.com/doi/abs/10.1177/0361198121998692

5. Next Steps

This Southeast Region pilot pedestrian exposure study provides insights that can be used to improve pedestrian volume data collection statewide. Our findings can potentially be incorporated into existing WisDOT-supported planning tools and safety analysis procedures used in the Highway Safety Improvement Program (HSIP).[13] The following sections present short-term and longer-term actions to implement the findings of this research.

5.1. Short-Term Implementation Actions

Short-term implementation actions involve creating tools directly from the results of this research. These tools can help inform existing WisDOT processes for scoping roadway projects and prioritizing locations for safety improvements.

5.1.1. Create an Interactive Statewide Pedestrian Volume Map

Our pedestrian crossing volume model from the Southeast Region should be applied statewide, and the annual pedestrian crossing estimates should be made available on an interactive pedestrian volume map (similar to the WisDOT TC Map for traffic counts).[14] This tool would provide planners and engineers at WisDOT and other agencies with pedestrian volume information that would be useful to:

- Develop and review Transportation Alternatives Program (TAP) and other grant applications.
- Help prioritize pedestrian needs as a part of the Safety Certification Process (SCP) for reconstruction, resurfacing, or spot improvement projects.
- Quantify pedestrian exposure at specific intersections to estimate pedestrian crash risk, integrating this information into the Highway Safety Improvement Program (HSIP) analysis process.
- Inform roadway project scoping discussions.
- Estimate future pedestrian volume increases due to new land development projects.
- Help represent latent pedestrian demand at locations that currently lack sidewalks or safe pedestrian crossings.

WisDOT should identify an appropriate platform for this interactive pedestrian volume map. One possibility is to integrate the pedestrian volume estimates as a layer that can be added to the traffic crash data in Community Maps[15] or added to WisDOT's publicly-accessible sidewalk and curb ramp map.[16] Another option would be to add the pedestrian volume estimates to a new, separate, publicly-accessible map hosted by WisDOT.

To populate the map with estimated pedestrian volumes for all intersections along major roadways in the state, it will be necessary to create a GIS point layer of intersections and collect all necessary inputs for the model across the entire state (e.g., census tract population, census block jobs, bus stops, retail businesses, restaurant and bar businesses, schools, and census tract household vehicle ownership).

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[13] Federal Highway Administration. Wisconsin Highway Safety Improvement Program: 2020 Annual Report, https://safety.fhwa.dot.gov/hsip/reports/pdf/2020/wi.pdf, 2020.

[14] Wisconsin Department of Transportation. Traffic counts: TCMap (Traffic Count Map), https://wisconsindot.gov/Pages/projects/data-plan/traf-counts/default.aspx, 2021.

[15] Wisconsin Traffic Operations and Safety Laboratory. The WisTransPortal System. Community Maps: Wisconsin County Traffic Safety Commissions Crash Mapping, https://transportal.cee.wisc.edu/partners/community-maps/, 2021.

[16] Wisconsin Department of Transportation. Interactive map of curb ramps and sidewalks along state highways, https://www.arcgis.com/apps/webappviewer/index.html?id=98f74e8262e348b28ab8622e10532d90, 2021.

After conducting basic GIS queries, the model equation can be applied to create estimates for all intersections statewide. With an additional step, the number of pedestrian crashes (or injuries) reported within 50m of each intersection could be divided by the total pedestrian volume estimate during a specific number of years to create a pedestrian crash (or injury) rate. This could also be displayed on the interactive map.

The initial statewide application will be a useful proof of concept. Since the model was developed in the Southeast Region, it will be important for WisDOT and other agency staff in other regions throughout the state to conduct validation counts. We expect that some of these counts will be different than the model-estimated pedestrian volumes, so they will help highlight limitations of the model. These validation counts should be compiled in a new database that can be used to refine the model (see more details below).

5.1.2. Integrate the Trail Crossing Safety Performance Function into Systemic Safety Analysis Procedures

Our trail crossing crash analysis produced a SPF that estimates the number of trail user crashes expected within an eight-year period based on trail crossing characteristics. WisDOT should integrate this SPF into the analysis procedures used to conduct systemic safety analyses for the HSIP. This may involve adding the SPF to an internal WisDOT spreadsheet or systemwide databases like the Meta-Manager Highway Asset Management System.[17] This trail crossing SPF would be useful to:

- Integrate into the HSIP, expanding the range of SPFs considered by WisDOT for systemic safety analysis.
- Inform the SCP for any potential roadway project that includes a trail crossing.
- Develop and review TAP and other grant applications.

Like the pedestrian volume model, the trail crossing SPF is also a new method that was developed in the Southeast Region and should be reviewed and refined in the future. In particular, WisDOT should compile more trail user counts to estimate annual trail crossing volumes at other locations throughout the state. Adding more sites will increase the predictive accuracy of the SPF and make it more applicable statewide (see more details below).

5.2. Longer-Term Implementation Actions

Longer-term implementation actions involve additional data collection and analysis to refine the tools that are tested in the short term. They also include testing new data collection methods.

5.2.1. Develop a Statewide Pedestrian Count Database

Pedestrian exposure data should be expanded statewide using the data collection and analysis techniques developed in this study. This includes collecting pedestrian counts in more locations and coordinating pedestrian count efforts across all five WisDOT regions.

- *Compile existing pedestrian intersection crossing counts.* In the Southeast Region, many of pedestrian crossing counts have been collected from 6 am to 7 pm as a part of routine field data collection of intersection turning movements. Some have been collected along with bicycle counts. Others have been collected by local jurisdictions. Other WisDOT regions should also compile pedestrian counts that they have collected previously or are available from other existing sources.

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[17] Wisconsin Department of Transportation. Transportation Asset Management Plan, https://wisconsindot.gov/Documents/projects/multimodal/tamp.pdf, 2019.

- *Collect new pedestrian crossing counts at more intersections.* To complement existing counts, WisDOT regions should work with local agencies to collect these data at a larger sample of intersections. More intersection counts will make it possible to validate and develop better pedestrian intersection volume models.
- *Begin to collect pedestrian crossing volumes at a sample of mid-block locations.* Initially, we planned to collect mid-block pedestrian crossing counts during this study. Unfortunately, the COVID-19 pandemic caused us to abandon plans for in-person data collection. However, crossings between intersections are where some of the most severe pedestrian injuries occur, so mid-block crossing volumes will be important to collect and predict in the future. Mid-block counts can be collected for similar durations as intersection counts. Quantifying mid-block pedestrian exposure is essential to understanding pedestrian crash risk.
- *Install automated counters at more sidewalk locations to document pedestrian activity patterns.* Continuous data are needed to identify hourly, daily, and seasonal patterns of pedestrian activity. These data can then be used to expand shorter-duration pedestrian counts (such as the intersection and mid-block counts mentioned above) collected during different time periods to annual volume estimates in a consistent way. Having automated counters at more locations will identify different types of patterns that will allow short-term counts to be expanded more accurately.
- *Compile all pedestrian counts and annualized pedestrian volume estimates into a single statewide database.* Each count location recorded in this database should include key information specified in the FHWA Non-Motorized count format guidelines.[18] These items include the longitude and latitude of each specific count location (in decimal degrees), information about the site conditions, date, time of day, count direction, count duration, weather conditions, and summarized hourly volumes for each crossing. It should also identify the general type of count, including intersection crossings, mid-block crossings, or screenline counts and the technology used for counting.

As this statewide database is developed, the overall set of locations should be reviewed to determine how well it represents different community settings (e.g., urban, rural), surrounding neighborhood characteristics (e.g., age, race, income level), types of roadways (e.g., arterial, collector, local), development densities (e.g., high, medium, low), and land use categories (e.g., residential, commercial, mixed-use). Underrepresented location types should be prioritized for new counts. Eventually, a systematically-selected sample of the available count locations should be used to track pedestrian activity over time, refine pedestrian volume models, and develop new pedestrian safety performance functions.

5.2.2. Develop and Refine Statewide Pedestrian Volume Models

We used existing pedestrian intersection crossing count data from the Southeast Region to create a seven-county pedestrian volume model and recommend applying that model statewide in the short term. This model should be refined using the additional intersection counts described above. Further, the same modeling concepts could be applied to develop statewide pedestrian mid-block crossing models once data are available. As the number of counts available within each region increases, it may become possible to develop region-specific pedestrian volume models. This could account for regional

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[18] Federal Highway Administration. Coding Nonmotorized Station Location Information in the 2016 Traffic Monitoring Guide Format, https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/tmg_coding/fhwahep17011.pdf, 2016.

differences in attitudes towards walking, responses to seasonal weather conditions, and other cultural factors that are impractical to include as model variables.

5.2.3. Create Statewide Pedestrian Safety Performance Functions

Safety performance functions (SPFs) are central to a systemic safety analysis approach. They can identify locations within the roadway network that have the highest potential for future pedestrian crashes, based on roadway design and other characteristics of the surrounding environment. Our model of trail user crashes at roadway crossings is an example of a SPF. Since pedestrian exposure is highly correlated with the number of pedestrian crashes at any given location, it is essential to have good exposure data to develop pedestrian SPFs. Eventually, the new pedestrian count database and pedestrian volume model estimates recommended above can be combined with roadway design and other variables to develop pedestrian SPFs for intersections, mid-block crossings of roadway segments, or roadway corridors (e.g., one-mile lengths of roadway, including multiple intersections and roadway segments). As additional counts are collected along trails, our initial trail user crossing SPF can also be updated and expanded to represent the entire state. These SPFs should be integrated into the HSIP implementation process.

5.2.4. Continue to Explore Automated Video Analysis for Pedestrian Data Collection

Our initial exploration of automated video analysis shows potential to collect continuous pedestrian crossing counts and document important vehicle speed and conflict events. While the technology does not yet appear to be reliable enough to use on video collected from existing WisDOT traffic cameras, it is likely that video cameras set up with the specific purpose of collecting pedestrian data (e.g., higher from the ground; covering all crosswalks at an intersection) could provide useful information. Challenges of conducting specialized video camera data collection for pedestrian safety would be purchasing new video cameras for this purpose and allocating staff time to install and manage the cameras in the field. Given these constraints, the next logical step may be to continue to pilot test this technology in a few locations with high numbers of pedestrian crashes.