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By S. I. Guler, V. V. Gayah, H. Liu,
L. Chowdhury and S. French

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University

PennState
College of Engineering
LARSON TRANSPORTATION
INSTITUTE

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16. Abstract

Careful data-driven analysis of these key focus areas is needed to provide guidance on the most cost-effective methods to improve safety performance from a behavioral perspective. The objective of this project was to develop a behavioral traffic safety-related data analysis report that identifies behavioral issues that may contribute to crashes and determine appropriate countermeasures that can be applied to address these issues. First, behavioral safety issues were quantified using available data. Then, appropriate behavioral safety countermeasures to address the issues identified were recommended. Finally, an implementation plan for the most promising countermeasures was developed.

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Behavioral Safety Project

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Prepared by:

S. Ilgin Guler
Associate Professor, Penn State University

Vikash V. Gayah
Associate Professor, Penn State University

Hao Liu
Postdoctoral Researcher, Penn State University

Lamiya Chowdhury
Graduate Student Researcher, Penn State University

Sydney French
French Engineering

Department of Civil and Environmental Engineering
The Pennsylvania State University
217 Sackett Building
University Park, PA 16802

Prepared for:
The Pennsylvania Department of Transportation

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1. INTRODUCTION

Traffic safety is a key priority of the Pennsylvania Department of Transportation (PennDOT). Over the past 4 years, annual traffic fatalities have remained steady and total injuries from traffic crashes have decreased from 80,612 in 2017 to 69,599 in 2021 (ignoring 2020 due to impacts of COVID-19). The number of reported traffic crashes annually has also remained mostly steady between 2017 and 2021, although a significant decline was observed in 2020 and 2021, likely due to the COVID-19 pandemic and its impacts. While this trend is promising, considerable work remains. Fatalities and injuries due to traffic crashes not only result in a loss of lives and bodily harm, but they also contribute to an economic loss of over $29 billion annually within Pennsylvania[1]. Thus, there is a need to continue improving safety performance on Pennsylvania roadways through a combination of educational activities, infrastructure improvements, and enforcement measures. To this end, PennDOT is interested in applying data-driven methods to identify safety problems, determine safety priorities, allocate resources, and evaluate the effectiveness of these actions.

One aspect of this approach is to focus on safety-related issues associated with driver behavior. Although there are three main potential contributing factors for any crash (vehicle, roadway/environmental, and driver), human-related factors are the most dominant. Driver actions (or inactions) were identified as a critical factor that contributed to more than 94 percent of crashes (National Highway Traffic Safety Administration and US Department of Transportation, 2015). Thus, to reduce crashes and improve safety performance, it is imperative to develop a comprehensive plan to address behavioral issues. The Pennsylvania Strategic Highway Safety Plan has specifically identified 13 focus areas (Pennsylvania Department of Transportation, 2017) that are particularly relevant to behavioral safety issues:

- Aggressive driving and speeding
- Bicycle safety
- Child passenger safety
- Commercial motor vehicle safety
- Distracted driving
- Enforcement outreach
- Impaired driving
- Mature drivers
- Motorcycle safety
- Pedestrian safety
- Seat belt use
- Teen drivers
- Work zone safety

Careful data-driven analysis of these key focus areas is needed to provide guidance on the most cost-effective methods to improve safety performance from a behavioral perspective. The objective of this project was to develop a behavioral traffic safety-related data analysis report that

[1] https://www.penndot.gov/TravelInPA/Safety/Documents/2021_CFB_linked.pdf

identifies behavioral issues that may contribute to crashes and determine appropriate countermeasures that can be applied to address these issues. First, behavioral safety issues were quantified using available data. Then, appropriate behavioral safety countermeasures to address the issues identified were recommended. Finally, an implementation plan for the most promising countermeasures was developed.

This report describes the data collection effort, summarizes the data analysis that was undertaken, documents the behavioral countermeasures that could be used to reduce number of crashes—focusing on areas of concern identified as a part of the data analysis—and, lastly, provides an implementation plan. The remainder of this report is organized as follows. The following section describes the data collection activities that were performed as a part of this task. The next section summarizes the behavioral safety issues that were identified. This is followed by a summary of findings from the data analysis. The next section provides potential behavioral countermeasures that could be implemented for each of the areas of concern. Finally, the concluding section summarizes promising countermeasures and provides a potential implementation plan.

2. DATA COLLECTION

In this first task, data from existing sources were collected to quantify behavioral traffic safety issues within Pennsylvania. The data were collected at the individual county level for the last 8 years for which they were available, from 2014 to 2021, inclusive. The data were collected from seven different sources:

1) Pennsylvania Crash Information Tool (PCIT)
2) PennDOT Roadway Management System (RMS) Database
3) U.S. Census data, specifically the American Community Survey (ACS) data
4) PennDOT Driver and Vehicle Services Annual Report of Registrations
5) PennDOT Crash Reporting System (CRS)
6) Bureau of Drivers Licensing (BDL)
7) Administrative Office of Pennsylvania Courts (AOPC)

The first four sources are publicly accessible and thus readily available to the research team. Data from the latter three sources were obtained via special requests as a part of this project. Detailed information on the data elements collected from each of these sources is described below.

PCIT

The following data elements were collected from the PCIT database. These data elements were aggregated for each county-year combination, for a total of 536 observations:

1) Total number of crashes within the given county for that year
2) Total number of fatalities of belted crash occupants
3) Total number of suspected serious injuries of belted crash occupants
4) Total number of fatalities of unbelted crash occupants
5) Total number of suspected serious injuries of unbelted crash occupants
6) Total number of unbelted crash occupants
7) Total number of crashes that involve bicycles
8) Total number of bicyclist fatalities
9) Total number of bicyclist suspected serious injuries
10) Total number of crashes that involve pedestrians
11) Total number of pedestrian fatalities
12) Total number of crashes that involve motorcycles
13) Total number of motorcyclist fatalities
14) Total number of crashes that involve commercial vehicles
15) Total number of crashes that only involve passenger vehicles
16) Total number of crashes that occurred in a work zone
17) Total number of child passenger (under the age of 8) fatalities
18) Total number of child passenger (under the age of 8) suspected serious injuries
19) Total number of young drivers involved in crashes (ages 16–20)
20) Total number of mature drivers involved in crashes (ages 65 and up)
21) Total number of crashes that involved at least one aggressive driving action
22) Total number of crashes that involved at least one speeding vehicle

23) Total number of crashes that involved at least one impaired driver
24) Total number of crashes that involved at least one distracted driver

To obtain the elements listed above, various crash data files – specifically, the “Crash” and “Flag” data files – were obtained for each year and joined using the Crash Record Number (CRN) that serves as a unique identifier for each crash. Data elements 1–20 listed above were obtained from the “Crash” file. Note that the number of crashes that only involve passenger vehicles was calculated as the number of crashes that do not involve bicyclists, pedestrians, commercial vehicles, motorcyclists, buses, trucks, horse buggies, and other non-motorists. The remaining data elements were obtained from the “Flag” dataset. The aggressive driving action was determined using the NHTSA aggressive driving flag, and the speeding vehicle action was determined using the speeding-related flag. Note that one crash can have multiple flags; e.g., a single crash can be categorized as aggressive driving, speeding, impaired driving, and distracted driving.

These data elements were primarily used to quantify the number of crashes (by type) within each county-year combination. However, the magnitude alone was not reflective of the magnitude of potential safety issues, since they do not account for exposure. Thus, additional data elements (described below) were collected to account for exposure within each of the safety-critical issues.

RMS

The following data elements were collected for each county and each year from the PennDOT RMS database:

1) Average daily vehicle miles traveled (VMT)
2) Average daily truck miles traveled

Note that the two metrics above are not directly available in the RMS database. Instead, they were calculated as the sum of the VMT on individual state-owned roadway segments within each county. These VMT values for individual state-owned roadway segments were computed as the product of the annual average daily traffic on that segment and its length.

These values served as a measure of exposure for the amount of driving by all vehicles and trucks within each county-year combination.

ACS

The following data elements were collected for each county and each year from the ACS database:

1) Population
2) Population density (people/mi^2)
3) Population of young people (ages 16–20)
4) Population of mature people (ages 65+)
5) Percentage of trips to work by walking
6) Percentage of trips to work by taxi, motorcycle, biking, and other means
7) Percentage of trips to work by biking

Notice that the percentage of trips to work by biking was only available for a subset of all counties. These values served as an exposure measure for population, and amount of walking and biking trips within each county-year combination.

PennDOT Driver and Vehicle Services Annual Report of Registrations

The number of total motorcycles registered was obtained for each county and each year from the PennDOT Driver and Vehicle Services Annual Report of Registrations. This was used as an exposure metric for motorcycle crashes.

CRS

Due to the lack of available data on work zone locations and durations within Pennsylvania, work zone crash reports were used as a proxy. Detailed crash reports of select work zone crashes were obtained using the CRS system and manually read to understand characteristics of work zone-related crashes.

BDL

The following data were requested and obtained for each county and each year from the BDL:

1) The total number of registered drivers
2) The total number of registered young drivers (ages 16–20)
3) The total number of registered mature drivers (ages 65+)

These data were used as a measure of exposure for young and mature driver-involved crashes.

AOPC

The following data elements were requested and obtained from the AOPC for each county and each year:

1) Number of citations for aggressive driving
2) Number of citations for distracted driving
3) Number of arrests for impaired driving
4) Number of citations for speeding
5) Number of citations for unbelted driving
6) Number of citations in work zones

Note that Philadelphia does not report through the statewide Magisterial District Judge System but has its own system. Hence, AOPC data do not include information for Philadelphia. However, data for impaired driving arrests were available for Philadelphia. Hence, Philadelphia was omitted for the citation-based analysis except for impaired driving arrests.

Title 75 of the Pennsylvania Consolidated Statues[2] was used to assemble citations that would relate to the NHTSA aggressive driving definition. A list of the sections of citations used to create the aggressive driving citations is as follows:

1) 3111 – obedience to traffic-control devices
2) 3111.1 – obedience to traffic-control devices warning of hazardous conditions
3) 3112 – traffic control signals (running red light)
4) 3303 – overtaking vehicle on the left (careless passing or lane change)
5) 3304 – overtaking vehicle on the right (careless passing or lane change)
6) 3305 – limitations on overtaking on the left (careless passing or lane change)
7) 3307 – no-passing zones
8) 3309 – driving on roadways laned for traffic (careless passing or lane change)
9) 3310 – following too closely
10) 3312 – limited-access highway entrances and exits (making improper entrance to highway/making improper exit from highway)
11) 3322 – vehicle turning left (improper/careless turning)
12) 3323 – stop signs and yield signs
13) 3324 – vehicle entering or crossing roadway (making improper entrance to highway/making improper exit from highway)
14) 3331 – required position and method of turning (improper/careless turning and turning from wrong lane)
15) 3332 – limitations on turning around
16) 3334 – turning movements and required signals (improper/careless turning)
17) 3714 – careless driving
18) 3733 – fleeing or attempting to elude police officer

Note that section 3714 citations (careless driving) might actually be indicative of speeding, distracted driving, or aggressive driving violations. For example, some speeding violations might receive a section 3714 violation in addition to or instead of a speed citation, particularly to have an enhanced penalty option. Similarly, some distracted driving violations might be given a section 3714 citation due to the specific distracted driving laws that only have categories for texting and wearing headphones for all drivers, and hands-free communication for commercial vehicle drivers. In this report, section 3714 is used as an indicator for aggressive driving citations, since this can be used to address multiple violations (which is similar to the NHTSA definition of an aggressive driving behavior) and also to address a series of violations that occurred over a distance.

The following citations were used to describe distracted driving:

1) 3314 – prohibiting use of hearing impairment devices, and
2) 3316 – prohibiting text-based communications.

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[2] 1 Pa. C.S. § 1928 (rule of strict and liberal construction)
https://www.legis.state.pa.us/WU01/LI/LI/CT/PDF/75/75.PDF

The impaired driving arrests were obtained from Section 3802 – driving under influence of alcohol or controlled substance. Note that data from Philadelphia were also available for this category.

The speeding citations were obtained from:

1) Section 3361 – driving vehicle at safe speed
2) Section 3362 – maximum speed limits

The number of unbelted citations was obtained from Section 4581 – restraint systems.

The citations in works zones were obtained from Section 3326 – duty of driver in construction and maintenance areas or on highway safety corridors.

3. SUMMARY OF BEHAVIORAL SAFETY ISSUES IDENTIFIED USING EXISTING DATA

The collected data were summarized by both county and PennDOT Engineering District (referred to as districts hereafter, where individual districts are made up of multiple counties). The following shows the data summary by county; similar summaries by district can be found in Appendix A and are omitted from the body of the report for brevity.

The data are typically presented in bar charts that show an **average** annual count (averaged over the years of 2014 to 2021, inclusive) or an **average** normalized annual count (averages of annual counts divided by some exposure measure) of the metric considered on the y-axis across different counties shown on the x-axis. Hence, each number on the y-axis can be interpreted as the average value of a given metric observed averaged over the years of 2014 to 2021, inclusive, for a given county. Average counts instead of total counts are used to avoid errors resulting from missing values. For normalized annual counts, the average annual count of crashes was divided by the variable considered for normalization. For example, if the average number of crashes per VMT is shown, the average number of crashes in a given county over the years of 2014 to 2021 was divided by the average VMT in that county over the years of 2014 to 2021. This normalization would be interpreted as the average number of crashes that would occur for every vehicle mile traveled within a given county.

Results for total crashes

Figure 1 shows the average number of crashes per year for each county. The average number of crashes per year per county was found to be 1,834, and 18 counties were above this average. It can be seen that Allegheny and Philadelphia counties have the largest average number of crashes per year, approximately 12,000 and 11,000 per year, respectively. This is expected, since these are the largest counties (by population) within Pennsylvania.

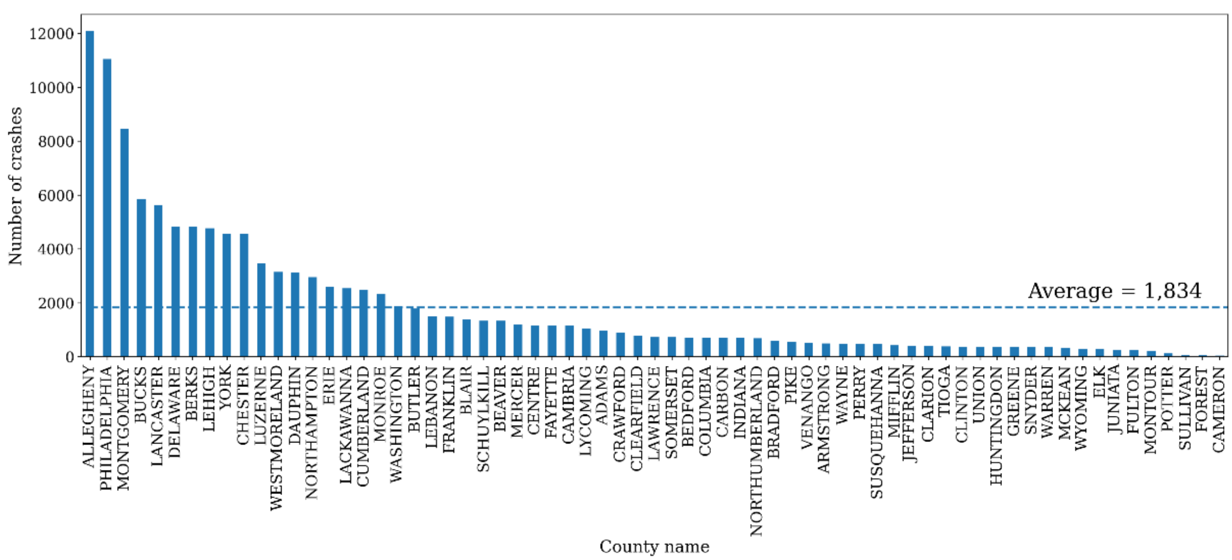

Figure 1 Average number of crashes per year by county (2014-2021)

Since the number of crashes highly depends on the population and vehicle trips within a county, using these two as exposure metrics to normalize the number of crashes is next considered. Figure

2 provides the number of crashes normalized using total population (i.e., annual crashes per person), while Figure 3 shows the number of crashes normalized by vehicle miles traveled.

The average number of crashes per person is approximately 0.01, and the average number of crashes per mile traveled is 0.0004. It can be seen that this normalization significantly changes the order of the counties in terms of crash risk. When considering total population as the exposure metric, Fulton and Bedford counties have the largest crash rates and Philadelphia County has the lowest. When considering total VMT as the exposure metric, however, Philadelphia County has the highest crash rate. Hence, it is important to consider appropriate exposure metrics that are consistent with needs to assess the safety of different counties within PA. Either population or VMT could be appropriate exposure metrics for different purposes (e.g., if the target for safety improvements is the entire population or just vehicle drivers).

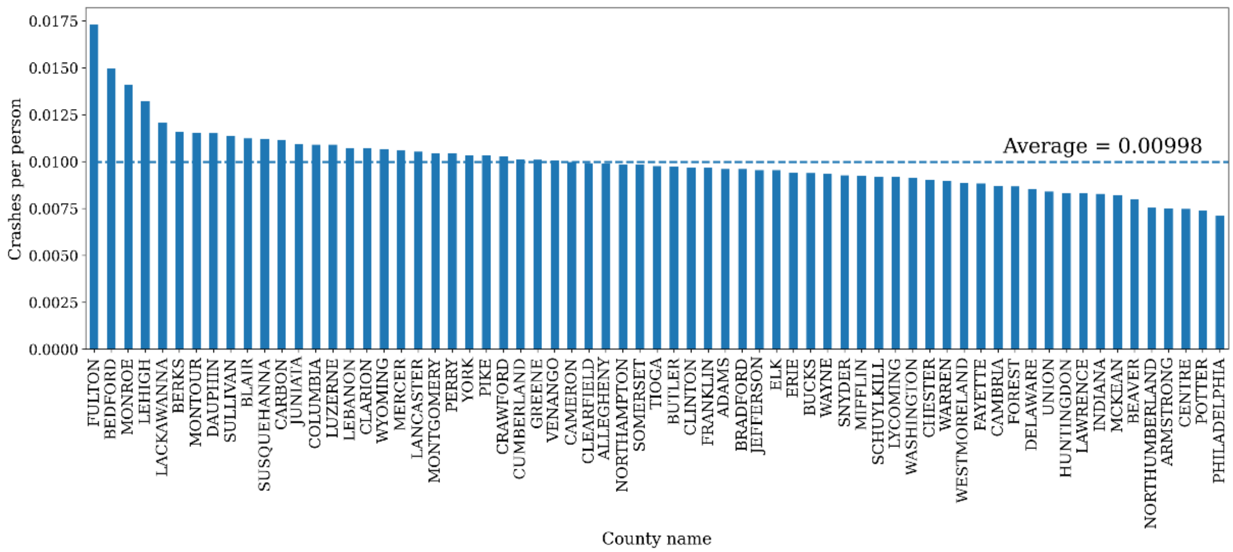

Figure 2 Average number of crashes per person per year by county (2014-2021)

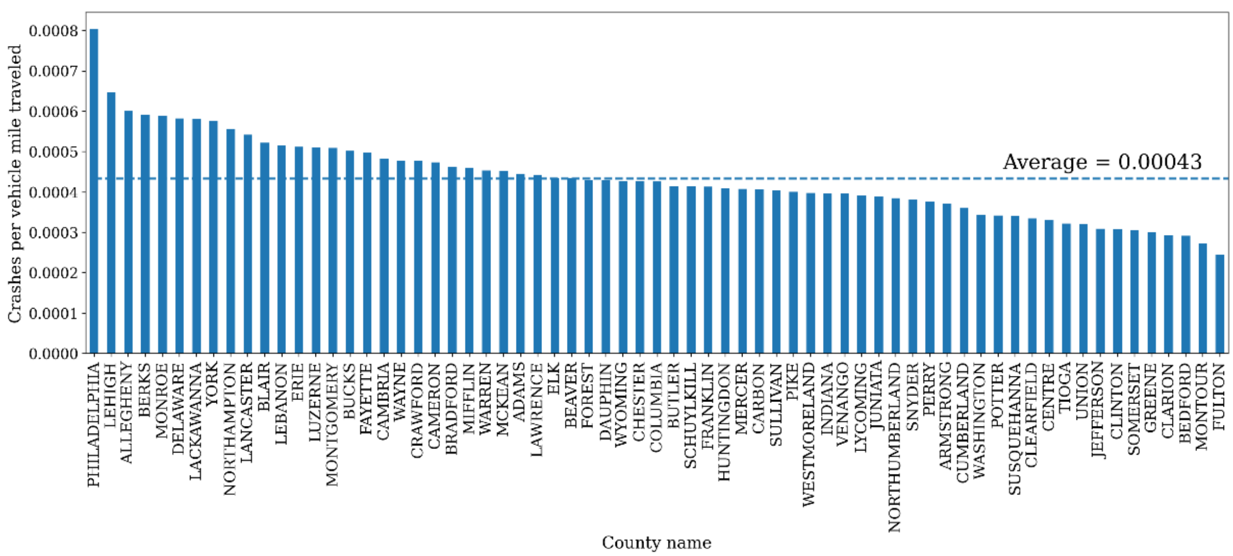

Figure 3 Average number of crashes per VMT per year by county (2014-2021)

Table 1 provides the average number of total crashes, total crashes per population, and total crashes per VMT per county.

Table 1 Average number of total crashes, total crashes per population and total crashes per VMT per year (2014-2021)

County	Total crashes	Total crashes per pop	Total crashes per VMT
ADAMS	969	0.00962	0.00044
ALLEGHENY	12097	0.00990	0.00060
ARMSTRONG	497	0.00751	0.00037
BEAVER	1337	0.00800	0.00043
BEDFORD	722	0.01498	0.00029
BERKS	4837	0.01161	0.00059
BLAIR	1392	0.01125	0.00052
BRADFORD	589	0.00961	0.00046
BUCKS	5856	0.00939	0.00050
BUTLER	1788	0.00972	0.00042
CAMBRIA	1161	0.00870	0.00048
CAMERON	46	0.00998	0.00047
CARBON	714	0.01114	0.00041
CENTRE	1176	0.00748	0.00033
CHESTER	4565	0.00902	0.00043
CLARION	413	0.01072	0.00029
CLEARFIELD	790	0.00993	0.00033
CLINTON	378	0.00969	0.00031
COLUMBIA	719	0.01092	0.00043
CRAWFORD	893	0.01029	0.00048
CUMBERLAND	2471	0.01012	0.00036
DAUPHIN	3126	0.01153	0.00043
DELAWARE	4838	0.00854	0.00058
ELK	290	0.00955	0.00044
ERIE	2602	0.00942	0.00051
FAYETTE	1164	0.00885	0.00050
FOREST	61	0.00868	0.00043
FRANKLIN	1483	0.00967	0.00041
FULTON	257	0.01733	0.00025
GREENE	371	0.01011	0.00030
HUNTINGDON	373	0.00834	0.00041
INDIANA	712	0.00830	0.00040
JEFFERSON	415	0.00955	0.00031
JUNIATA	269	0.01094	0.00039
LACKAWANNA	2551	0.01208	0.00058
LANCASTER	5641	0.01054	0.00054
LAWRENCE	733	0.00834	0.00044
LEBANON	1496	0.01074	0.00052

County	Total crashes	Total crashes per pop	Total crashes per VMT
LEHIGH	4778	0.01321	0.00065
LUZERNE	3463	0.01090	0.00051
LYCOMING	1045	0.00919	0.00039
MCKEAN	337	0.00820	0.00045
MERCER	1198	0.01059	0.00041
MIFFLIN	424	0.00924	0.00046
MONROE	2344	0.01413	0.00059
MONTGOMERY	8465	0.01044	0.00051
MONTOUR	209	0.01154	0.00027
NORTHAMPTON	2961	0.00988	0.00056
NORTHUMBERLAND	696	0.00754	0.00039
PERRY	470	0.01043	0.00038
PHILADELPHIA	11056	0.00711	0.00080
PIKE	567	0.01033	0.00040
POTTER	121	0.00738	0.00034
SCHUYLKILL	1338	0.00920	0.00042
SNYDER	371	0.00928	0.00038
SOMERSET	731	0.00984	0.00031
SULLIVAN	69	0.01137	0.00040
SUSQUEHANNA	463	0.01123	0.00034
TIOGA	393	0.00976	0.00032
UNION	375	0.00841	0.00032
VENANGO	531	0.01008	0.00040
WARREN	359	0.00898	0.00045
WASHINGTON	1867	0.00914	0.00034
WAYNE	479	0.00937	0.00048
WESTMORELAND	3150	0.00887	0.00040
WYOMING	292	0.01068	0.00043
YORK	4569	0.01033	0.00058

Next, crashes that involve different travel modes are considered. Figure 4 provides the fraction of crashes involving four travel modes of interest (bicycle, commercial vehicle, motorcycle, and pedestrian). Figure 5 provides the fraction of crashes involving only passenger vehicles, which are the crashes that do not involve bicyclists, pedestrians, commercial vehicles, motorcycles, buses, trucks, horse buggies, or other non-motorists. Figure 4 shows that – of the four modes – commercial vehicles comprise the largest share of crashes, while bicyclists comprise the lowest in most counties. Also in most counties, the fraction of crashes involving motorcycles is greater than those involving pedestrians. This is not true for Philadelphia County, where pedestrians comprise a large share of all crashes, along with bicyclists. The ratio of crashes involving commercial vehicles is highest in Fulton County (14.4%), motorcycles is highest in Cameron County (8.2%), and pedestrians and bicyclists is highest in Philadelphia County (12.8% and 3.5%, respectively). Figure 5 shows that the average fraction of passenger vehicle crashes is 0.68, and Monroe County has the largest fraction of passenger vehicle crashes. Note that the remaining fraction represents a combination of bicycle, pedestrian, commercial vehicle, motorcycle, bus, truck, horse buggy, or other non-motorist crashes. Also notice that even though Philadelphia County has the largest fraction of bicycle, commercial, motorcycle, and pedestrian crashes, it does not have the lowest fraction of passenger-vehicle-only crashes. This implies that the types of crashes not depicted in either Figure 4 or Figure 5, namely buses, trucks, horse buggies, or other non-motorists, is likely lower in Philadelphia County compared to some other counties.

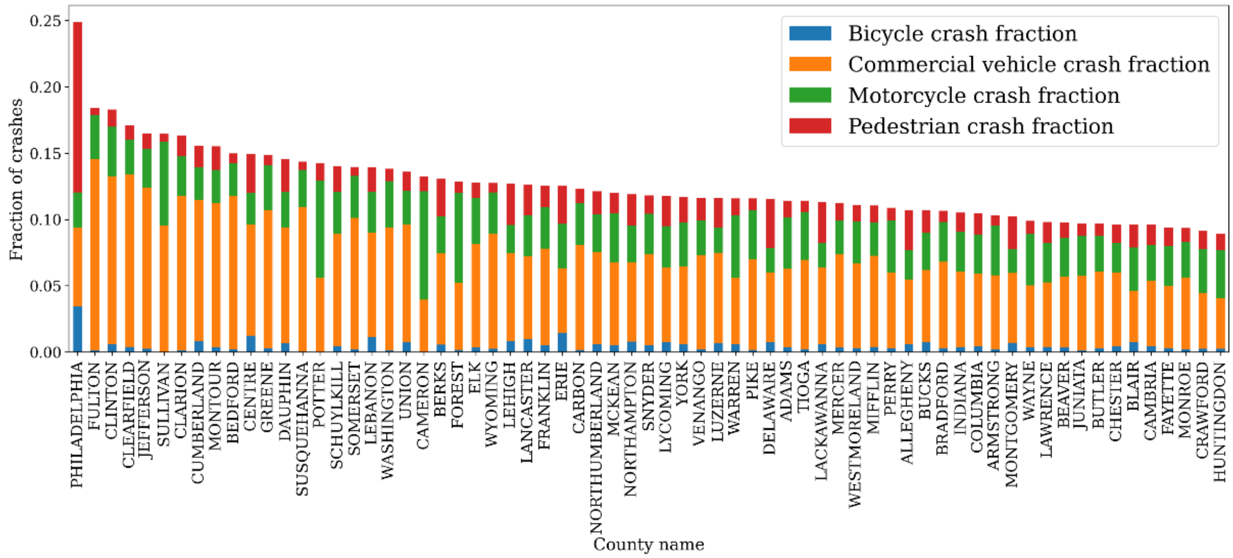

Figure 4 Fraction of crashes involving bicycles, commercial vehicles, motorcycles and pedestrians by county (2104-2021)

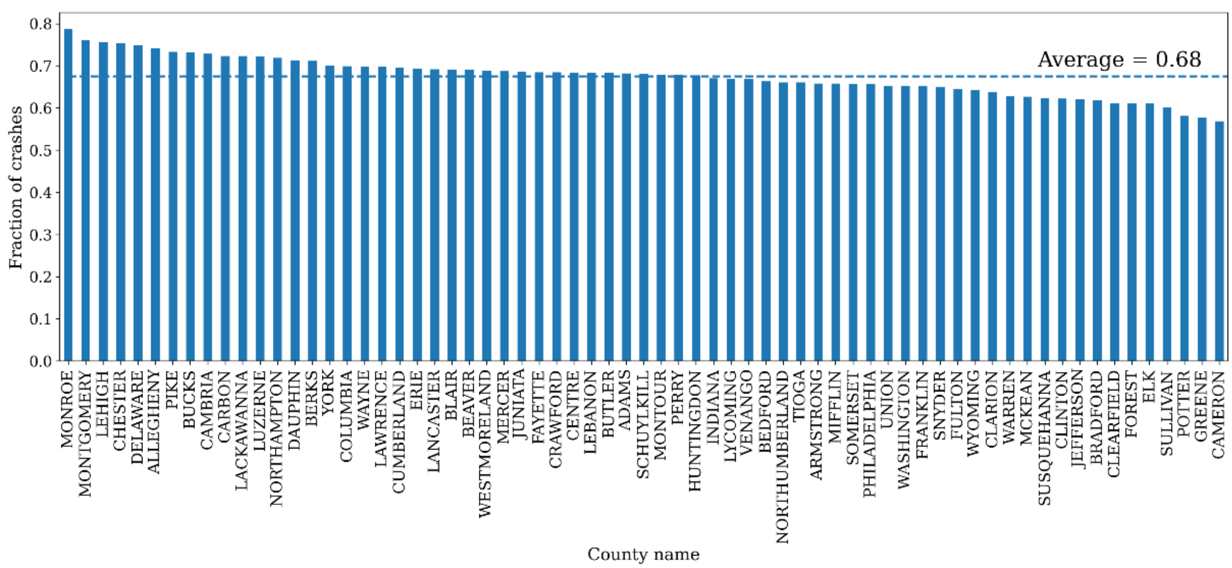

Figure 5 Fraction of crashes involving only passenger vehicles by county (2014-2021)

Table 2 shows the fraction of bicycle, commercial vehicles, motorcycles, pedestrian and passenger-vehicle-only crashes.

Table 2 Fraction of crashes that involve bicycles, commercial vehicles, motorcycles, pedestrians and only passenger vehicles by county (2014-2021)

	Fraction of				
County	Bicycle crashes	Commercial vehicle crashes	Motorcycle crashes	Pedestrian crashes	Only passenger vehicle crashes
ADAMS	0.00358	0.059	0.039	0.013	0.682
ALLEGHENY	0.00588	0.049	0.022	0.030	0.742
ARMSTRONG	0.00231	0.056	0.038	0.008	0.659
BEAVER	0.00354	0.054	0.029	0.012	0.691
BEDFORD	0.00214	0.115	0.025	0.008	0.664
BERKS	0.00576	0.069	0.028	0.028	0.712
BLAIR	0.00737	0.039	0.032	0.017	0.692
BRADFORD	0.00289	0.065	0.030	0.008	0.618
BUCKS	0.00728	0.055	0.028	0.017	0.732
BUTLER	0.00287	0.058	0.027	0.009	0.684
CAMBRIA	0.00451	0.049	0.027	0.015	0.729
CAMERON	0.00000	0.040	0.082	0.011	0.569
CARBON	0.00171	0.079	0.032	0.011	0.724
CENTRE	0.01250	0.084	0.024	0.029	0.684
CHESTER	0.00454	0.055	0.022	0.014	0.754
CLARION	0.00147	0.116	0.030	0.015	0.638
CLEARFIELD	0.00389	0.130	0.026	0.011	0.612
CLINTON	0.00629	0.126	0.037	0.013	0.622
COLUMBIA	0.00415	0.055	0.030	0.016	0.700
CRAWFORD	0.00250	0.042	0.033	0.014	0.685
CUMBERLAND	0.00858	0.106	0.025	0.016	0.697
DAUPHIN	0.00673	0.087	0.027	0.025	0.713
DELAWARE	0.00726	0.053	0.018	0.038	0.749
ELK	0.00347	0.078	0.035	0.011	0.611
ERIE	0.01457	0.049	0.033	0.028	0.694
FAYETTE	0.00304	0.047	0.030	0.014	0.686
FOREST	0.00174	0.051	0.068	0.008	0.611
FRANKLIN	0.00539	0.073	0.031	0.016	0.652
FULTON	0.00143	0.144	0.033	0.005	0.645
GREENE	0.00291	0.104	0.034	0.008	0.578
HUNTINGDON	0.00253	0.038	0.037	0.012	0.678
INDIANA	0.00385	0.057	0.030	0.014	0.671
JEFFERSON	0.00266	0.121	0.029	0.012	0.622
JUNIATA	0.00148	0.056	0.030	0.010	0.687
LACKAWANNA	0.00612	0.058	0.019	0.031	0.724
LANCASTER	0.00994	0.062	0.031	0.023	0.692
LAWRENCE	0.00401	0.049	0.030	0.016	0.698
LEBANON	0.01144	0.079	0.031	0.018	0.684
LEHIGH	0.00840	0.066	0.021	0.031	0.756

County	Fraction of Bicycle crashes	Commercial vehicle crashes	Motorcycle crashes	Pedestrian crashes	Only passenger vehicle crashes
LUZERNE	0.00674	0.068	0.019	0.022	0.723
LYCOMING	0.00739	0.056	0.031	0.023	0.669
MCKEAN	0.00541	0.063	0.037	0.015	0.627
MERCER	0.00352	0.070	0.026	0.013	0.688
MIFFLIN	0.00410	0.069	0.025	0.013	0.658
MONROE	0.00222	0.054	0.027	0.010	0.787
MONTGOMERY	0.00718	0.053	0.018	0.024	0.761
MONTOUR	0.00377	0.109	0.025	0.018	0.680
NORTHAMPTON	0.00803	0.060	0.028	0.023	0.719
NORTHUMBERLAND	0.00590	0.070	0.029	0.017	0.661
PERRY	0.00280	0.057	0.039	0.010	0.679
PHILADELPHIA	0.03461	0.059	0.026	0.128	0.657
PIKE	0.00182	0.068	0.037	0.009	0.733
POTTER	0.00000	0.056	0.073	0.013	0.581
SCHUYLKILL	0.00448	0.085	0.032	0.019	0.680
SNYDER	0.00502	0.069	0.030	0.014	0.651
SOMERSET	0.00228	0.099	0.032	0.007	0.658
SULLIVAN	0.00000	0.096	0.063	0.006	0.601
SUSQUEHANNA	0.00064	0.109	0.028	0.006	0.624
TIOGA	0.00191	0.068	0.036	0.008	0.661
UNION	0.00733	0.089	0.026	0.014	0.653
VENANGO	0.00214	0.071	0.026	0.017	0.669
WARREN	0.00608	0.050	0.047	0.013	0.629
WASHINGTON	0.00154	0.093	0.035	0.009	0.653
WAYNE	0.00384	0.047	0.039	0.010	0.698
WESTMORELAND	0.00293	0.064	0.032	0.012	0.689
WYOMING	0.00256	0.087	0.031	0.007	0.643
YORK	0.00607	0.059	0.033	0.019	0.701

NHTSA aggressive driving, speeding related, distracted driving and impaired driving

Between 2014 and 2021, 52,379 crashes per year out of the average 122,913 crashes per year observed in Pennsylvania (approximately 42%) involved at least one of the behavioral safety issues being considered: NHTSA aggressive driving, distracted driving, impaired driving, or speeding related. An average of 29,354 crashes had speeding related listed, 14,103 had distracted driving listed, 11,815 had impaired driving listed, and 6,776 had NHTSA aggressive driving listed as one of the behavioral safety issues. Note that some crashes may have one or more of these listed as an observed behavior. Out of all crashes that involved a NHTSA aggressive driving behavior, a distracted driver, an impaired driver or was speeding related, 57% had speeding related listed as a reason for the crash, 27% had distracted driving listed, 23% had impaired driving listed, and 13%

had NHTSA aggressive driving listed (note that because one crash can have multiple flagged behaviors, these percentages do not sum to one).

Figure 6 shows a Venn diagram of all the contributing factors to the crashes, considering total crashes of all severity levels across Pennsylvania and across all years considered (2014–2021, inclusive). An alternative to the Venn diagram, called an upset plot, is shown in Figure 7 and is used to convey the same information. In the upset plot, the rows on the bottom represent each of the four specific behavioral issues being illustrated. The various bars show the number of crashes associated with each of the behavior categories denoted by dots at the bottom of the plot. For example, the first bar denotes that there were an average of 22,073 crashes where speeding related was the only behavioral factor listed (out of the four considered) in Pennsylvania annually during this period. The last bar suggests that there are on average seven crashes that include NHTSA aggressive driving, impaired driving, and distracted driving. Looking at the upset plot, speeding related is the highest observed behavioral reason for crashes, followed by distracted driving. Impaired driving is the third highest behavioral reason, above the combination of NHTSA aggressive driving and speeding related. Note that the average number of crashes observed for a given behavioral safety issue can be determined by summing all the values where a black dot exists for that identified issue, and this value is designated by the horizontal bars on the bottom left-hand side of the figure.

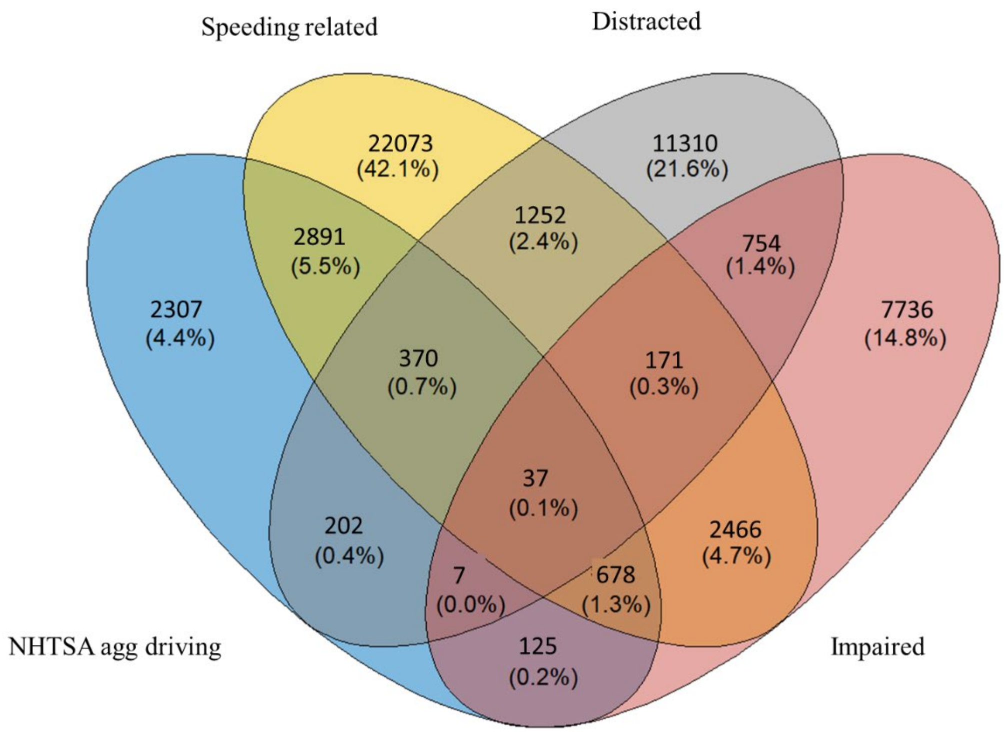

Figure 6 Venn diagram of average number of crashes that list NHTSA aggressive driving, speeding related, distracted driving, and impaired driving (2014-2021).

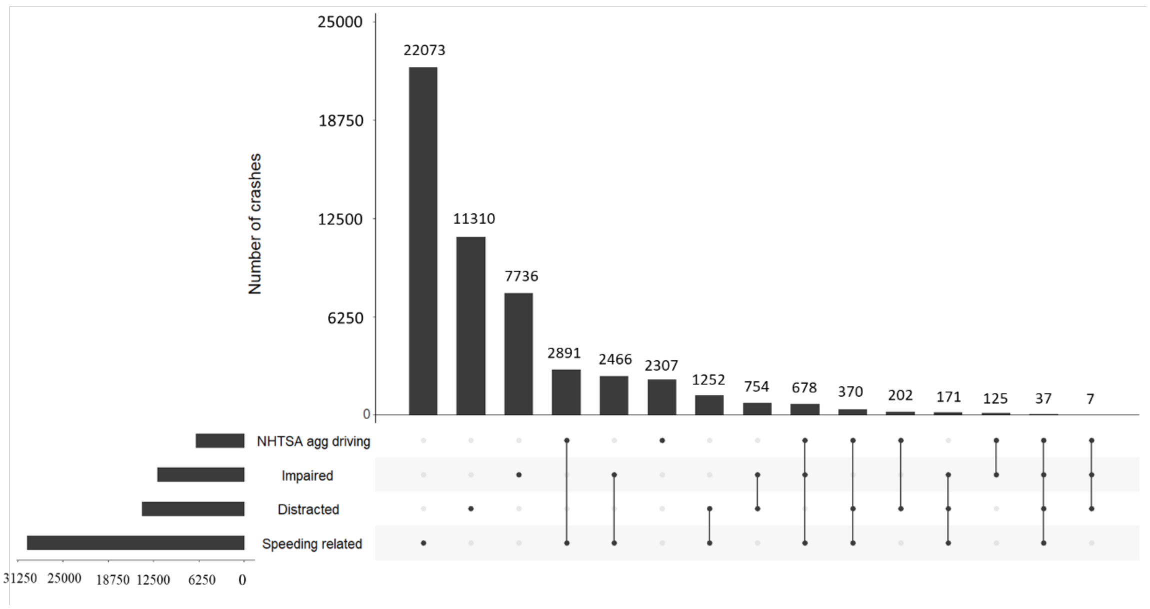

Figure 7 Upset diagram of average number of crashes that list NHTSA aggressive driving, speeding related, distracted driving, impaired driving and unbelted (2014-2021).

Figure 8 reveals that the general trend of speeding related being the top contributor to crashes holds true across individual counties.

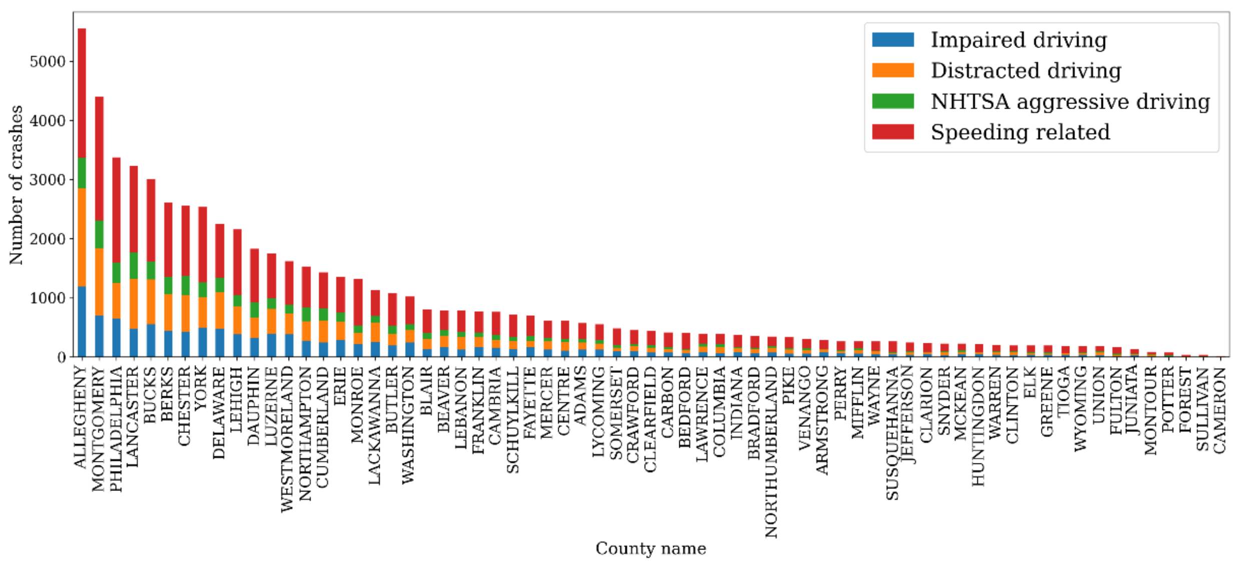

Figure 8 Average number of NHTSA aggressive driving, distracted driving, impaired driving or speeding related crashes per year by county (2014-2021)

Table 3 shows the number of crashes involving each of the four driving behaviors in Figure 8.

Table 3 Average number of crashes involving impaired driving, distracted driving, NHTSA aggressive driving and speeding related (2014-2021)

County	Impaired Driving	Distracted Driving	NHTSA Aggressive Driving	Speeding related
ADAMS	130	115	63	265
ALLEGHENY	1191	1659	515	2187
ARMSTRONG	85	42	15	151
BEAVER	174	182	97	333
BEDFORD	68	46	28	270
BERKS	441	624	291	1258
BLAIR	134	171	98	403
BRADFORD	71	69	20	199
BUCKS	559	753	303	1390
BUTLER	194	195	137	551
CAMBRIA	157	136	80	394
CAMERON	4	4	1	11
CARBON	75	68	29	248
CENTRE	107	144	53	308
CHESTER	422	622	329	1191
CLARION	42	33	18	141
CLEARFIELD	74	83	50	240
CLINTON	35	46	16	100
COLUMBIA	66	102	49	183
CRAWFORD	103	83	32	236
CUMBERLAND	246	370	213	603
DAUPHIN	325	338	258	913
DELAWARE	472	629	243	909
ELK	38	32	20	107
ERIE	285	309	157	599
FAYETTE	171	100	92	342
FOREST	8	4	3	28
FRANKLIN	164	173	81	353
FULTON	20	21	14	111
GREENE	37	22	15	122
HUNTINGDON	50	27	9	133
INDIANA	85	60	22	214
JEFFERSON	42	34	26	144
JUNIATA	30	18	7	78
LACKAWANNA	254	327	112	437
LANCASTER	482	834	457	1460
LAWRENCE	84	97	46	174
LEBANON	125	218	81	362
LEHIGH	383	479	188	1107
LUZERNE	400	415	180	753

County	Impaired Driving	Distracted Driving	NHTSA Aggressive Driving	Speeding related
LYCOMING	127	100	59	269
MCKEAN	48	41	25	113
MERCER	128	137	56	300
MIFFLIN	55	60	30	122
MONROE	225	187	126	784
MONTGOMERY	699	1137	473	2089
MONTOUR	16	26	8	41
NORTHAMPTON	280	330	228	696
NORTHUMBERLAND	76	81	33	158
PERRY	61	38	15	153
PHILADELPHIA	653	604	342	1780
PIKE	59	67	28	183
POTTER	15	7	5	48
SCHUYLKILL	138	137	66	375
SNYDER	33	47	23	124
SOMERSET	98	61	49	279
SULLIVAN	7	3	2	28
SUSQUEHANNA	44	27	18	175
TIOGA	39	24	8	121
UNION	31	47	15	90
VENANGO	57	67	25	156
WARREN	42	40	19	111
WASHINGTON	244	212	103	463
WAYNE	53	46	9	157
WESTMORELAND	389	351	145	737
WYOMING	39	26	14	112
YORK	492	520	252	1272

Figure 9 shows the trends in NHTSA aggressive driving, distracted driving, impaired driving and speeding related annually between 2014 and 2021. These proportions have remained fairly steady over the years, and speeding-related driving is the lead behavioral safety problem.

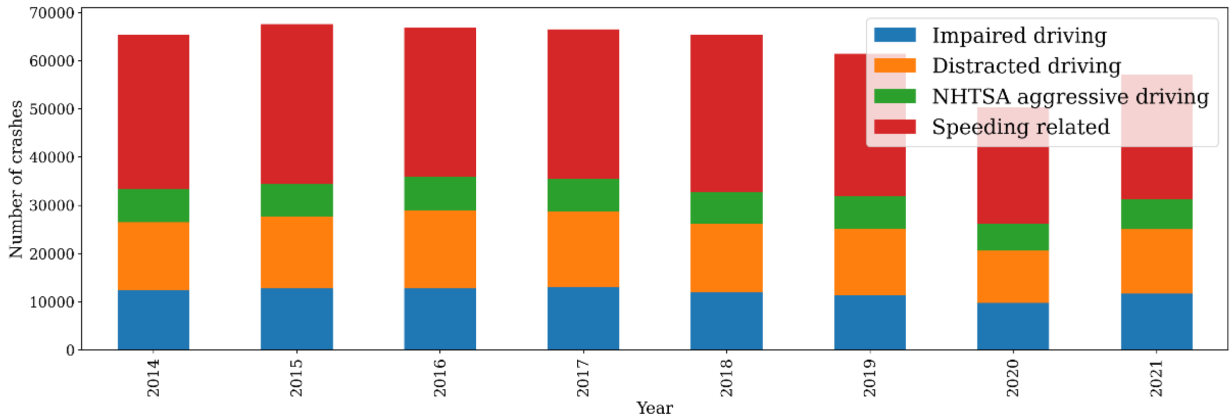

Figure 9 Number of NHTSA aggressive driving, distracted driving, impaired driving and speeding related crashes in each year (2014-2021)

Table 4 shows the total number of crashes involving impaired driving, distracted driving, NHTSA aggressive driving and speeding related over all counties in each year.

Table 4 Total number of crashes involving each driving behavior in each year (2014-2021)

Year	Impaired driving	Distracted driving	NHTSA aggressive driving	Speeding related
2014	12491	14024	6931	31998
2015	12779	14870	6799	33140
2016	12797	16093	7045	31015
2017	12977	15659	6882	31012
2018	11934	14212	6673	32634
2019	11317	13784	6757	29637
2020	9789	10829	5619	24178
2021	11702	13347	6223	25890

Figure 10 provides the rates of crashes involving NHTSA aggressive driving, distracted driving, impaired driving, or speeding related per VMT. In other words, the average number of NHTSA aggressive driving, distracted driving, impaired driving, or speeding-related crashes per year is divided by the average VMT per year for each county. Notice that the importance of different driving behaviors remains the same when comparing the total crashes that involve these behaviors to the total crashes that involve these behaviors per VMT. However, the magnitude of the problem becomes more evenly distributed across different counties. The results of this normalization remain consistent with the results obtained from the total crashes per VMT (i.e., the issues of NHTSA aggressive driving, distracted driving, impaired driving, or speeding related follow the general trends of crashes when considering VMT as the exposure metric).

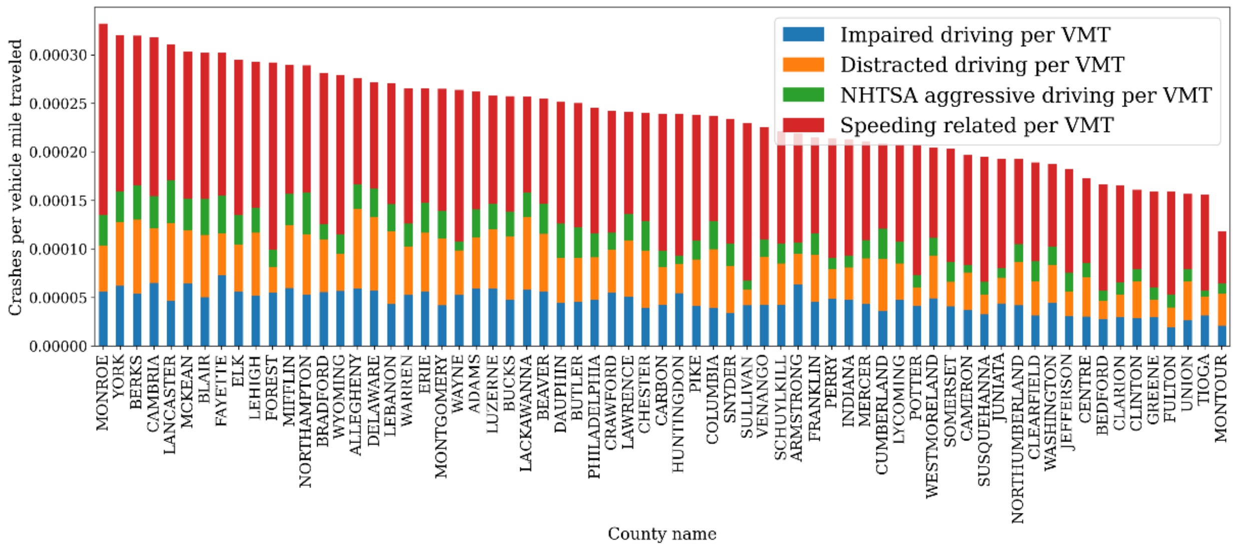

Figure 10 Average number of NHTSA aggressive driving, distracted driving, impaired driving or speeding related crashes per VMT by county (2014-2021)

Figure 11 provides crash rates involving NHTSA aggressive driving, distracted driving, impaired driving, or speeding related normalized by total population in each county (in a similar manner to the VMT normalization). Note that the conclusions related to the relative contribution of different driving behaviors do not change much with this normalization compared to VMT. However, the order of counties with these issues does change. For example, Monroe and York counties have the largest average number of crashes caused by different driving behaviors, while Fulton and Bedford counties have the largest average number of crashes per population caused by different driving behaviors.

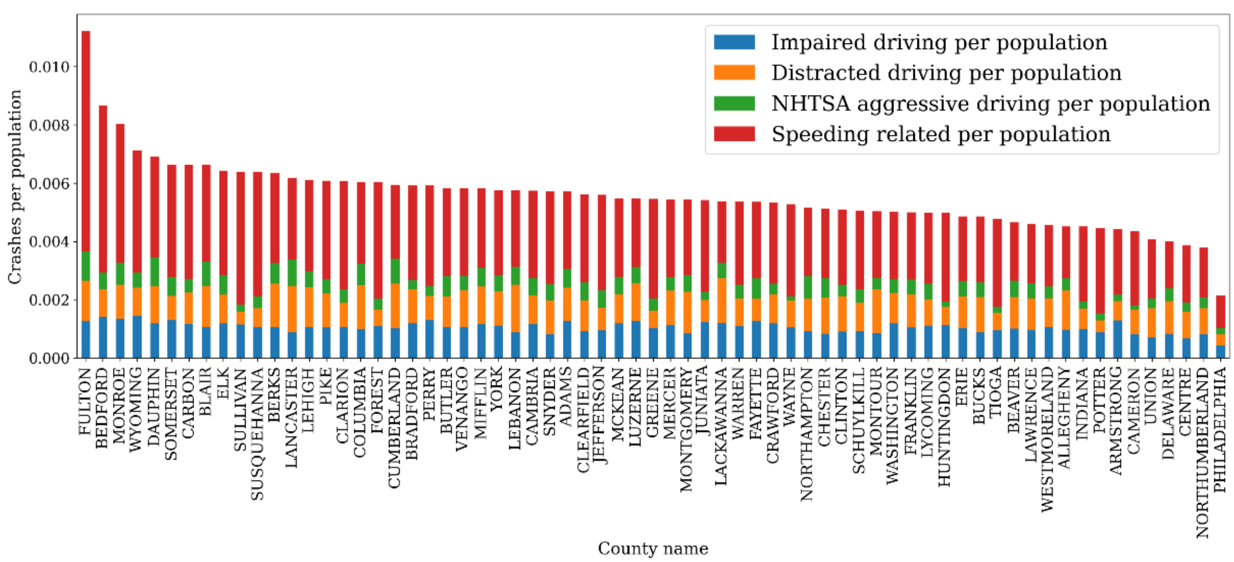

Figure 11 NHTSA aggressive driving, distracted driving, impaired driving or speeding related crashes per population by county (2014-2021)

Table 5 provides the normalized number of crashes involving impaired, distracted, NHTSA aggressive and speeding related driving behavior by VMT and population in each county.

Table 5 Normalized number of each type of crashes by VMT and population (2014-2021)

County	Normalized by VMT				Normalized by pop			
	Impaired	Distracted	NHTSA Aggressive	Speeding Related	Impaired	Distracted	NHTSA Aggressive	Speeding Related
ADAMS	0.0000595	0.0000527	0.0000288	0.000121	0.00127	0.00115	0.000633	0.00267
ALLEGHENY	0.0000592	0.0000823	0.0000255	0.000109	0.00097	0.00134	0.000417	0.00179
ARMSTRONG	0.0000637	0.0000314	0.0000114	0.000112	0.00129	0.00066	0.000218	0.00225
BEAVER	0.0000564	0.0000592	0.0000315	0.000108	0.00102	0.00108	0.000566	0.00200
BEDFORD	0.0000277	0.0000187	0.0000113	0.000109	0.00140	0.00095	0.000585	0.00574
BERKS	0.0000539	0.0000763	0.0000356	0.000154	0.00106	0.00149	0.000699	0.00309
BLAIR	0.0000503	0.0000642	0.0000370	0.000151	0.00108	0.00140	0.000835	0.00331
BRADFORD	0.0000556	0.0000542	0.0000159	0.000156	0.00121	0.00115	0.000329	0.00324
BUCKS	0.0000479	0.0000646	0.0000260	0.000119	0.00089	0.00121	0.000494	0.00226
BUTLER	0.0000453	0.0000453	0.0000317	0.000128	0.00106	0.00104	0.000709	0.00302
CAMBRIA	0.0000651	0.0000563	0.0000331	0.000164	0.00117	0.00098	0.000592	0.00300
CAMERON	0.0000376	0.0000378	0.0000078	0.000114	0.00081	0.00084	0.000153	0.00256
CARBON	0.0000427	0.0000386	0.0000165	0.000141	0.00117	0.00108	0.000471	0.00391
CENTRE	0.0000301	0.0000406	0.0000149	0.000087	0.00068	0.00092	0.000321	0.00196
CHESTER	0.0000395	0.0000583	0.0000309	0.000112	0.00083	0.00124	0.000672	0.00239
CLARION	0.0000299	0.0000231	0.0000125	0.000100	0.00107	0.00082	0.000458	0.00373
CLEARFIELD	0.0000315	0.0000350	0.0000210	0.000102	0.00093	0.00105	0.000612	0.00303
CLINTON	0.0000286	0.0000378	0.0000130	0.000082	0.00091	0.00121	0.000404	0.00259
COLUMBIA	0.0000394	0.0000604	0.0000289	0.000108	0.00100	0.00149	0.000751	0.00281
CRAWFORD	0.0000548	0.0000445	0.0000173	0.000126	0.00119	0.00099	0.000371	0.00279
CUMBERLAND	0.0000359	0.0000542	0.0000310	0.000088	0.00102	0.00154	0.000864	0.00252
DAUPHIN	0.0000446	0.0000463	0.0000354	0.000125	0.00119	0.00127	0.000995	0.00344
DELAWARE	0.0000570	0.0000758	0.0000292	0.000110	0.00083	0.00112	0.000435	0.00161
ELK	0.0000563	0.0000480	0.0000304	0.000160	0.00119	0.00098	0.000673	0.00358
ERIE	0.0000562	0.0000606	0.0000307	0.000118	0.00102	0.00109	0.000514	0.00224
FAYETTE	0.0000731	0.0000428	0.0000395	0.000147	0.00127	0.00075	0.000701	0.00263
FOREST	0.0000550	0.0000261	0.0000184	0.000193	0.00109	0.00056	0.000384	0.00400
FRANKLIN	0.0000457	0.0000482	0.0000225	0.000098	0.00104	0.00114	0.000507	0.00232
FULTON	0.0000193	0.0000203	0.0000135	0.000106	0.00128	0.00138	0.001010	0.00756
GREENE	0.0000297	0.0000181	0.0000123	0.000099	0.00103	0.00062	0.000398	0.00342
HUNTINGDON	0.0000543	0.0000297	0.0000093	0.000145	0.00113	0.00063	0.000188	0.00303
INDIANA	0.0000475	0.0000335	0.0000124	0.000120	0.00099	0.00070	0.000255	0.00257
JEFFERSON	0.0000308	0.0000253	0.0000193	0.000107	0.00095	0.00078	0.000596	0.00327
JUNIATA	0.0000438	0.0000263	0.0000100	0.000113	0.00122	0.00077	0.000284	0.00315
LACKAWANNA	0.0000578	0.0000747	0.0000254	0.000099	0.00121	0.00153	0.000543	0.00210
LANCASTER	0.0000464	0.0000804	0.0000440	0.000141	0.00090	0.00158	0.000909	0.00279
LAWRENCE	0.0000507	0.0000581	0.0000277	0.000105	0.00097	0.00109	0.000508	0.00203
LEBANON	0.0000432	0.0000750	0.0000279	0.000125	0.00090	0.00162	0.000614	0.00262

County	Normalized by VMT				Normalized by pop			
	Impaired	Distracted	NHTSA Aggressive	Speeding Related	Impaired	Distracted	NHTSA Aggressive	Speeding Related
LEHIGH	0.0000519	0.0000650	0.0000255	0.000150	0.00107	0.00137	0.000539	0.00314
LUZERNE	0.0000591	0.0000613	0.0000266	0.000111	0.00127	0.00131	0.000546	0.00237
LYCOMING	0.0000476	0.0000376	0.0000220	0.000100	0.00112	0.00089	0.000553	0.00242
MCKEAN	0.0000642	0.0000546	0.0000332	0.000151	0.00119	0.00100	0.000570	0.00273
MERCER	0.0000436	0.0000466	0.0000190	0.000102	0.00112	0.00118	0.000480	0.00267
MIFFLIN	0.0000598	0.0000645	0.0000324	0.000133	0.00117	0.00128	0.000649	0.00271
MONROE	0.0000565	0.0000470	0.0000318	0.000197	0.00135	0.00116	0.000753	0.00478
MONTGOMERY	0.0000421	0.0000686	0.0000285	0.000126	0.00086	0.00141	0.000584	0.00260
MONTOUR	0.0000209	0.0000333	0.0000100	0.000054	0.00084	0.00151	0.000398	0.00230
NORTHAMPTON	0.0000527	0.0000621	0.0000430	0.000131	0.00093	0.00110	0.000771	0.00237
NORTHUMBERLAND	0.0000418	0.0000450	0.0000182	0.000088	0.00081	0.00090	0.000354	0.00172
PERRY	0.0000488	0.0000301	0.0000123	0.000123	0.00132	0.00081	0.000345	0.00345
PHILADELPHIA	0.0000476	0.0000440	0.0000249	0.000129	0.00043	0.00039	0.000219	0.00112
PIKE	0.0000417	0.0000473	0.0000195	0.000129	0.00104	0.00117	0.000511	0.00337
POTTER	0.0000417	0.0000186	0.0000129	0.000134	0.00089	0.00041	0.000242	0.00293
SCHUYLKILL	0.0000427	0.0000423	0.0000204	0.000116	0.00093	0.00096	0.000471	0.00271
SNYDER	0.0000336	0.0000486	0.0000235	0.000128	0.00082	0.00116	0.000553	0.00320
SOMERSET	0.0000407	0.0000255	0.0000204	0.000117	0.00132	0.00082	0.000642	0.00387
SULLIVAN	0.0000420	0.0000159	0.0000096	0.000162	0.00115	0.00043	0.000254	0.00455
SUSQUEHANNA	0.0000327	0.0000202	0.0000131	0.000129	0.00108	0.00064	0.000404	0.00426
TIOGA	0.0000315	0.0000194	0.0000067	0.000099	0.00096	0.00059	0.000202	0.00303
UNION	0.0000263	0.0000401	0.0000131	0.000077	0.00070	0.00102	0.000320	0.00205
VENANGO	0.0000423	0.0000496	0.0000181	0.000116	0.00106	0.00127	0.000471	0.00301
WARREN	0.0000525	0.0000502	0.0000237	0.000140	0.00108	0.00096	0.000464	0.00286
WASHINGTON	0.0000447	0.0000388	0.0000187	0.000085	0.00119	0.00104	0.000492	0.00231
WAYNE	0.0000526	0.0000462	0.0000089	0.000156	0.00105	0.00092	0.000153	0.00316
WESTMORELAND	0.0000491	0.0000443	0.0000182	0.000093	0.00108	0.00097	0.000403	0.00211
WYOMING	0.0000568	0.0000381	0.0000203	0.000164	0.00144	0.00098	0.000516	0.00419
YORK	0.0000620	0.0000657	0.0000319	0.000161	0.00112	0.00118	0.000537	0.00293

Figure 12 through Figure 15 provide each considered type of behavioral issue associated with a crash as a rate normalized by the number of citations associated with that type of behavior. In other words, the number of impaired driving crashes is divided by the number of impaired driving arrests, the number of distracted driving crashes is divided by the number of distracted driving citations, the number of NHTSA aggressive driving crashes is divided by the number of NHTSA aggressive driving citations, and the number of speeding-related crashes is divided by the number of speeding citations. The rate of impaired driver crashes per citation was 0.25, the rate of distracted driving crashes per citation was 8, the rate of NHTSA aggressive driving crashes per citation was 0.0096, and the rate of speeding-related crashes per citation was 0.094. Notice that a number greater than 1 implies that the number of citations given for that type of behavioral issue is less than the number of times it leads to crashes. Comparing the magnitudes of the different types of behavioral issues normalized by their respective citation types shows that distracted driving has the least number of citations per crash compared to the other types of crashes as there are more crashes of this type compared to citations made for this type of behavior. While impaired driving has a rate of crashes per arrest less than 1, this value does increase up to 0.40 for Wayne County. Hence, in Wayne County there are two impaired driving crashes per five impaired driving arrests, which is above the average rate of one impaired driving crash per four impaired driving arrests for Pennsylvania.

The behavioral issue that received the most citations per crash was NHTSA aggressive driving. As previously mentioned (please see Data Collection section), section 3714 citations for careless driving are included in the set of citations for NHTSA aggressive driving. As discussed, this citation could be indicative of speeding related, NHTSA aggressive driving, and/or distracted driving violations. However, this citation only makes up approximately 10% of all citations within the NHTSA aggressive driving category. Hence, even without section 3714 citations being included in the NHTSA aggressive driving category, NHTSA aggressive driving would remain as the behavioral issue with the most citations per crash. On the other hand, if section 3714 citations were included as a distracted driving citation, distracted driving would remain as the behavioral issue with the least citations per crash, with an average number of crashes per citation of 0.6. In general, the counties that have the largest number of crashes per citation for different behavioral issues highly depends on the type of issue being considered.

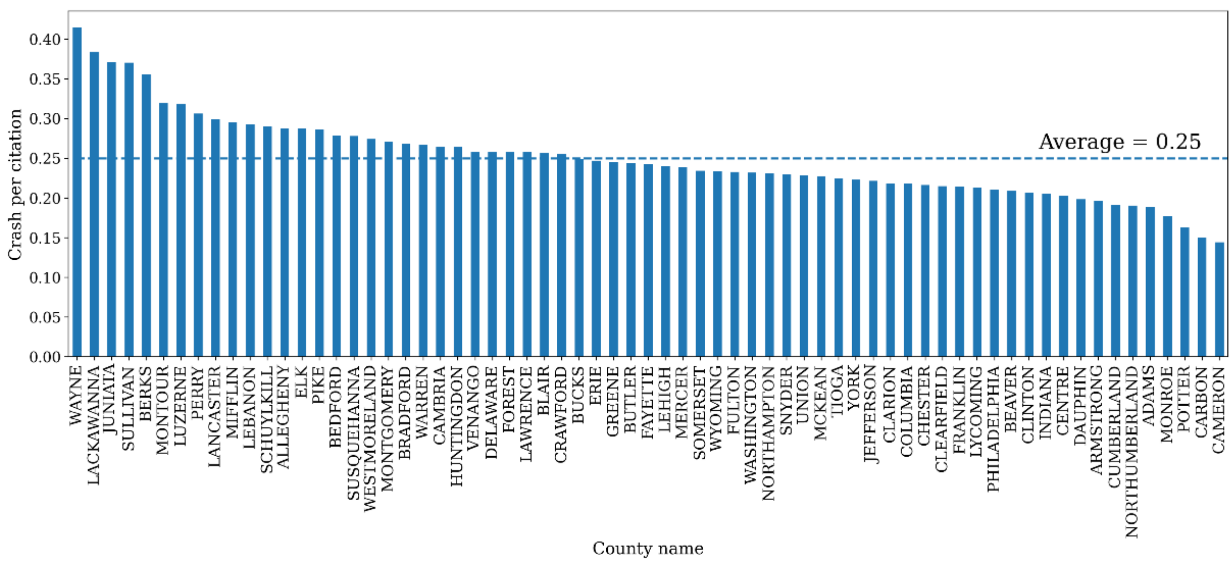

Figure 12 Average number of impaired driver crashes per impaired driver citations by county (2014-2021)

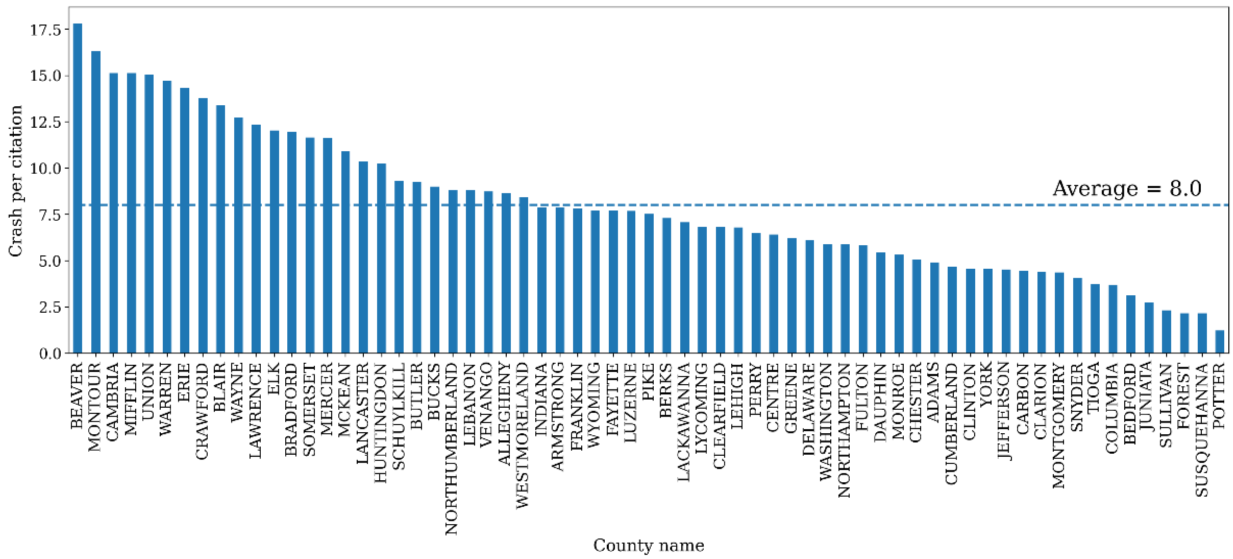

Figure 13 Average number of distracted driver crashes per distracted driver citations by county (2014-2021)

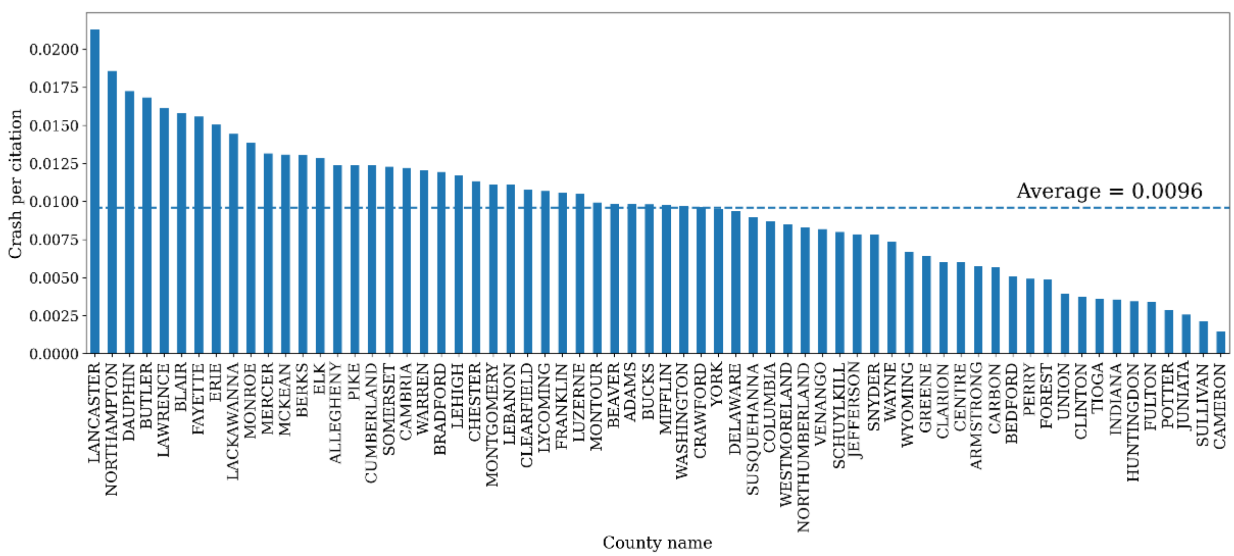

Figure 14 Average number of NHTSA aggressive driver crashes per aggressive driver citations by county (2014-2021)

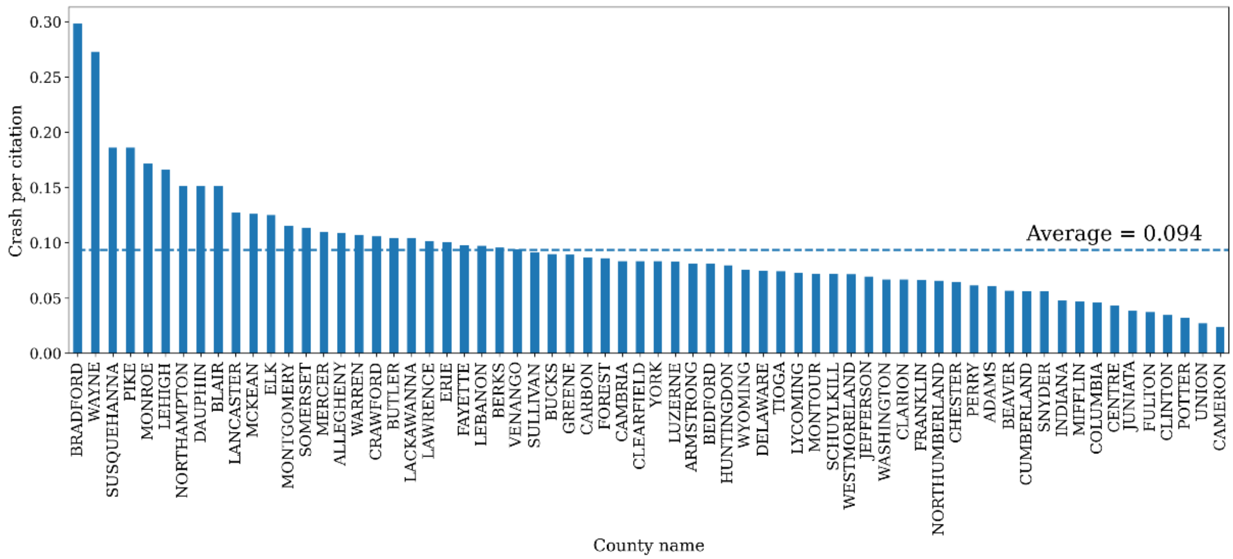

Figure 15 Average number of speeding related crashes per speeding citations by county (2014-2021)

Table 6 provides the average number of crashes involving impaired, distracted, NHTSA aggressive, and speeding-related driving using the number of citations or arrests in each county. Note that in Cameron County, one of the two citations used for distracted driving, Section 3314 – prohibiting the use of hearing impairment devices – was not available. Hence, distracted driving was not normalized by the number of citations in Cameron County due to the very small number of citations in Section 3316 – prohibiting text-based communications in Cameron County.

Table 6 Average number of impaired driving, distracted driving, NHTSA aggressive driving or speeding related crashes per citation or arrest (2014-2021)

County	Impaired Driving	Distracted Driving	NHTSA Aggressive Driving	Speeding Related
ADAMS	0.189	4.920	0.0098	0.061
ALLEGHENY	0.288	8.630	0.0124	0.109
ARMSTRONG	0.196	7.880	0.0057	0.082
BEAVER	0.209	17.800	0.0099	0.057
BEDFORD	0.279	3.140	0.0051	0.081
BERKS	0.356	7.310	0.0131	0.096
BLAIR	0.257	13.400	0.0158	0.152
BRADFORD	0.268	12.000	0.0119	0.298
BUCKS	0.250	9.000	0.0098	0.090
BUTLER	0.244	9.260	0.0168	0.104
CAMBRIA	0.265	15.100	0.0122	0.084
CAMERON	0.144		0.0015	0.024
CARBON	0.150	4.450	0.0057	0.087
CENTRE	0.203	6.410	0.0060	0.043
CHESTER	0.216	5.050	0.0113	0.065
CLARION	0.218	4.420	0.0060	0.067

County	Impaired Driving	Distracted Driving	NHTSA Aggressive Driving	Speeding Related
CLEARFIELD	0.215	6.830	0.0108	0.084
CLINTON	0.207	4.570	0.0037	0.035
COLUMBIA	0.218	3.700	0.0087	0.046
CRAWFORD	0.256	13.800	0.0096	0.106
CUMBERLAND	0.191	4.700	0.0124	0.056
DAUPHIN	0.199	5.460	0.0172	0.152
DELAWARE	0.258	6.110	0.0094	0.075
ELK	0.287	12.000	0.0129	0.125
ERIE	0.247	14.300	0.0151	0.100
FAYETTE	0.243	7.740	0.0156	0.098
FOREST	0.258	2.170	0.0049	0.086
FRANKLIN	0.214	7.800	0.0106	0.066
FULTON	0.233	5.820	0.0034	0.037
GREENE	0.246	6.210	0.0064	0.089
HUNTINGDON	0.264	10.200	0.0035	0.080
INDIANA	0.205	7.880	0.0036	0.048
JEFFERSON	0.222	4.540	0.0079	0.070
JUNIATA	0.371	2.750	0.0026	0.039
LACKAWANNA	0.384	7.090	0.0144	0.104
LANCASTER	0.299	10.400	0.0213	0.127
LAWRENCE	0.258	12.300	0.0161	0.102
LEBANON	0.293	8.800	0.0111	0.097
LEHIGH	0.240	6.790	0.0117	0.166
LUZERNE	0.319	7.690	0.0105	0.083
LYCOMING	0.213	6.840	0.0107	0.073
MCKEAN	0.228	10.900	0.0131	0.126
MERCER	0.239	11.600	0.0132	0.110
MIFFLIN	0.295	15.100	0.0098	0.047
MONROE	0.177	5.330	0.0138	0.172
MONTGOMERY	0.271	4.370	0.0111	0.116
MONTOUR	0.320	16.300	0.0099	0.072
NORTHAMPTON	0.232	5.880	0.0186	0.152
NORTHUMBERLAND	0.191	8.820	0.0083	0.066
PERRY	0.307	6.520	0.0049	0.062
PHILADELPHIA [3]	0.211			
PIKE	0.287	7.530	0.0124	0.186
POTTER	0.163	1.230	0.0029	0.032
SCHUYLKILL	0.290	9.320	0.0080	0.072
SNYDER	0.229	4.100	0.0078	0.056

[3] Please see Data Collection section on unavailability of distracted driving, NHTSA aggressive driving and speeding citations for Philadelphia.

County	Impaired Driving	Distracted Driving	NHTSA Aggressive Driving	Speeding Related
SOMERSET	0.235	11.700	0.0123	0.113
SULLIVAN	0.370	2.330	0.0022	0.092
SUSQUEHANNA	0.278	2.170	0.0090	0.186
TIOGA	0.225	3.730	0.0036	0.074
UNION	0.228	15.100	0.0040	0.027
VENANGO	0.258	8.730	0.0082	0.094
WARREN	0.267	14.700	0.0121	0.107
WASHINGTON	0.232	5.900	0.0097	0.067
WAYNE	0.415	12.800	0.0074	0.273
WESTMORELAND	0.274	8.420	0.0085	0.072
WYOMING	0.234	7.740	0.0067	0.076
YORK	0.223	4.560	0.0095	0.084

Bicycle safety

Figure 16 provides the average number of crashes involving bicycles per county. The average number of bicycle crashes across all counties per year was 16, and 15 counties were above this average. However, it can be seen that Philadelphia County has by far the largest number of crashes involving bicycles, followed by Allegheny County. Many counties have on average less than 25 crashes per year involving bicycles.

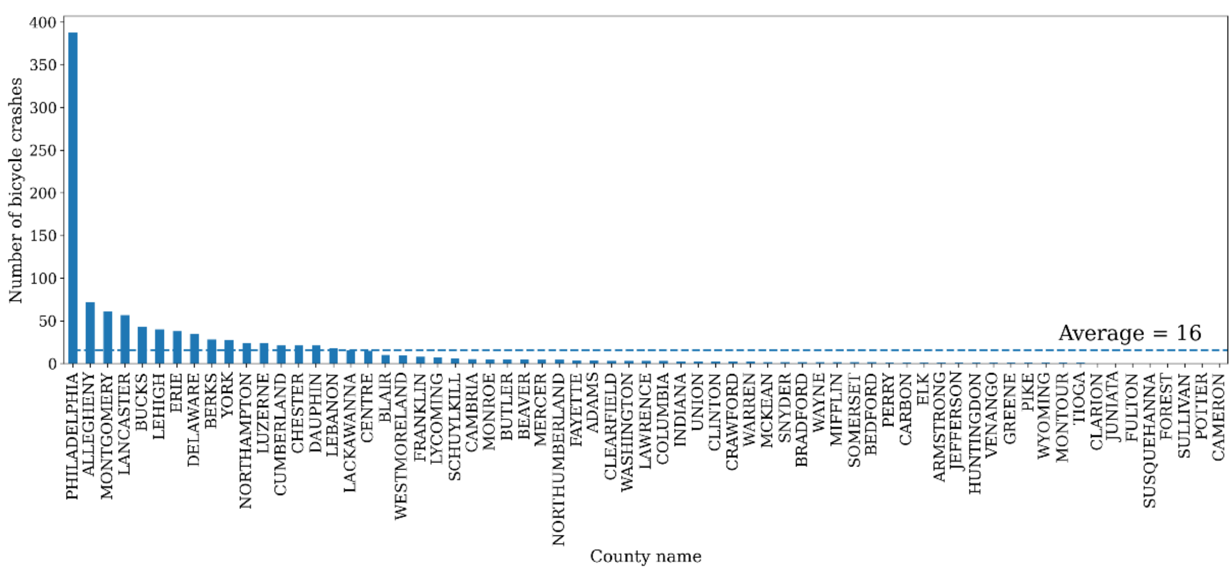

Figure 16 Average number of bicycle crashes per year by county (2014-2021)

The average annual number of bicyclist fatalities and serious injuries from crashes are shown in Figure 17. Philadelphia County is observed to have the largest average number of crashes per year that involve a bicyclist fatality or serious injury.

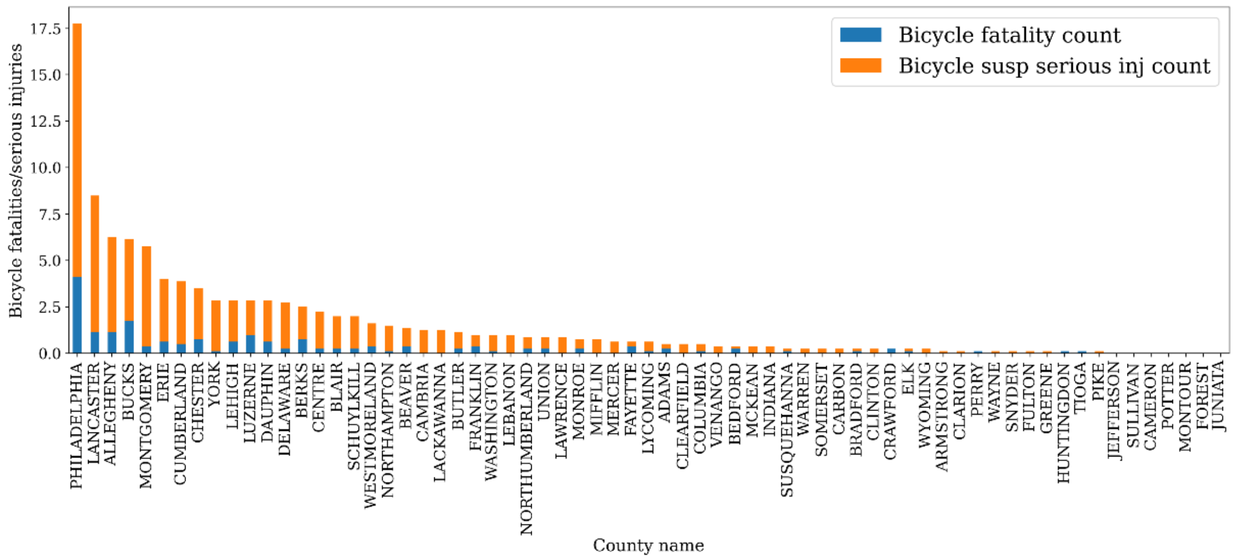

Figure 17 Average number of bicycle fatalities and serious injuries per year by county (2014-2021)

Table 7 provides the average number of bicycle crashes, fatalities, and suspicious serious injuries in each county.

Table 7 Average number of bicycle crashes, fatalities and suspicious serious injuries in each county (2014-2021)

County name	Bicycle crashes	Bicycle fatalities	Bicycle suspected serious injuries
ADAMS	3.50	0.25	0.25
ALLEGHENY	72.13	1.13	5.13
ARMSTRONG	1.13	0.00	0.13
BEAVER	4.75	0.38	1.00
BEDFORD	1.63	0.25	0.13
BERKS	28.25	0.75	1.75
BLAIR	10.38	0.25	1.75
BRADFORD	1.75	0.13	0.13
BUCKS	43.00	1.75	4.38
BUTLER	5.13	0.25	0.88
CAMBRIA	5.38	0.00	1.25
CAMERON	0.00	0.00	0.00
CARBON	1.25	0.00	0.25
CENTRE	14.88	0.25	2.00
CHESTER	21.13	0.75	2.75
CLARION	0.63	0.00	0.13
CLEARFIELD	3.13	0.00	0.50
CLINTON	2.63	0.00	0.25
COLUMBIA	3.00	0.13	0.38
CRAWFORD	2.25	0.25	0.00
CUMBERLAND	21.38	0.50	3.38

County name	Bicycle crashes	Bicycle fatalities	Bicycle suspected serious injuries
DAUPHIN	21.13	0.63	2.25
DELAWARE	34.88	0.25	2.50
ELK	1.13	0.13	0.13
ERIE	38.13	0.63	3.38
FAYETTE	3.63	0.38	0.25
FOREST	0.13	0.00	0.00
FRANKLIN	8.00	0.38	0.63
FULTON	0.38	0.00	0.13
GREENE	1.00	0.00	0.13
HUNTINGDON	1.13	0.13	0.00
INDIANA	2.75	0.00	0.38
JEFFERSON	1.13	0.00	0.00
JUNIATA	0.38	0.00	0.00
LACKAWANNA	15.50	0.00	1.25
LANCASTER	56.75	1.13	7.38
LAWRENCE	3.00	0.00	0.88
LEBANON	17.50	0.00	1.00
LEHIGH	40.25	0.63	2.25
LUZERNE	23.75	1.00	1.88
LYCOMING	7.63	0.13	0.50
MCKEAN	1.88	0.00	0.38
MERCER	4.25	0.00	0.63
MIFFLIN	1.75	0.00	0.75
MONROE	5.13	0.25	0.50
MONTGOMERY	61.13	0.38	5.38
MONTOUR	0.75	0.00	0.00
NORTHAMPTON	24.13	0.13	1.38
NORTHUMBERLAND	4.25	0.25	0.63
PERRY	1.25	0.13	0.00
PHILADELPHIA	387.63	4.13	13.63
PIKE	1.00	0.00	0.13
POTTER	0.00	0.00	0.00
SCHUYLKILL	6.00	0.25	1.75
SNYDER	1.88	0.00	0.13
SOMERSET	1.63	0.00	0.25
SULLIVAN	0.00	0.00	0.00
SUSQUEHANNA	0.25	0.13	0.13
TIOGA	0.75	0.13	0.00
UNION	2.63	0.25	0.63
VENANGO	1.13	0.00	0.38
WARREN	2.13	0.00	0.25
WASHINGTON	3.00	0.13	0.88

County name	Bicycle crashes	Bicycle fatalities	Bicycle suspected serious injuries
WAYNE	1.75	0.00	0.13
WESTMORELAND	9.50	0.38	1.25
WYOMING	0.75	0.00	0.25
YORK	27.63	0.13	2.75

Figure 18 through Figure 21 provide average rates of crashes involving bicycles (both total and those with fatalities or serious injuries) normalized using the total population and population density. When considering population, Philadelphia County has the largest number of bicycle crashes per population despite its large population. However, when considering population density, Erie and Lancaster counties have the largest average number of bicycle crashes per population density. Lancaster County consistently appears in the top three counties when considering bicyclist fatalities and serious injuries, regardless of normalization.

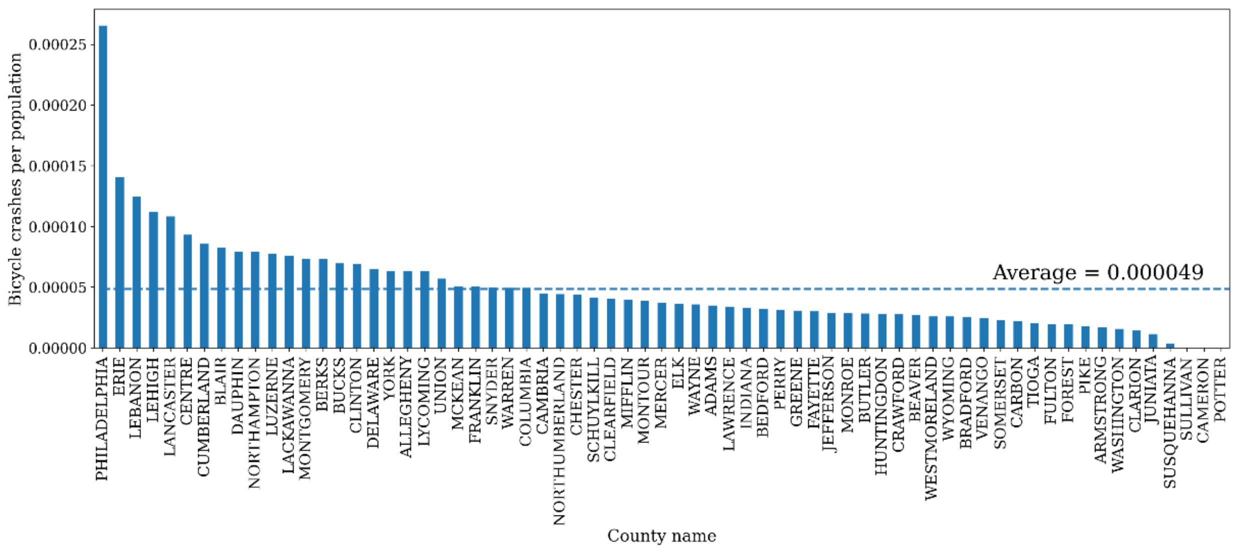

Figure 18 Average number of bicycle crashes per population per year by county (2014-2021)

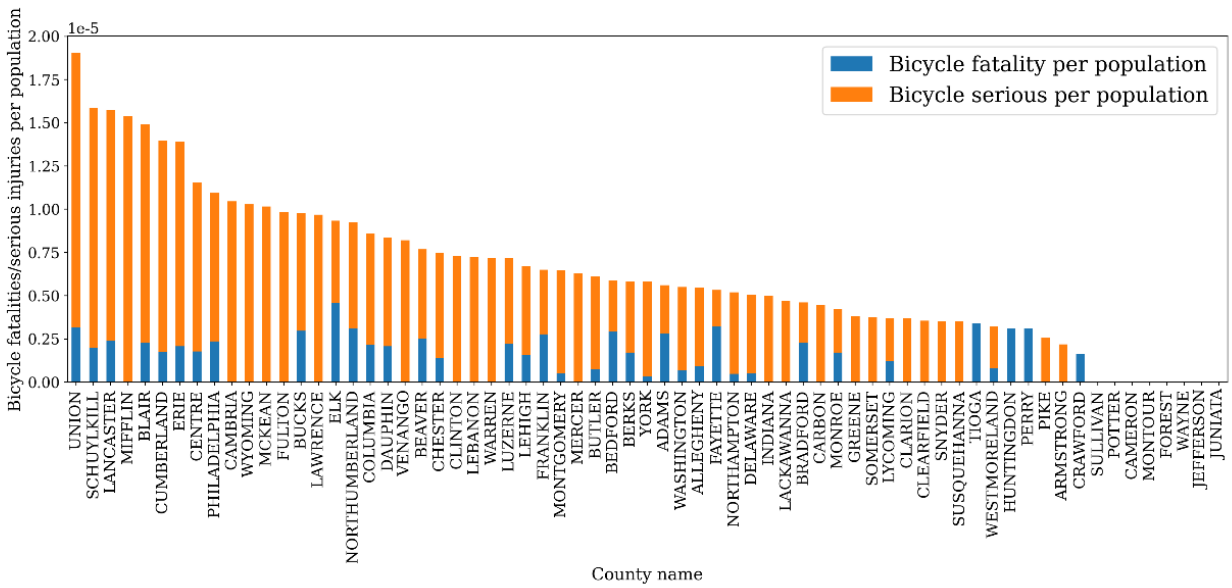

Figure 19 Average number of bicycle fatalities and serious injuries per population per year by county (2014-2021)

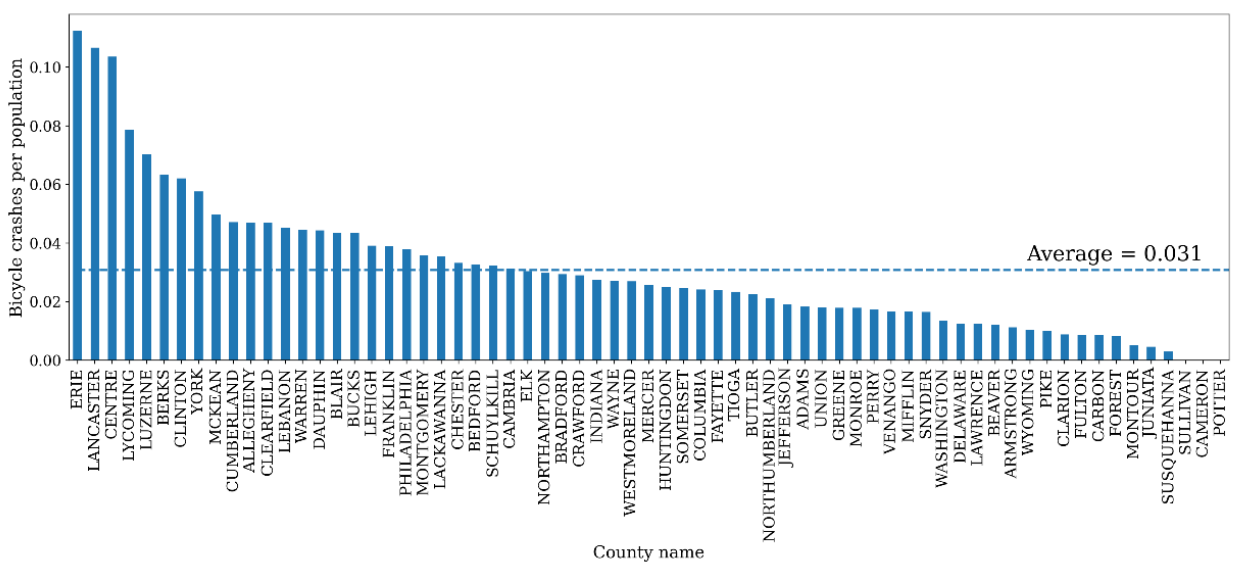

Figure 20 Average number of bicycle crashes per population density per year by county (2014-2021)

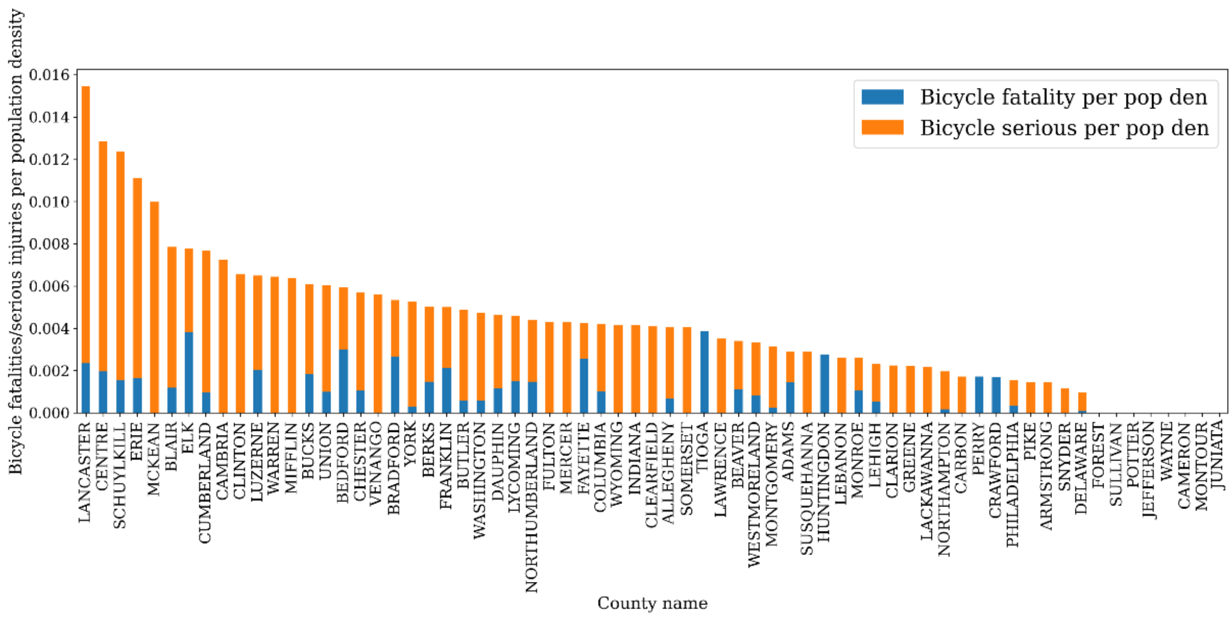

Figure 21 Average number of bicycle fatalities and serious injuries per population density per year by county (2014-2021)

Table 8 provides the normalized number of bicycle crashes, fatalities, and serious injuries in each county by using population and population density, respectively.

Table 8 Average number of bicycle crashes, fatalities and serious injuries in each county normalized by population and population density (2014-2021)

County	Average bicycle crashes per population			Average bicycle crashes per population density		
	All	Fatality	Serious	All	Fatality	Serious
ADAMS	0.0000350	0.00000281	0.00000280	0.0183	0.00147	0.00146
ALLEGHENY	0.0000632	0.00000093	0.00000454	0.0471	0.00069	0.00338
ARMSTRONG	0.0000170	0.00000000	0.00000219	0.0113	0.00000	0.00145
BEAVER	0.0000272	0.00000253	0.00000515	0.0121	0.00112	0.00229
BEDFORD	0.0000322	0.00000296	0.00000292	0.0326	0.00300	0.00297
BERKS	0.0000732	0.00000171	0.00000413	0.0634	0.00148	0.00357
BLAIR	0.0000824	0.00000227	0.00001265	0.0434	0.00120	0.00667
BRADFORD	0.0000253	0.00000229	0.00000232	0.0294	0.00265	0.00269
BUCKS	0.0000698	0.00000296	0.00000684	0.0434	0.00184	0.00425
BUTLER	0.0000284	0.00000077	0.00000536	0.0226	0.00061	0.00426
CAMBRIA	0.0000451	0.00000000	0.00001047	0.0313	0.00000	0.00726
CAMERON	0.0000000	0.00000000	0.00000000	0.0000	0.00000	0.00000
CARBON	0.0000222	0.00000000	0.00000446	0.0086	0.00000	0.00172
CENTRE	0.0000932	0.00000177	0.00000979	0.1037	0.00197	0.01088
CHESTER	0.0000436	0.00000139	0.00000611	0.0332	0.00106	0.00464
CLARION	0.0000146	0.00000000	0.00000369	0.0089	0.00000	0.00225
CLEARFIELD	0.0000407	0.00000000	0.00000355	0.0469	0.00000	0.00410
CLINTON	0.0000691	0.00000000	0.00000730	0.0621	0.00000	0.00656

County	Average bicycle crashes per population			Average bicycle crashes per population density		
	All	Fatality	Serious	All	Fatality	Serious
COLUMBIA	0.0000494	0.00000214	0.00000645	0.0242	0.00105	0.00316
CRAWFORD	0.0000280	0.00000164	0.00000000	0.0290	0.00171	0.00000
CUMBERLAND	0.0000857	0.00000177	0.00001220	0.0472	0.00097	0.00672
DAUPHIN	0.0000795	0.00000209	0.00000627	0.0444	0.00116	0.00350
DELAWARE	0.0000652	0.00000051	0.00000457	0.0125	0.00010	0.00087
ELK	0.0000366	0.00000459	0.00000475	0.0305	0.00382	0.00395
ERIE	0.0001407	0.00000208	0.00001186	0.1124	0.00166	0.00947
FAYETTE	0.0000301	0.00000321	0.00000211	0.0240	0.00256	0.00169
FOREST	0.0000194	0.00000000	0.00000000	0.0084	0.00000	0.00000
FRANKLIN	0.0000505	0.00000278	0.00000373	0.0389	0.00215	0.00287
FULTON	0.0000197	0.00000000	0.00000986	0.0086	0.00000	0.00432
GREENE	0.0000309	0.00000000	0.00000383	0.0179	0.00000	0.00221
HUNTINGDON	0.0000281	0.00000313	0.00000000	0.0250	0.00278	0.00000
INDIANA	0.0000329	0.00000000	0.00000497	0.0274	0.00000	0.00415
JEFFERSON	0.0000289	0.00000000	0.00000000	0.0190	0.00000	0.00000
JUNIATA	0.0000116	0.00000000	0.00000000	0.0046	0.00000	0.00000
LACKAWANNA	0.0000760	0.00000000	0.00000470	0.0354	0.00000	0.00219
LANCASTER	0.0001084	0.00000240	0.00001332	0.1067	0.00236	0.01311
LAWRENCE	0.0000342	0.00000000	0.00000968	0.0124	0.00000	0.00351
LEBANON	0.0001247	0.00000000	0.00000724	0.0453	0.00000	0.00263
LEHIGH	0.0001121	0.00000158	0.00000512	0.0391	0.00055	0.00179
LUZERNE	0.0000775	0.00000224	0.00000494	0.0703	0.00204	0.00448
LYCOMING	0.0000631	0.00000122	0.00000248	0.0785	0.00152	0.00309
MCKEAN	0.0000506	0.00000000	0.00001015	0.0498	0.00000	0.00999
MERCER	0.0000376	0.00000000	0.00000628	0.0256	0.00000	0.00429
MIFFLIN	0.0000399	0.00000000	0.00001540	0.0166	0.00000	0.00639
MONROE	0.0000289	0.00000170	0.00000255	0.0179	0.00105	0.00157
MONTGOMERY	0.0000735	0.00000052	0.00000593	0.0358	0.00026	0.00289
MONTOUR	0.0000390	0.00000000	0.00000000	0.0051	0.00000	0.00000
NORTHAMPTON	0.0000792	0.00000047	0.00000473	0.0298	0.00018	0.00178
NORTHUMBERLAND	0.0000444	0.00000309	0.00000615	0.0212	0.00148	0.00293
PERRY	0.0000311	0.00000310	0.00000000	0.0173	0.00172	0.00000
PHILADELPHIA	0.0002655	0.00000237	0.00000857	0.0380	0.00034	0.00123
PIKE	0.0000179	0.00000000	0.00000257	0.0101	0.00000	0.00146
POTTER	0.0000000	0.00000000	0.00000000	0.0000	0.00000	0.00000
SCHUYLKILL	0.0000415	0.00000199	0.00001390	0.0323	0.00154	0.01081
SNYDER	0.0000497	0.00000000	0.00000353	0.0165	0.00000	0.00117
SOMERSET	0.0000228	0.00000000	0.00000376	0.0247	0.00000	0.00407
SULLIVAN	0.0000000	0.00000000	0.00000000	0.0000	0.00000	0.00000
SUSQUEHANNA	0.0000035	0.00000000	0.00000352	0.0029	0.00000	0.00293
TIOGA	0.0000206	0.00000340	0.00000000	0.0234	0.00386	0.00000

County	Average bicycle crashes per population			Average bicycle crashes per population density		
	All	Fatality	Serious	All	Fatality	Serious
UNION	0.0000572	0.00000318	0.00001588	0.0181	0.00101	0.00504
VENANGO	0.0000244	0.00000000	0.00000821	0.0167	0.00000	0.00561
WARREN	0.0000496	0.00000000	0.00000719	0.0445	0.00000	0.00645
WASHINGTON	0.0000158	0.00000069	0.00000481	0.0136	0.00059	0.00415
WAYNE	0.0000361	0.00000000	0.00000000	0.0271	0.00000	0.00000
WESTMORELAND	0.0000261	0.00000080	0.00000243	0.0270	0.00083	0.00251
WYOMING	0.0000259	0.00000000	0.00001029	0.0105	0.00000	0.00417
YORK	0.0000633	0.00000032	0.00000549	0.0576	0.00029	0.00499

Figure 22 and Figure 23 provide average rates of crashes involving bicycles (both total and those with fatalities or serious injuries) normalized by the percentage of bicycle trips. Montgomery County has the largest number of bicycle crashes or bicycle fatalities and serious injuries per bicycle trip percentage, followed by York and Philadelphia Counties.

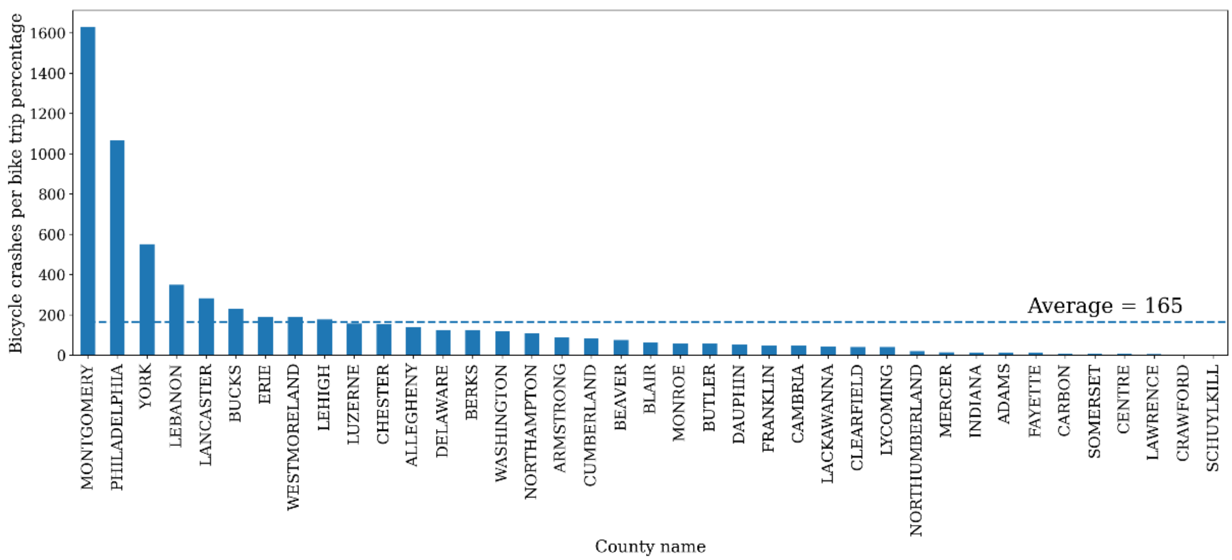

Figure 22 Average number of bicycle crashes per bicycle trip percentage by county (2014-2021)

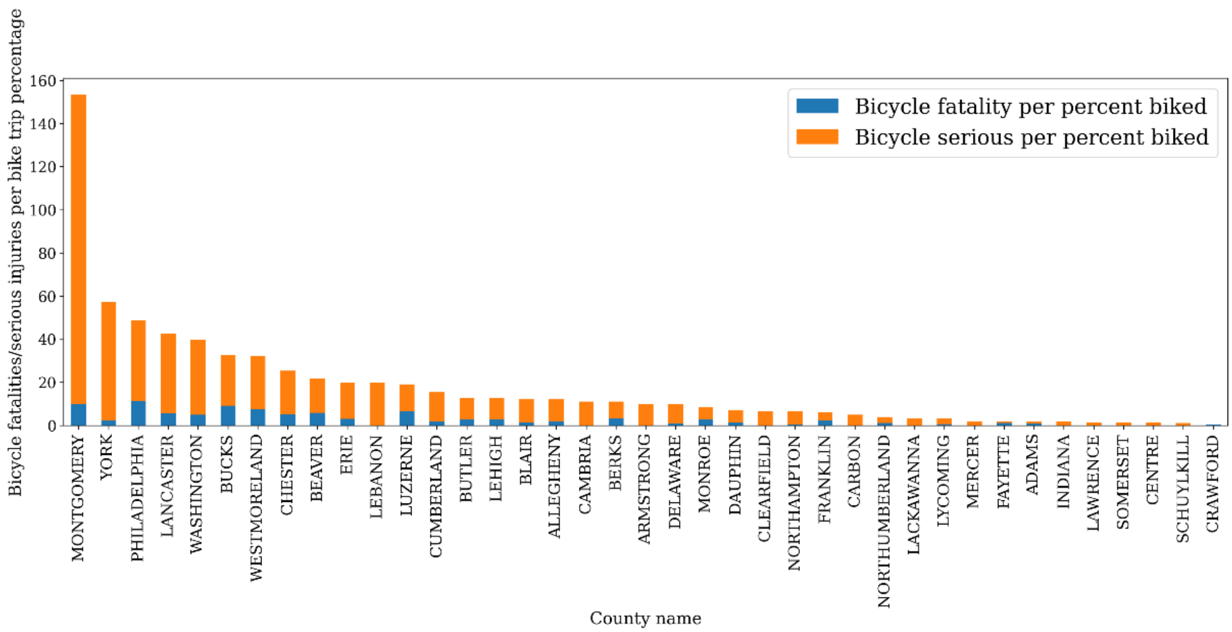

Figure 23 Average number of bicycle fatalities and serious injuries per bicycle trip percentage by county (2014-2021)

Table 9 provides the average number of bicycle crashes, fatalities, and serious injuries normalized by the percentage of bicycle trips, respectively. Notice that the percentage of bicycle trips was only available for a subset of counties in the ACS.

Table 9 Average number of bicycle crashes per bicycle trip percentage (2014-2021)

County	Per bicycle trip percentage		
	Crashes	Fatalities	Serious injuries
ADAMS	13.330	0.950	0.950
ALLEGHENY	140.730	2.200	10.000
ARMSTRONG	90.000	0.000	10.000
BEAVER	76.000	6.000	16.000
BEDFORD			
BERKS	125.560	3.330	7.780
BLAIR	63.850	1.540	10.770
BRADFORD			
BUCKS	229.330	9.330	23.330
BUTLER	58.570	2.860	10.000
CAMBRIA	47.780	0.000	11.110
CAMERON			
CARBON	12.500	0.000	2.500
CENTRE	9.080	0.150	1.220
CHESTER	153.640	5.450	20.000
CLARION			
CLEARFIELD	41.670	0.000	6.670
CLINTON			

County	Per bicycle trip percentage		
	Crashes	Fatalities	Serious injuries
COLUMBIA			
CRAWFORD	4.500	0.500	0.000
CUMBERLAND	85.500	2.000	13.500
DAUPHIN	52.810	1.560	5.630
DELAWARE	126.820	0.910	9.090
ELK			
ERIE	190.630	3.130	16.880
FAYETTE	12.080	1.250	0.830
FOREST			
FRANKLIN	49.230	2.310	3.850
FULTON			
GREENE			
HUNTINGDON			
INDIANA	13.750	0.000	1.880
JEFFERSON			
JUNIATA			
LACKAWANNA	44.290	0.000	3.570
LANCASTER	283.750	5.630	36.880
LAWRENCE	5.110	0.000	1.490
LEBANON	350.000	0.000	20.000
LEHIGH	178.890	2.780	10.000
LUZERNE	158.330	6.670	12.500
LYCOMING	40.670	0.670	2.670
MCKEAN			
MERCER	14.170	0.000	2.080
MIFFLIN			
MONROE	58.570	2.860	5.710
MONTGOMERY	1630.000	10.000	143.330
MONTOUR			
NORTHAMPTON	107.220	0.560	6.110
NORTHUMBERLAND	20.000	1.180	2.940
PERRY			
PHILADELPHIA	1069.310	11.380	37.590
PIKE			
POTTER			
SCHUYLKILL	3.720	0.160	1.090
SNYDER			
SOMERSET	9.290	0.000	1.430
SULLIVAN			
SUSQUEHANNA			
TIOGA			
UNION			

County	Per bicycle trip percentage		
	Crashes	Fatalities	Serious injuries
VENANGO			
WARREN			
WASHINGTON	120.000	5.000	35.000
WAYNE			
WESTMORELAND	190.000	7.500	25.000
WYOMING			
YORK	552.500	2.500	55.000

Pedestrian safety

The average number of crashes per year between 2014 and 2021 that involve pedestrians is shown in Figure 24. The average number of pedestrian crashes per year was 60, with 14 counties above this average. As can be seen, Philadelphia County has a disproportionally high level of crashes that involve pedestrians, similar to the observation related to bicycle crashes.

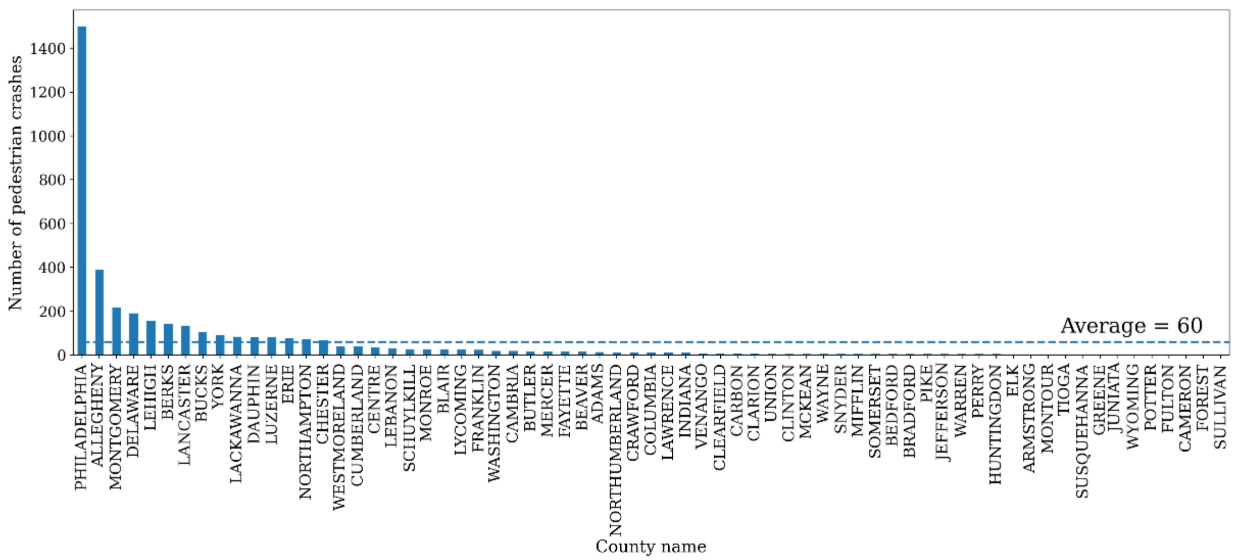

Figure 24 Average number of crashes involving pedestrians per year by county (2014-2021)

Philadelphia County also has the largest average number of pedestrian crashes when normalized by the total population or the percentage of walking trips, see Figure 25 and Figure 27. However, Berks and Centre counties have the largest average number of pedestrian crashes per total population density, see Figure 26.

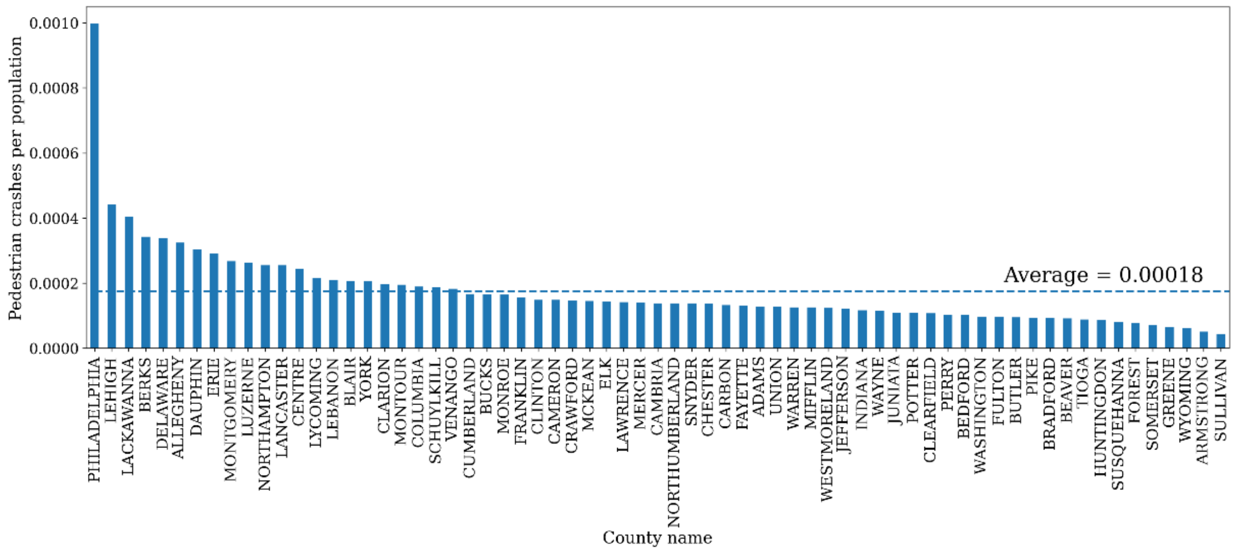

Figure 25 Average nmber of crashes involving pedestrians per population per year by county (2014-2021)

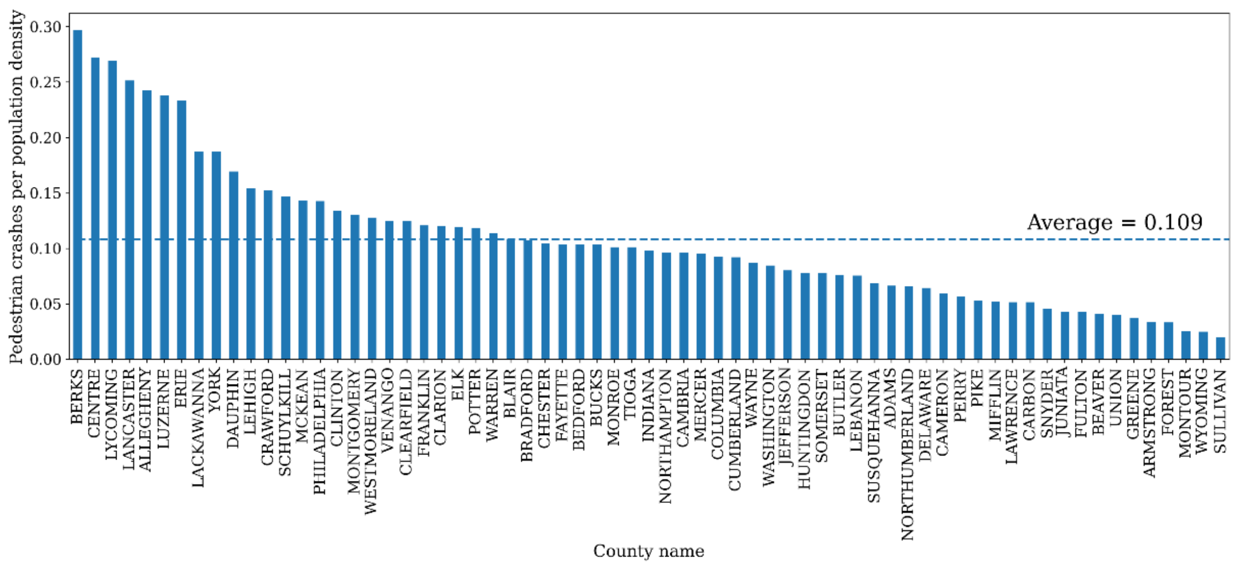

Figure 26 Average number of crashes involving pedestrians per population density per year by county (2014-2021)

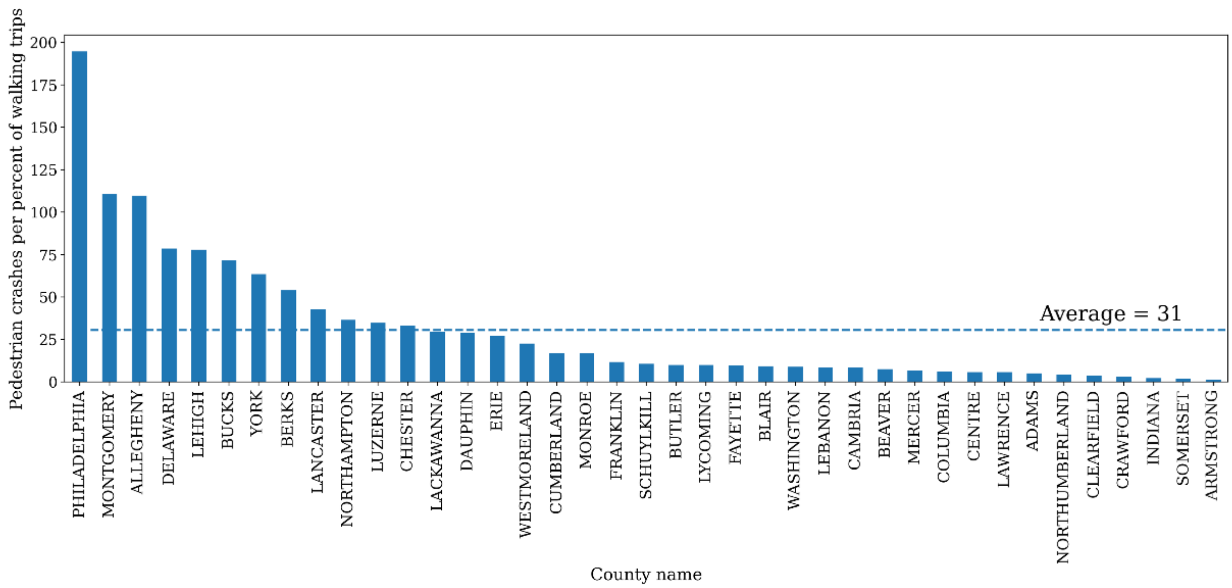

Figure 27 Average number of crashes involving pedestrians per percentage of walking trips by county (2014-2021)

Table 10 provides the average number of pedestrian crashes, and the average number of pedestrian crashes normalized using population, population density, and percent of walking trips in each county. Note that the percentage of walking trips was only available for a subset of counties from the ACS database, and hence pedestrian crashes per percentage of walking trips is calculated only for this subset of counties.

Table 10 Average number of pedestrian crashes and the average number of pedestrian crashes normalized using population, population density and percent of walking trips by county (2014-2021)

County name	Ped crash	Ped crash per pop	Ped crash per pop den	Ped crash per percent walked
ADAMS	13.500	0.000128	0.067	5.040
ALLEGHENY	389.800	0.000325	0.242	109.789
ARMSTRONG	3.900	0.000051	0.034	1.468
BEAVER	16.000	0.000092	0.041	7.532
BEDFORD	5.400	0.000102	0.104	
BERKS	142.100	0.000343	0.297	54.128
BLAIR	25.100	0.000206	0.109	9.306
BRADFORD	5.300	0.000093	0.108	
BUCKS	105.800	0.000166	0.104	71.522
BUTLER	17.600	0.000096	0.076	9.926
CAMBRIA	18.400	0.000139	0.096	8.396
CAMERON	0.600	0.000149	0.060	
CARBON	8.000	0.000133	0.052	
CENTRE	36.800	0.000245	0.273	5.861
CHESTER	68.800	0.000138	0.105	33.030

County name	Ped crash	Ped crash per pop	Ped crash per pop den	Ped crash per percent walked
CLARION	7.500	0.000197	0.120	
CLEARFIELD	9.000	0.000108	0.125	3.514
CLINTON	5.800	0.000149	0.134	
COLUMBIA	12.300	0.000189	0.093	6.015
CRAWFORD	12.600	0.000147	0.152	2.821
CUMBERLAND	41.300	0.000167	0.092	17.147
DAUPHIN	82.600	0.000303	0.169	28.718
DELAWARE	190.900	0.000338	0.065	78.688
ELK	4.000	0.000143	0.119	
ERIE	79.300	0.000292	0.234	27.074
FAYETTE	16.900	0.000130	0.104	9.634
FOREST	0.500	0.000078	0.033	
FRANKLIN	24.600	0.000157	0.121	11.742
FULTON	1.400	0.000098	0.043	
GREENE	2.800	0.000065	0.037	
HUNTINGDON	4.600	0.000088	0.078	
INDIANA	10.000	0.000117	0.098	2.179
JEFFERSON	5.100	0.000122	0.080	
JUNIATA	2.500	0.000110	0.043	
LACKAWANNA	83.500	0.000404	0.188	29.610
LANCASTER	134.100	0.000255	0.251	42.930
LAWRENCE	11.900	0.000143	0.052	5.781
LEBANON	28.400	0.000209	0.076	8.449
LEHIGH	157.600	0.000442	0.154	77.922
LUZERNE	82.300	0.000263	0.238	34.684
LYCOMING	25.000	0.000216	0.269	9.921
MCKEAN	5.800	0.000146	0.143	
MERCER	16.900	0.000140	0.096	6.570
MIFFLIN	5.500	0.000126	0.052	
MONROE	25.800	0.000164	0.101	17.110
MONTGOMERY	216.600	0.000268	0.131	110.604
MONTOUR	3.600	0.000195	0.026	
NORTHAMPTON	72.400	0.000256	0.096	36.527
NORTHUMBERLAND	12.600	0.000138	0.066	4.406
PERRY	4.900	0.000103	0.057	
PHILADELPHIA	1498.600	0.000999	0.143	194.735
PIKE	5.300	0.000094	0.053	
POTTER	1.600	0.000109	0.118	
SCHUYLKILL	27.500	0.000189	0.147	10.548
SNYDER	5.600	0.000138	0.046	
SOMERSET	5.400	0.000072	0.078	1.815
SULLIVAN	0.400	0.000045	0.020	

County name	Ped crash	Ped crash per pop	Ped crash per pop den	Ped crash per percent walked
SUSQUEHANNA	3.300	0.000082	0.068	
TIOGA	3.600	0.000089	0.101	
UNION	6.100	0.000127	0.040	
VENANGO	9.400	0.000183	0.125	
WARREN	4.900	0.000127	0.114	
WASHINGTON	19.400	0.000098	0.085	8.917
WAYNE	5.600	0.000116	0.087	
WESTMORELAND	41.800	0.000124	0.128	22.585
WYOMING	2.100	0.000062	0.025	
YORK	90.100	0.000206	0.188	63.532

Notice that when considering the percentage of trips as an exposure metric, bicyclists appear to have a larger crash rate than pedestrians. The average number of pedestrian crashes per percentage of walking trips was 31, as compared to the average number of bicycle crashes per percentage of biking trips, which was 165.

To better compare travel by different modes, Figure 28 shows the average number of crashes for four travel modes – car, bicycle, motorcycle, and walking – normalized using the percentage of trips by each travel mode as the exposure metric. This figure shows that when considering the percentage of trips as the exposure, cars have the lowest crash rates in all counties, and bicyclists have the highest crash rates in most counties. In Philadelphia and Montgomery counties, motorcyclists and pedestrians have a similar crash rate; however, in all other counties, motorcyclists have a higher crash rate than pedestrians.

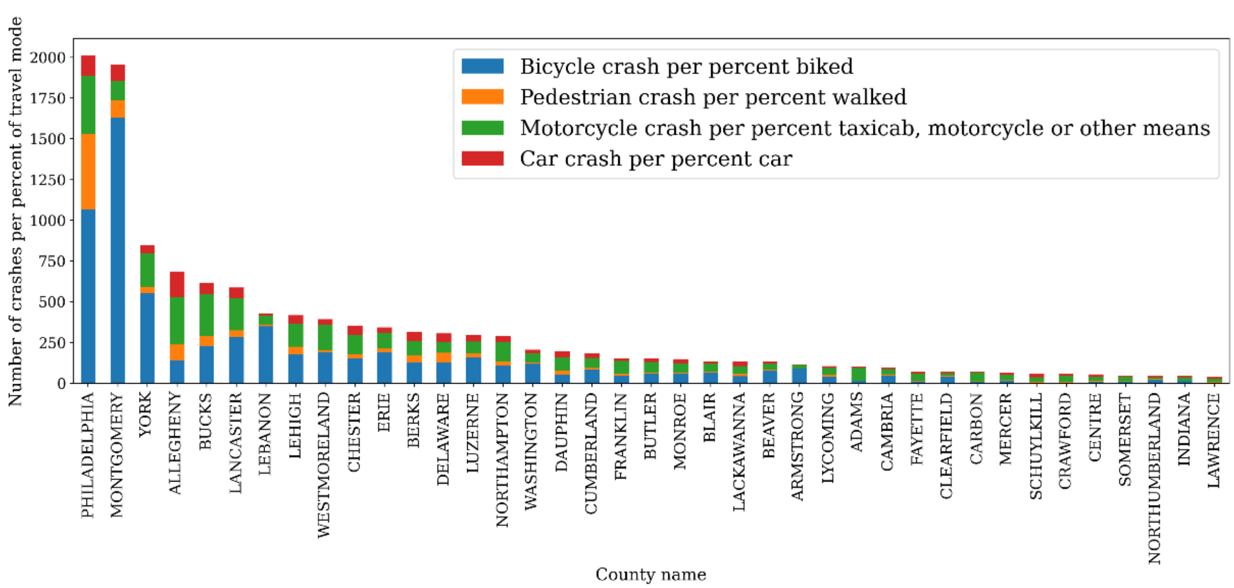

Figure 28 Average number of crashes per percentage of four travel modes by county (2014-2021)

In addition to the results for individual counties, the aggregated normalized crashes for the state for these four travel models are shown in Table 11. The values in Table 11 are computed as the total number of crashes for a travel mode in the state divided by the percentage of trips made using the same travel mode in the state. In Table 11, year 2020 is missing, since the trip data are not available in the American Community Survey. In 2014 and 2016–2019, bicyclists have the largest number of crashes per percentage of trips, while in 2015 and 2021 motorcyclists have the largest number of crashes per percentage of trips. In all years, pedestrians and cars have a similar number of crashes per percentage of trips.

Table 11 Normalized number of crashes using the percent of trips of four travel modes in the state (2014-2019 and 2021, note that 2020 is missing due to trip data being not available)

Number of crashes per percent of trips	2014	2015	2016	2017	2018	2019	2021
Bicycle	4,722	3,764	4,553	3,968	3,983	5,987	1,921
Pedestrian	1,156	1,246	1,359	1,347	1,461	1,311	1,078
Motorcycle	3,528	4,400	3,473	3,057	2,488	2,736	2,367
Car	1,252	1,313	1,338	1,303	1,328	1,301	1,452

Child passenger safety

The average number of child deaths and suspected serious injury counts are shown in Figure 29. Notice that the numbers are small with at most one child death on average per year per county.

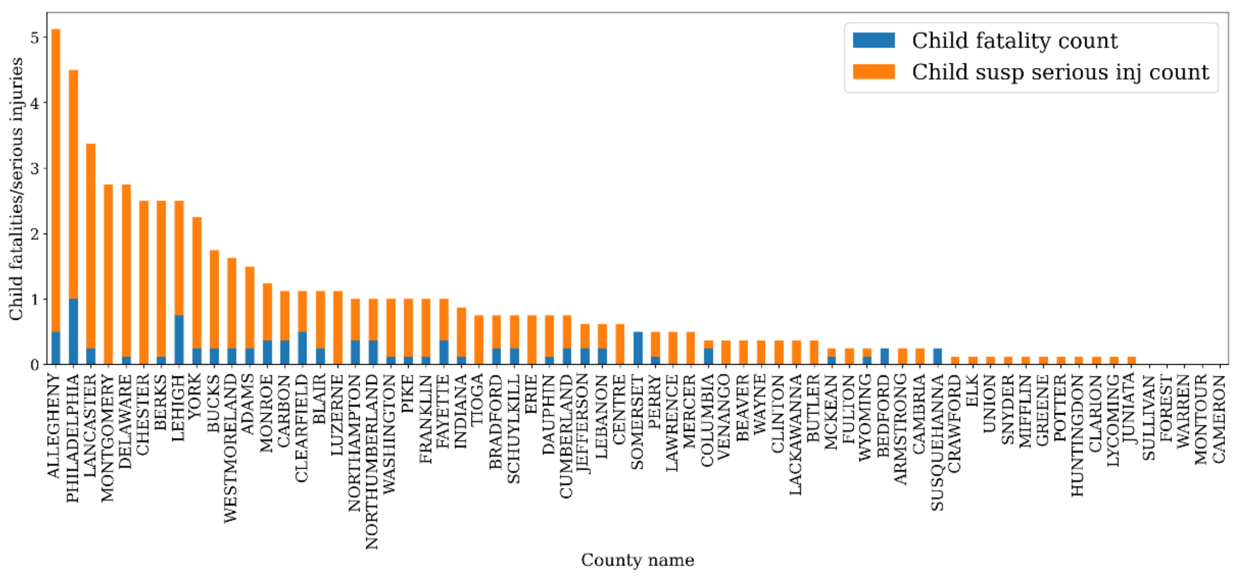

Figure 29 Average number of child passenger fatalities and serious injuries per year by county (2014-2021)

The average number of child deaths and suspected serious injury counts normalized by the population at or under the age of eight is shown in Figure 30.

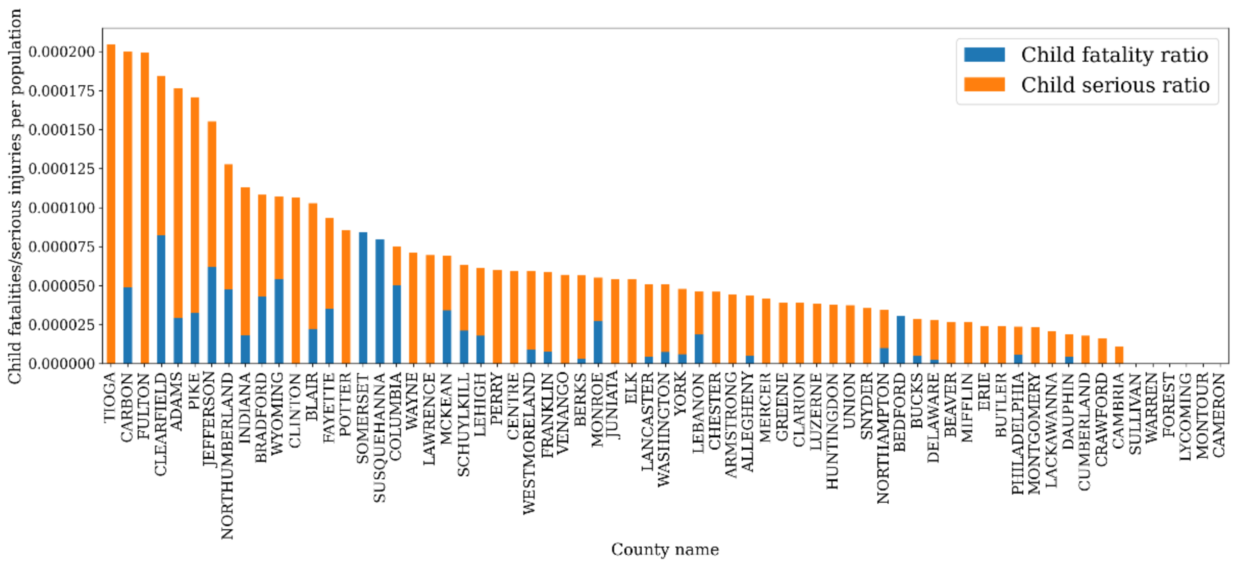

Figure 30 Average number of child fatalities and suspected serious injury counts per population at or under the age of eight per year by county (2014-2021)

Table 12 provides the average and normalized child fatalities and serious injuries by population at or under the age of eight in each county.

Table 12 Average and normalized child fatalities and serious injuries by population in each county (2014-2021)

	Average child:			
County name	Fatality	Serious injury	Fatality per population	Serious injury per population
ADAMS	0.250	1.250	0.0000295	0.000147
ALLEGHENY	0.500	4.625	0.0000050	0.000039
ARMSTRONG	0.000	0.250	0.0000000	0.000045
BEAVER	0.000	0.375	0.0000000	0.000027
BEDFORD	0.250	0.000	0.0000306	0.000000
BERKS	0.125	2.375	0.0000032	0.000054
BLAIR	0.250	0.875	0.0000224	0.000080
BRADFORD	0.250	0.500	0.0000432	0.000065
BUCKS	0.250	1.500	0.0000048	0.000024
BUTLER	0.000	0.375	0.0000000	0.000024
CAMBRIA	0.000	0.250	0.0000000	0.000011
CAMERON	0.000	0.000	0.0000000	0.000000
CARBON	0.375	0.750	0.0000489	0.000151
CENTRE	0.000	0.625	0.0000000	0.000060
CHESTER	0.000	2.500	0.0000000	0.000046
CLARION	0.000	0.125	0.0000000	0.000039
CLEARFIELD	0.500	0.625	0.0000824	0.000102
CLINTON	0.000	0.375	0.0000000	0.000107
COLUMBIA	0.250	0.125	0.0000502	0.000025

			Average child:	
County name	Fatality	Serious injury	Fatality per population	Serious injury per population
CRAWFORD	0.000	0.125	0.0000000	0.000016
CUMBERLAND	0.250	0.500	0.0000000	0.000018
DAUPHIN	0.125	0.625	0.0000047	0.000014
DELAWARE	0.125	2.625	0.0000024	0.000026
ELK	0.000	0.125	0.0000000	0.000054
ERIE	0.000	0.750	0.0000000	0.000024
FAYETTE	0.375	0.625	0.0000351	0.000059
FOREST	0.000	0.000	0.0000000	0.000000
FRANKLIN	0.125	0.875	0.0000080	0.000051
FULTON	0.000	0.250	0.0000000	0.000199
GREENE	0.000	0.125	0.0000000	0.000039
HUNTINGDON	0.000	0.125	0.0000000	0.000038
INDIANA	0.125	0.750	0.0000184	0.000095
JEFFERSON	0.250	0.375	0.0000620	0.000093
JUNIATA	0.000	0.125	0.0000000	0.000054
LACKAWANNA	0.000	0.375	0.0000000	0.000021
LANCASTER	0.250	3.125	0.0000045	0.000047
LAWRENCE	0.000	0.500	0.0000000	0.000070
LEBANON	0.250	0.375	0.0000188	0.000028
LEHIGH	0.750	1.750	0.0000180	0.000043
LUZERNE	0.000	1.125	0.0000000	0.000039
LYCOMING	0.000	0.125	0.0000000	0.000000
MCKEAN	0.125	0.125	0.0000343	0.000035
MERCER	0.000	0.500	0.0000000	0.000042
MIFFLIN	0.000	0.125	0.0000000	0.000027
MONROE	0.375	0.875	0.0000272	0.000028
MONTGOMERY	0.000	2.750	0.0000000	0.000023
MONTOUR	0.000	0.000	0.0000000	0.000000
NORTHAMPTON	0.375	0.625	0.0000100	0.000025
NORTHUMBERLAND	0.375	0.625	0.0000479	0.000080
PERRY	0.125	0.375	0.0000000	0.000060
PHILADELPHIA	1.000	3.500	0.0000055	0.000018
PIKE	0.125	0.875	0.0000327	0.000138
POTTER	0.000	0.125	0.0000000	0.000086
SCHUYLKILL	0.250	0.500	0.0000212	0.000042
SNYDER	0.000	0.125	0.0000000	0.000036
SOMERSET	0.500	0.000	0.0000844	0.000000
SULLIVAN	0.000	0.000	0.0000000	0.000000
SUSQUEHANNA	0.250	0.000	0.0000797	0.000000
TIOGA	0.000	0.750	0.0000000	0.000205
UNION	0.000	0.125	0.0000000	0.000038

			Average child:	
County name	Fatality	Serious injury	Fatality per population	Serious injury per population
VENANGO	0.000	0.375	0.0000000	0.000057
WARREN	0.000	0.000	0.0000000	0.000000
WASHINGTON	0.125	0.875	0.0000074	0.000043
WAYNE	0.000	0.375	0.0000000	0.000071
WESTMORELAND	0.250	1.375	0.0000090	0.000050
WYOMING	0.125	0.125	0.0000543	0.000053
YORK	0.250	2.000	0.0000060	0.000042

The average child fatality rate (normalized using total children population) is compared to the average fatality rate of the entire population (normalized using total population) by plotting the two separately in Figure 31 and plotting the ratio of the two in Figure 32. As can be seen, in some counties – e.g., Clearfield or Somerset counties – the child death per population of children in that county is closer to the total fatality per population than other counties. Regardless, in every county the normalized children fatality rate is smaller than the total fatality rate, which suggests that children have a relatively lower risk of being fatally injured than the general population.

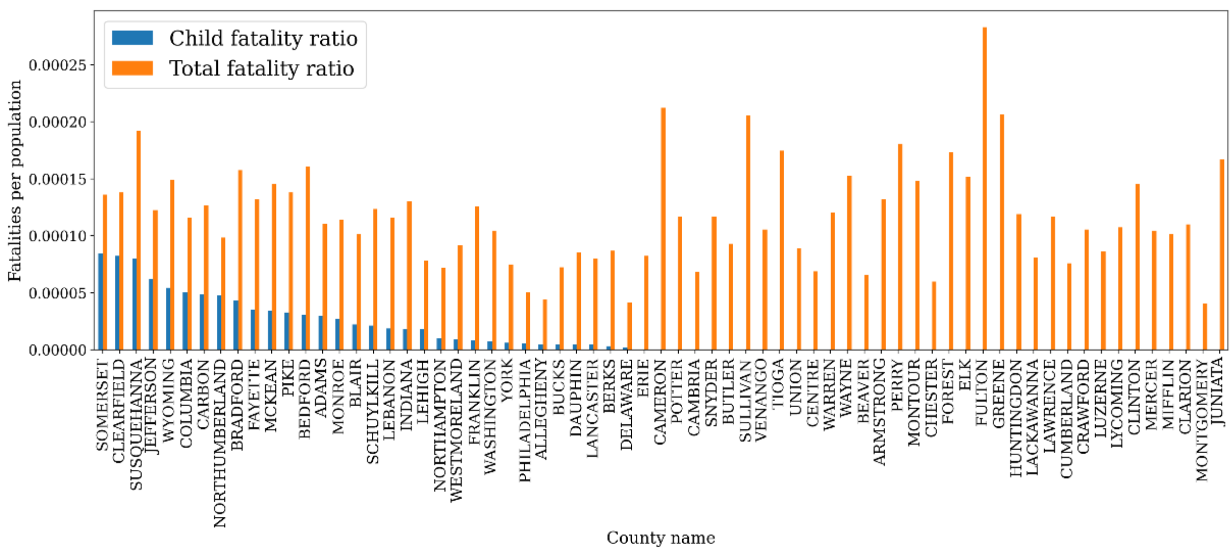

Figure 31 Average number of children fatalities per total child population vs. average number of fatalities per total population per year by county (2014-2021)

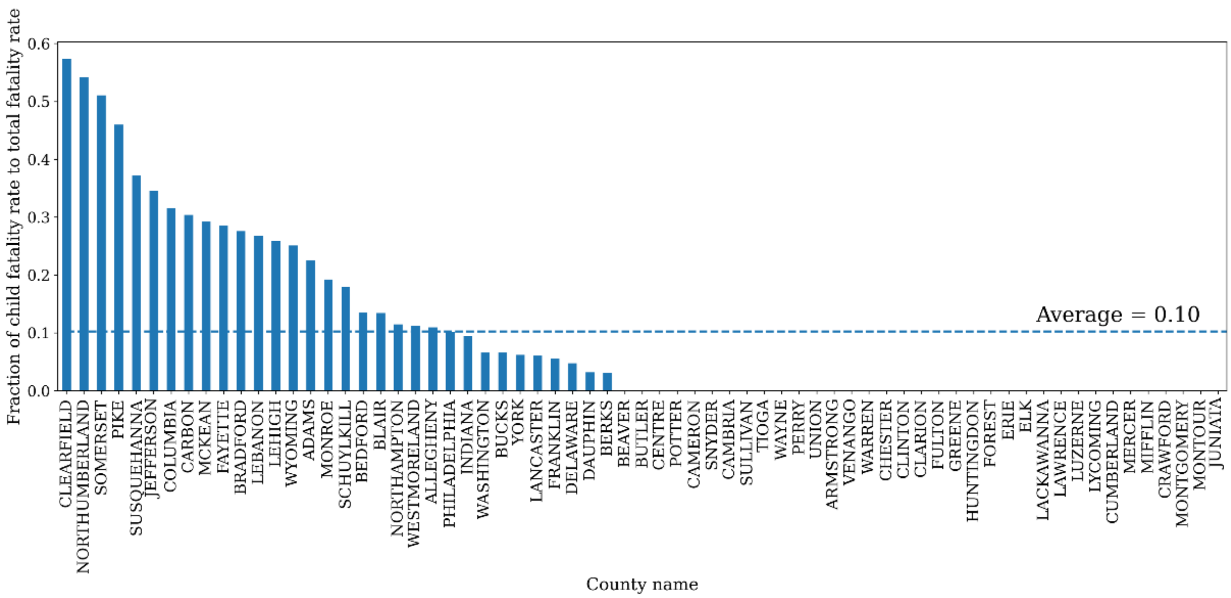

Figure 32 Ratio of average children fatalities per total child population to average number of fatalities per total population per year by county (2014-2021)

Table 13 shows the child fatality rate, total fatality rate, and the fraction of child fatality rate to total fatality rate. The last fraction represents the relative risk of child fatalities compared to overall fatalities within the specific county.

Table 13 Comparison between child fatality ratio and total fatality rate in each county (2014-2021)

County name	Child fatality rate	Total fatality rate	Fraction of child fatality rate to total fatality rate
ADAMS	0.0000295	0.000111	0.226
ALLEGHENY	0.0000050	0.000044	0.109
ARMSTRONG	0.0000000	0.000132	0.000
BEAVER	0.0000000	0.000066	0.000
BEDFORD	0.0000306	0.000161	0.136
BERKS	0.0000032	0.000087	0.031
BLAIR	0.0000224	0.000102	0.135
BRADFORD	0.0000432	0.000158	0.276
BUCKS	0.0000048	0.000072	0.066
BUTLER	0.0000000	0.000093	0.000
CAMBRIA	0.0000000	0.000068	0.000
CAMERON	0.0000000	0.000212	0.000
CARBON	0.0000489	0.000127	0.304
CENTRE	0.0000000	0.000069	0.000
CHESTER	0.0000000	0.000060	0.000
CLARION	0.0000000	0.000110	0.000
CLEARFIELD	0.0000824	0.000138	0.574
CLINTON	0.0000000	0.000145	0.000
COLUMBIA	0.0000502	0.000116	0.315

County name	Child fatality rate	Total fatality rate	Fraction of child fatality rate to total fatality rate
CRAWFORD	0.0000000	0.000105	0.000
CUMBERLAND	0.0000000	0.000076	0.000
DAUPHIN	0.0000047	0.000086	0.032
DELAWARE	0.0000024	0.000042	0.048
ELK	0.0000000	0.000152	0.000
ERIE	0.0000000	0.000082	0.000
FAYETTE	0.0000351	0.000132	0.285
FOREST	0.0000000	0.000173	0.000
FRANKLIN	0.0000080	0.000126	0.055
FULTON	0.0000000	0.000283	0.000
GREENE	0.0000000	0.000206	0.000
HUNTINGDON	0.0000000	0.000119	0.000
INDIANA	0.0000184	0.000130	0.095
JEFFERSON	0.0000620	0.000123	0.345
JUNIATA	0.0000000	0.000167	0.000
LACKAWANNA	0.0000000	0.000081	0.000
LANCASTER	0.0000045	0.000080	0.061
LAWRENCE	0.0000000	0.000117	0.000
LEBANON	0.0000188	0.000116	0.267
LEHIGH	0.0000180	0.000078	0.259
LUZERNE	0.0000000	0.000087	0.000
LYCOMING	0.0000000	0.000107	0.000
MCKEAN	0.0000343	0.000146	0.292
MERCER	0.0000000	0.000105	0.000
MIFFLIN	0.0000000	0.000102	0.000
MONROE	0.0000272	0.000114	0.192
MONTGOMERY	0.0000000	0.000041	0.000
MONTOUR	0.0000000	0.000148	0.000
NORTHAMPTON	0.0000100	0.000072	0.115
NORTHUMBERLAND	0.0000479	0.000099	0.542
PERRY	0.0000000	0.000181	0.000
PHILADELPHIA	0.0000055	0.000050	0.101
PIKE	0.0000327	0.000138	0.460
POTTER	0.0000000	0.000117	0.000
SCHUYLKILL	0.0000212	0.000124	0.180
SNYDER	0.0000000	0.000117	0.000
SOMERSET	0.0000844	0.000136	0.511
SULLIVAN	0.0000000	0.000206	0.000
SUSQUEHANNA	0.0000797	0.000192	0.373
TIOGA	0.0000000	0.000175	0.000
UNION	0.0000000	0.000089	0.000
VENANGO	0.0000000	0.000106	0.000

County name	Child fatality rate	Total fatality rate	Fraction of child fatality rate to total fatality rate
WARREN	0.0000000	0.000121	0.000
WASHINGTON	0.0000074	0.000105	0.067
WAYNE	0.0000000	0.000152	0.000
WESTMORELAND	0.0000090	0.000092	0.112
WYOMING	0.0000543	0.000149	0.251
YORK	0.0000060	0.000075	0.062

Commercial motor vehicle safety

The average number of commercial vehicle crashes is shown in Figure 33. Philadelphia and Allegheny counties are the top two counties with commercial vehicle crashes.

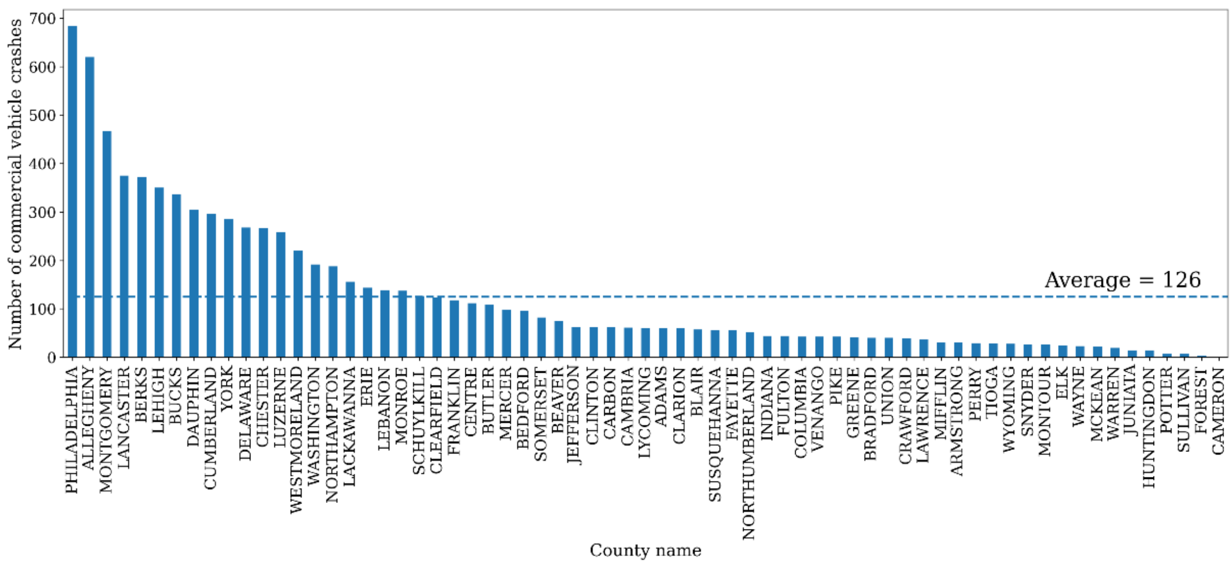

Figure 33 Average number of commercial vehicle crashes per year by county (2014-2021)

Figure 34 provides the average commercial vehicle crash rate normalized by the truck VMT. The figure shows that Philadelphia County remains as a location with a higher crash rate for commercial vehicles after this normalization, whereas Allegheny's rank moves to number five.

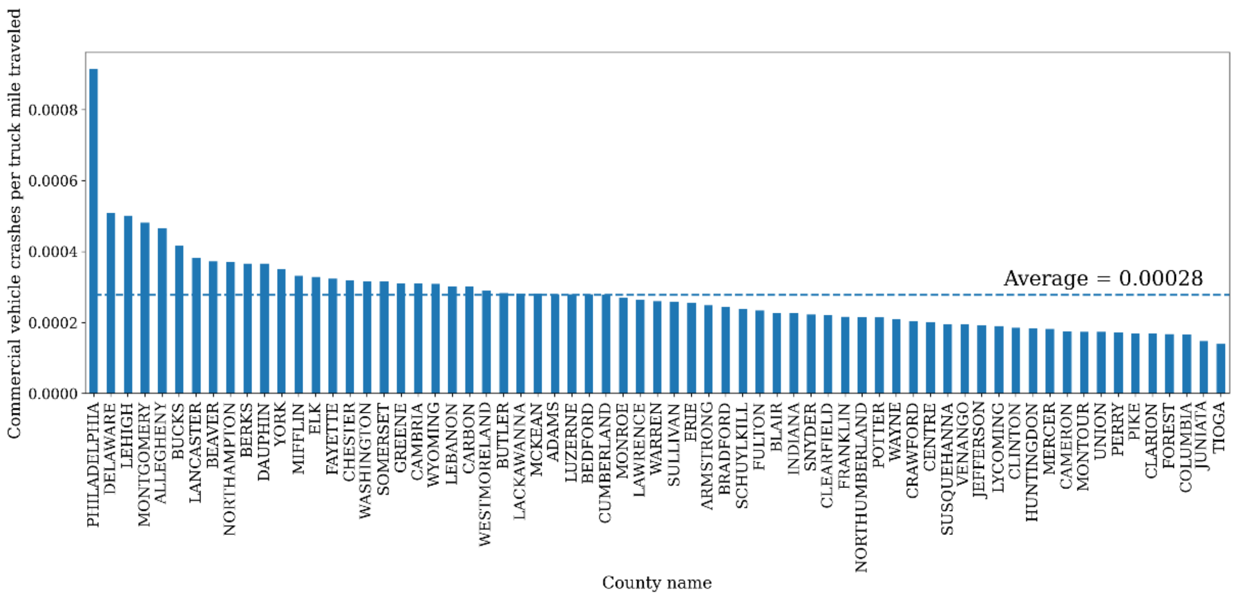

Figure 34 Commercial vehicle crashes per truck VMT per year by county (2014-2021)

Table 14 provides the average and normalized commercial vehicle (using truck VMT) crashes in each county.

Table 14 Average and normalized commercial vehicle (per truck VMT) crashes in each county (2014-2021)

County	Commercial crashes	Commercial crashes per VMT
ADAMS	60.000	0.000280
ALLEGHENY	620.130	0.000466
ARMSTRONG	30.130	0.000249
BEAVER	75.500	0.000373
BEDFORD	96.380	0.000280
BERKS	373.000	0.000367
BLAIR	57.500	0.000227
BRADFORD	40.630	0.000244
BUCKS	336.880	0.000417
BUTLER	109.630	0.000283
CAMBRIA	61.750	0.000311
CAMERON	1.630	0.000176
CARBON	62.000	0.000302
CENTRE	112.130	0.000202
CHESTER	267.250	0.000319
CLARION	59.750	0.000169
CLEARFIELD	123.500	0.000220
CLINTON	62.750	0.000186
COLUMBIA	43.130	0.000166
CRAWFORD	39.250	0.000204
CUMBERLAND	295.880	0.000279
DAUPHIN	305.000	0.000366

County	Commercial crashes	Commercial crashes per VMT
DELAWARE	268.000	0.000509
ELK	24.880	0.000328
ERIE	144.000	0.000256
FAYETTE	56.000	0.000324
FOREST	3.250	0.000168
FRANKLIN	118.250	0.000217
FULTON	44.000	0.000234
GREENE	42.000	0.000311
HUNTINGDON	14.750	0.000184
INDIANA	44.250	0.000227
JEFFERSON	63.130	0.000192
JUNIATA	15.000	0.000148
LACKAWANNA	156.000	0.000282
LANCASTER	374.880	0.000382
LAWRENCE	37.000	0.000264
LEBANON	138.880	0.000302
LEHIGH	350.130	0.000502
LUZERNE	257.880	0.000280
LYCOMING	60.880	0.000191
MCKEAN	22.250	0.000281
MERCER	98.380	0.000182
MIFFLIN	31.000	0.000331
MONROE	137.250	0.000269
MONTGOMERY	466.880	0.000482
MONTOUR	26.630	0.000174
NORTHAMPTON	187.880	0.000372
NORTHUMBERLAND	51.000	0.000216
PERRY	29.250	0.000173
PHILADELPHIA	683.500	0.000915
PIKE	42.500	0.000170
POTTER	7.000	0.000215
SCHUYLKILL	126.500	0.000238
SNYDER	27.380	0.000223
SOMERSET	82.750	0.000315
SULLIVAN	6.880	0.000259
SUSQUEHANNA	56.250	0.000196
TIOGA	28.880	0.000139
UNION	40.630	0.000174
VENANGO	42.880	0.000195
WARREN	19.380	0.000261
WASHINGTON	191.750	0.000317
WAYNE	23.130	0.000209
WESTMORELAND	219.630	0.000289

County	Commercial crashes	Commercial crashes per VMT
WYOMING	28.000	0.000309
YORK	285.000	0.000351

Young and mature drivers

The average number of young (16–20) and mature (65+) drivers involved in crashes per county per year is plotted in Figure 35. The average number of young drivers involved in crashes is similar to the number of mature drivers involved in crashes. In some counties – e.g., Allegheny, Philadelphia, and Delaware –more mature drivers are involved in crashes than young drivers. In other counties – e.g., Lancaster, York, and Chester – on average more young drivers are involved in crashes than mature drivers.

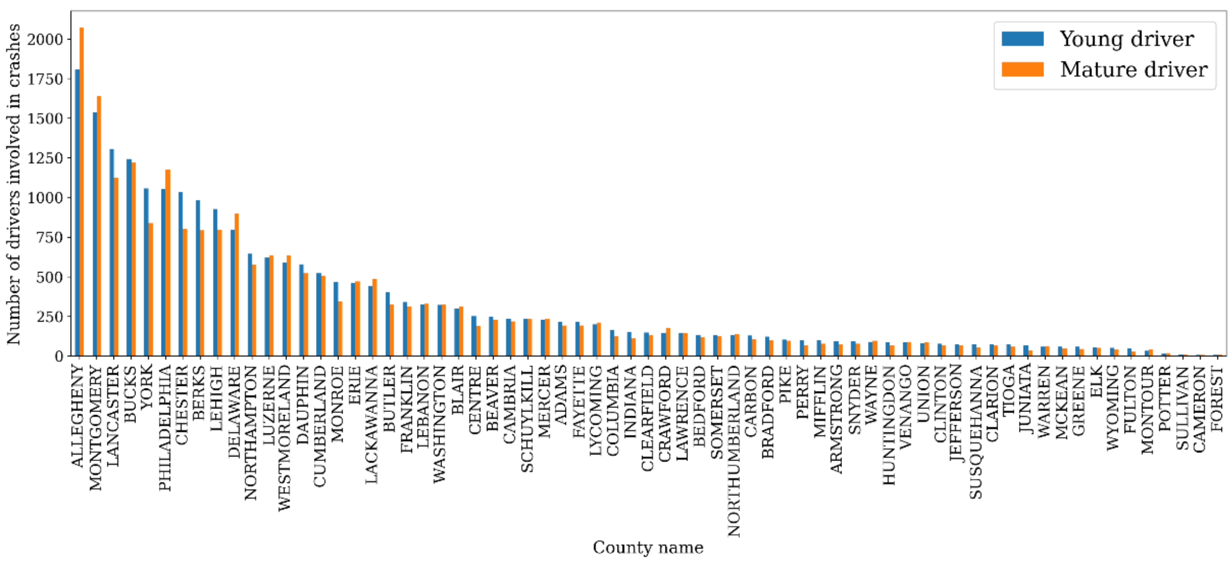

Figure 35 Average number of young (16-20) and mature (65+) drivers involved in crashes per year by county (2014-2021)

Young drivers have a larger average crash rate per population compared to mature drivers (see Figure 36).

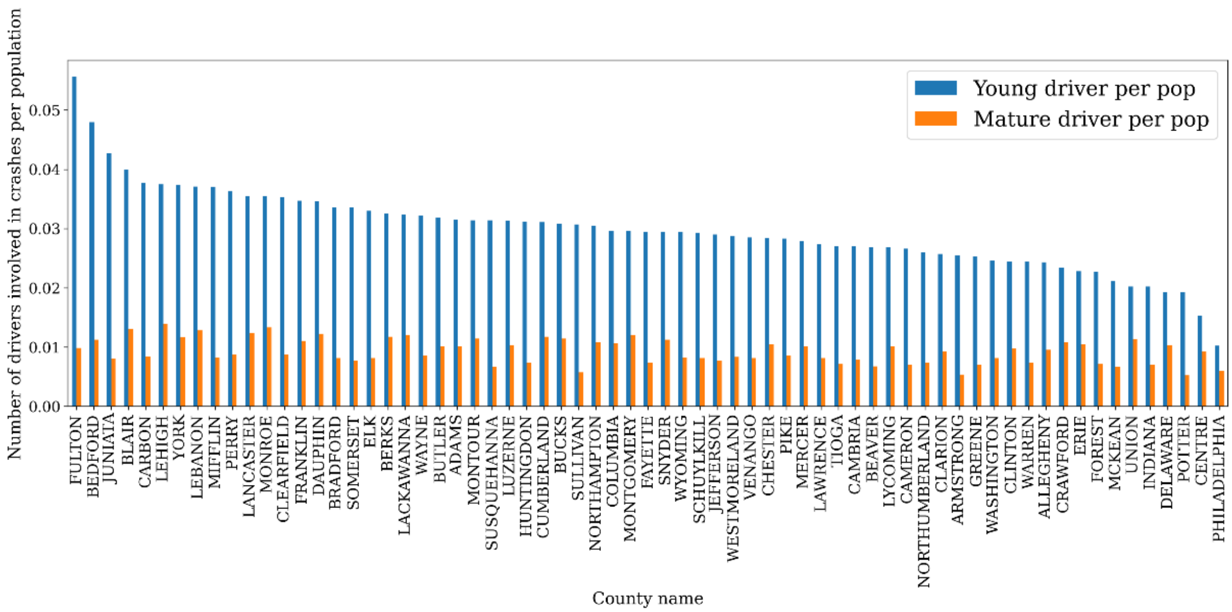

Figure 36 Average number of young (16-20) and mature (65+) drivers involved in crashes per population in each group per year by county

A similar conclusion is obtained when normalizing by the number of licensed drivers in each age group, as shown in Figure 37.

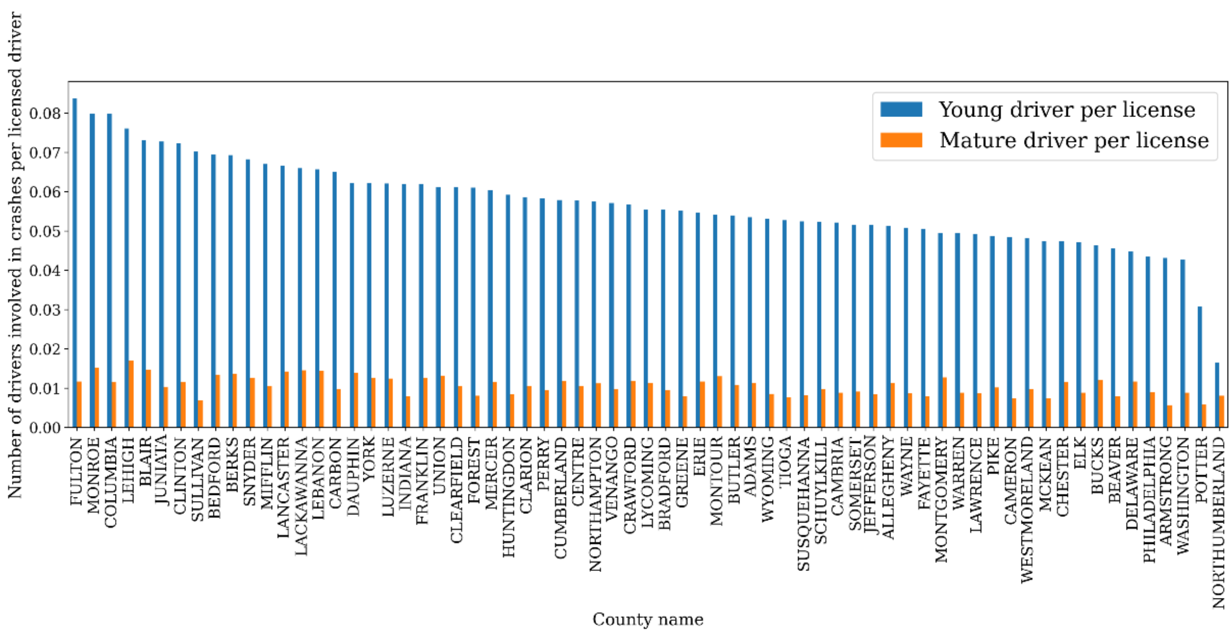

Figure 37 Average number of young (16-20) and mature (65+) drivers involved in crashes per licensed drivers in each group per year by county (2014-2021)

Table 15 shows the average number and the normalized number using population and number of licenses within the corresponding age groups of crashes involving young and mature drivers in each county.

Table 15 Average and normalized (using population and number of licenses) number of crashes involving young (16-20) and mature (65+) drivers in each county (2014-2021)

	Average number of crashes involving		Average number of crashes normalized by population		Average number of crashes normalized by number of licensed drivers	
County	Young Drivers	Mature Drivers	Young Drivers	Mature Drivers	Young Drivers	Mature Drivers
ADAMS	217.4	192.4	0.0315	0.0102	0.0536	0.0113
ALLEGHENY	1806.0	2072.0	0.0243	0.0096	0.0512	0.0113
ARMSTRONG	95.0	75.5	0.0256	0.0054	0.0432	0.0058
BEAVER	250.9	232.1	0.0269	0.0068	0.0457	0.0079
BEDFORD	135.0	117.3	0.0480	0.0113	0.0695	0.0134
BERKS	981.1	795.0	0.0326	0.0118	0.0694	0.0137
BLAIR	300.5	313.8	0.0400	0.0130	0.0730	0.0146
BRADFORD	121.6	99.5	0.0336	0.0082	0.0554	0.0095
BUCKS	1242.9	1221.8	0.0308	0.0114	0.0464	0.0122
BUTLER	406.3	327.1	0.0319	0.0101	0.0540	0.0108
CAMBRIA	235.5	219.4	0.0270	0.0079	0.0522	0.0088
CAMERON	6.6	7.6	0.0266	0.0070	0.0484	0.0075
CARBON	130.3	108.6	0.0377	0.0084	0.0652	0.0098
CENTRE	252.8	189.1	0.0154	0.0092	0.0578	0.0104
CHESTER	1035.9	800.0	0.0285	0.0105	0.0473	0.0116
CLARION	73.000	65.9	0.0257	0.0093	0.0587	0.0105
CLEARFIELD	149.5	135.5	0.0354	0.0088	0.0612	0.0106
CLINTON	78.6	66.0	0.0245	0.0098	0.0724	0.0115
COLUMBIA	163.9	127.3	0.0297	0.0107	0.0799	0.0116
CRAWFORD	147.4	179.3	0.0235	0.0109	0.0568	0.0118
CUMBERLAND	523.6	504.8	0.0311	0.0118	0.0579	0.0119
DAUPHIN	580.3	522.5	0.0346	0.0123	0.0623	0.0140
DELAWARE	797.6	896.5	0.0193	0.0104	0.0449	0.0117
ELK	57.9	51.5	0.0330	0.0081	0.0472	0.0089
ERIE	462.1	471.1	0.0229	0.0105	0.0546	0.0117
FAYETTE	213.8	194.4	0.0295	0.0074	0.0505	0.0079
FOREST	6.6	10.5	0.0227	0.0071	0.0611	0.0081
FRANKLIN	341.4	311.3	0.0347	0.0111	0.0619	0.0127
FULTON	48.6	29.9	0.0556	0.0099	0.0838	0.0117
GREENE	59.1	45.0	0.0254	0.0071	0.0552	0.0079
HUNTINGDON	88.5	65.3	0.0312	0.0074	0.0593	0.0085
INDIANA	152.6	110.0	0.0202	0.0070	0.0621	0.0080
JEFFERSON	76.8	66.6	0.0290	0.0077	0.0515	0.0085
JUNIATA	65.6	38.8	0.0427	0.0080	0.0728	0.0104
LACKAWANNA	443.6	488.5	0.0324	0.0121	0.0660	0.0146
LANCASTER	1305.9	1126.0	0.0355	0.0124	0.0666	0.0143
LAWRENCE	147.1	146.8	0.0274	0.0082	0.0492	0.0088
LEBANON	327.5	331.0	0.0372	0.0129	0.0658	0.0145
LEHIGH	927.8	797.5	0.0375	0.0139	0.0761	0.0170

County	Average number of crashes involving		Average number of crashes normalized by population		Average number of crashes normalized by number of licensed drivers	
	Young Drivers	Mature Drivers	Young Drivers	Mature Drivers	Young Drivers	Mature Drivers
LUZERNE	623.5	633.6	0.0313	0.0104	0.0621	0.0125
LYCOMING	200.0	212.3	0.0269	0.0102	0.0555	0.0113
MCKEAN	59.6	50.3	0.0212	0.0067	0.0474	0.0074
MERCER	229.3	233.3	0.0279	0.0101	0.0605	0.0116
MIFFLIN	98.6	77.9	0.0371	0.0083	0.0671	0.0106
MONROE	469.0	346.5	0.0355	0.0133	0.0799	0.0153
MONTGOMERY	1537.1	1638.0	0.0296	0.0121	0.0495	0.0128
MONTOUR	33.9	41.3	0.0315	0.0115	0.0541	0.0131
NORTHAMPTON	645.3	576.9	0.0305	0.0108	0.0576	0.0112
NORTHUMBERLAND	132.4	135.8	0.0261	0.0074	0.0166	0.0082
PERRY	99.4	68.8	0.0363	0.0087	0.0584	0.0095
PHILADELPHIA	1051.9	1176.4	0.0102	0.0060	0.0435	0.0090
PIKE	103.6	97.0	0.0283	0.0086	0.0487	0.0102
POTTER	17.4	19.5	0.0193	0.0053	0.0308	0.0060
SCHUYLKILL	233.0	233.0	0.0293	0.0081	0.0523	0.0098
SNYDER	94.4	77.5	0.0295	0.0113	0.0683	0.0126
SOMERSET	132.8	124.3	0.0336	0.0078	0.0515	0.0092
SULLIVAN	11.400	9.4	0.0307	0.0058	0.0703	0.0069
SUSQUEHANNA	75.300	57.8	0.0315	0.0066	0.0525	0.0082
TIOGA	73.000	59.0	0.0271	0.0071	0.0528	0.0077
UNION	83.500	86.8	0.0202	0.0113	0.0613	0.0133
VENANGO	88.100	89.0	0.0286	0.0082	0.0571	0.0098
WARREN	60.000	63.6	0.0244	0.0074	0.0495	0.0089
WASHINGTON	322.800	325.9	0.0247	0.0082	0.0428	0.0089
WAYNE	90.000	96.6	0.0323	0.0086	0.0508	0.0088
WESTMORELAND	591.800	635.1	0.0287	0.0084	0.0482	0.0097
WYOMING	52.400	43.4	0.0294	0.0083	0.0532	0.0086
YORK	1058.000	837.6	0.0375	0.0116	0.0622	0.0127

Motorcycle safety

The average number of motorcycle crashes, plotted per county, is shown in Figure 38. Philadelphia and Allegheny counties are the top two counties that experience motorcycle crashes.

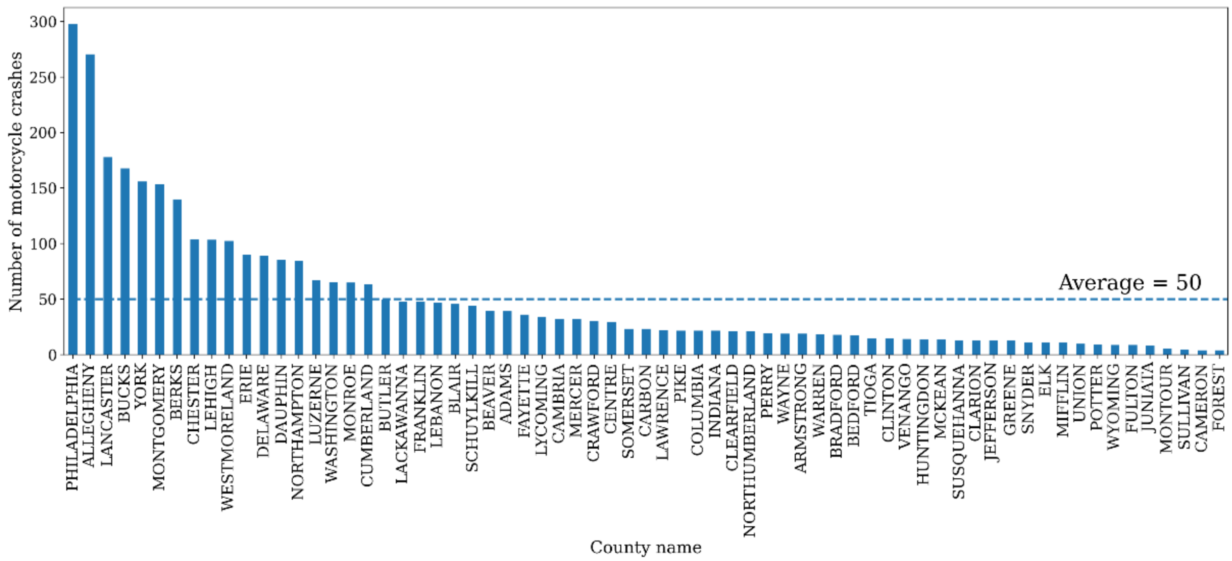

Figure 38 Average number of motorcycle crashes per year by county (2014-2021)

The average crash rate becomes more evenly distributed across the counties when normalizing by the number of registered motorcycle licenses within that county; see Figure 39.

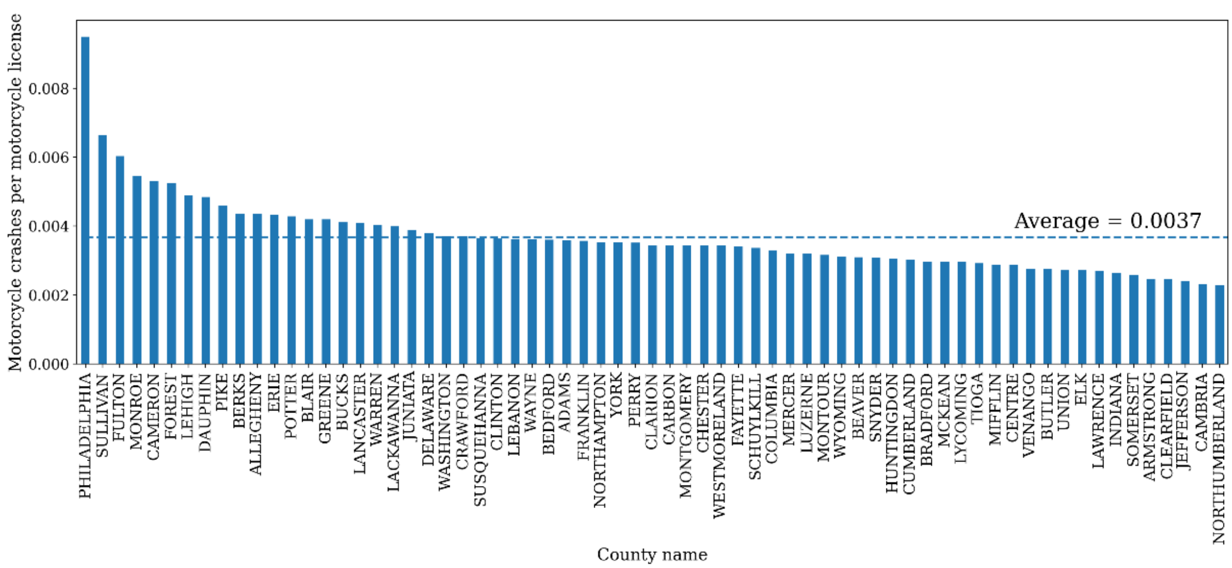

Figure 39 Average number of motorcycle crashes per motorcycle licenses per year by county (2014-2021)

A similar conclusion is obtained when normalizing the number of motorcycle crashes by the number of registered motorcycles, as shown in Figure 40. However, Philadelphia County appears to have a high number of motorcycle crashes per number of registered motorcycles compared to other counties.

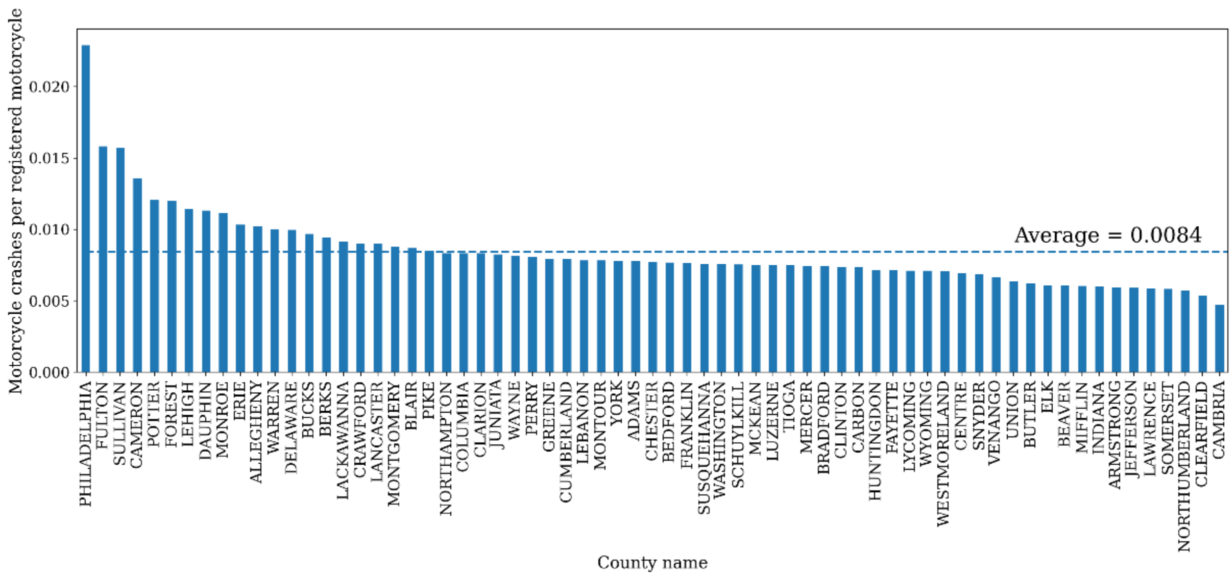

Figure 40 Average number of motorcycle crashes per registered motorcycles per year by county (2014-2021)

Table 16 shows the average and normalized number of motorcycle crashes using number of licenses and registrations, respectively, in each county.

Table 16 Average and normalized (using number of licenses and registrations) number of motorcycle crashes in each county (2014-2021)

County name	Motorcycle crashes	Motorcycle crashes per license	Motorcycle crashes per registration
ADAMS	37.125	0.00359	0.0074
ALLEGHENY	264.625	0.00435	0.0100
ARMSTRONG	18.500	0.00246	0.0058
BEAVER	38.500	0.00309	0.0059
BEDFORD	17.500	0.00361	0.0076
BERKS	135.750	0.00435	0.0092
BLAIR	44.625	0.00420	0.0085
BRADFORD	17.750	0.00297	0.0073
BUCKS	163.125	0.00411	0.0094
BUTLER	47.750	0.00275	0.0060
CAMBRIA	31.625	0.00233	0.0046
CAMERON	3.750	0.00530	0.0119
CARBON	22.500	0.00344	0.0071
CENTRE	28.875	0.00287	0.0068
CHESTER	101.125	0.00343	0.0075
CLARION	12.375	0.00345	0.0080
CLEARFIELD	20.625	0.00246	0.0052
CLINTON	14.000	0.00364	0.0070
COLUMBIA	21.375	0.00331	0.0082
CRAWFORD	29.500	0.00370	0.0088
CUMBERLAND	61.875	0.00303	0.0077

County name	Motorcycle crashes	Motorcycle crashes per license	Motorcycle crashes per registration
DAUPHIN	83.125	0.00484	0.0111
DELAWARE	86.750	0.00379	0.0097
ELK	10.250	0.00272	0.0056
ERIE	87.125	0.00434	0.0100
FAYETTE	34.875	0.00341	0.0069
FOREST	4.000	0.00524	0.0113
FRANKLIN	46.125	0.00357	0.0074
FULTON	8.625	0.00604	0.0154
GREENE	12.500	0.00419	0.0077
HUNTINGDON	13.375	0.00306	0.0069
INDIANA	21.250	0.00263	0.0059
JEFFERSON	12.125	0.00240	0.0056
JUNIATA	8.000	0.00389	0.0081
LACKAWANNA	46.875	0.00399	0.0090
LANCASTER	173.625	0.00409	0.0088
LAWRENCE	21.875	0.00271	0.0058
LEBANON	46.000	0.00363	0.0077
LEHIGH	100.750	0.00490	0.0111
LUZERNE	65.125	0.00319	0.0073
LYCOMING	32.375	0.00297	0.0067
MCKEAN	12.375	0.00297	0.0069
MERCER	30.625	0.00320	0.0071
MIFFLIN	10.625	0.00288	0.0060
MONROE	63.000	0.00546	0.0108
MONTGOMERY	151.750	0.00344	0.0087
MONTOUR	5.125	0.00316	0.0075
NORTHAMPTON	82.750	0.00353	0.0081
NORTHUMBERLAND	20.000	0.00228	0.0054
PERRY	18.375	0.00352	0.0077
PHILADELPHIA	290.875	0.00950	0.0224
PIKE	21.000	0.00459	0.0082
POTTER	8.875	0.00429	0.0111
SCHUYLKILL	42.250	0.00336	0.0073
SNYDER	10.875	0.00309	0.0065
SOMERSET	22.875	0.00259	0.0057
SULLIVAN	4.375	0.00665	0.0149
SUSQUEHANNA	12.875	0.00366	0.0076
TIOGA	14.250	0.00292	0.0072
UNION	9.500	0.00273	0.0061
VENANGO	14.000	0.00276	0.0066
WARREN	17.250	0.00404	0.0094
WASHINGTON	63.500	0.00372	0.0074

County name	Motorcycle crashes	Motorcycle crashes per license	Motorcycle crashes per registration
WAYNE	18.375	0.00362	0.0079
WESTMORELAND	100.375	0.00343	0.0069
WYOMING	8.875	0.00312	0.0070
YORK	151.500	0.00353	0.0076

Seat belt use

Figure 41 shows the average number of fatalities and serious injuries of belted occupants that were involved in a crash. Figure 42 shows the average number of fatalities and serious injuries of unbelted occupants that were involved in a crash. While the total magnitude of fatality and injury is similar, the proportion of fatalities is greater for the unbelted occupants compared to the belted occupants. Figure 43 compares the average number of fatalities of belted occupants to the average number of fatalities of unbelted occupants. In most counties there are more unbelted fatalities compared to belted fatalities; however, this is not true for all counties (e.g., Chester and Franklin counties). Figure 44 compares the average number of serious injuries of belted occupants to the average number of serious injuries of unbelted occupants. In most counties there are more belted serious injuries as compared to unbelted serious injuries, with a few exceptions such as Mercer County.

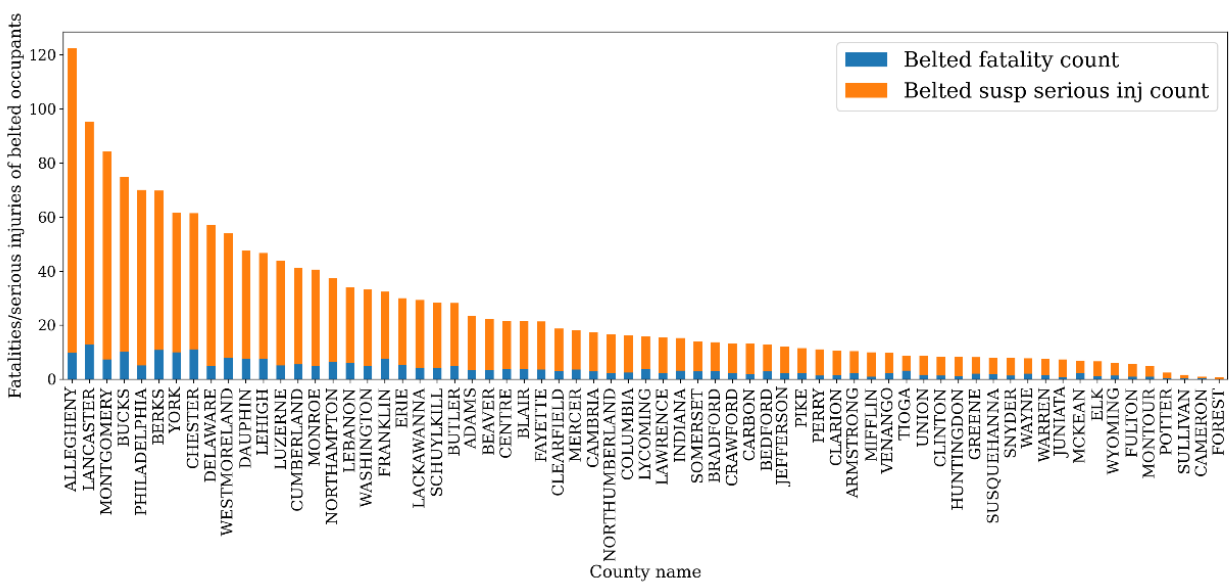

Figure 41 Average number of fatalities and serious injuries of belted occupants in crashes per year by county (2014-2021)

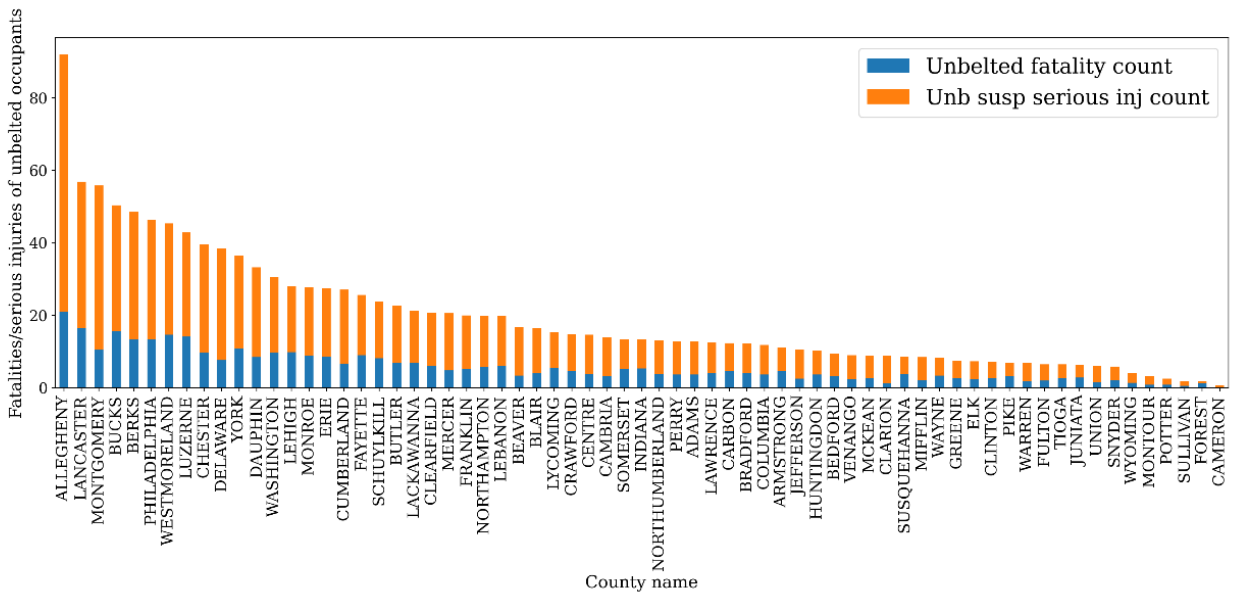

Figure 42 Average number of fatalities and serious injuries of unbelted occupants in crashes per year by county (2014-2021)

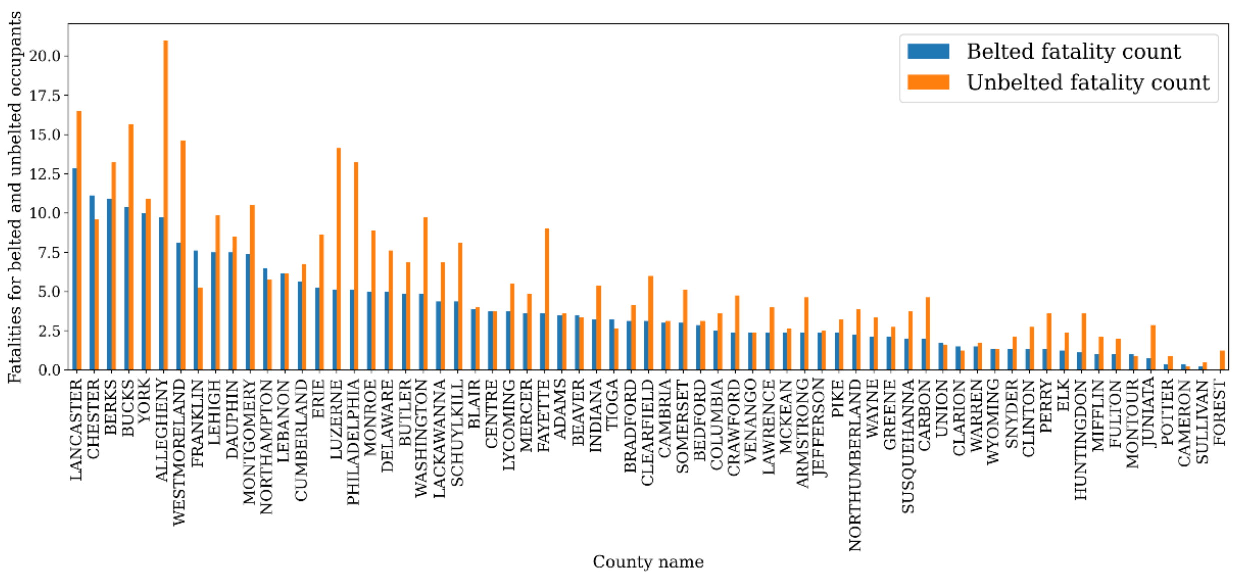

Figure 43 Average number of fatalities of belted and unbelted occupants in crashes per year by county (2014-2021)

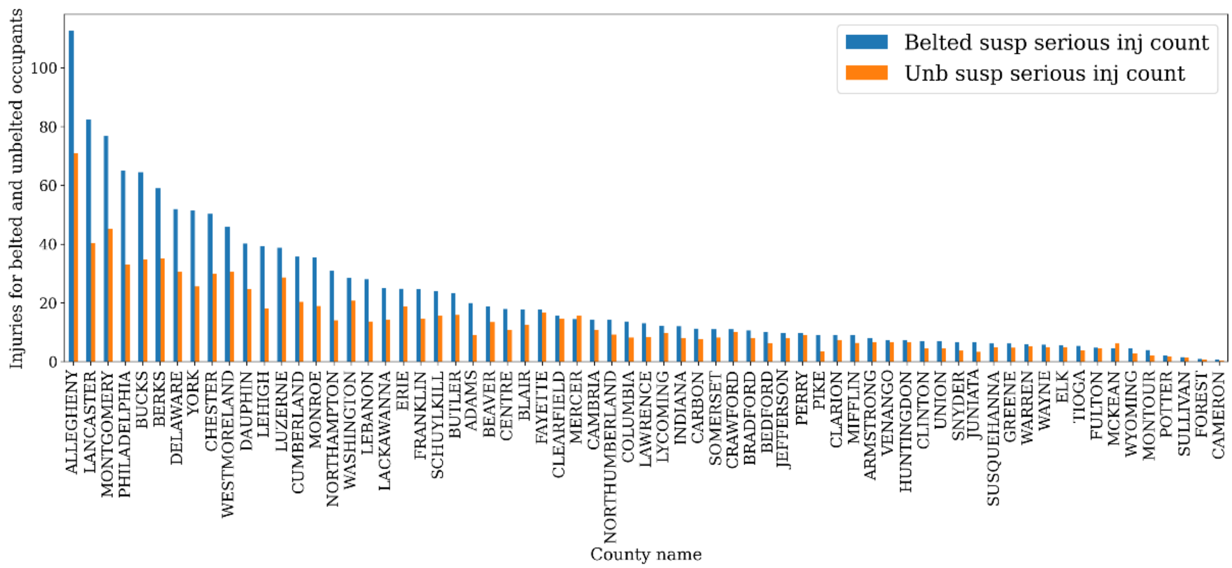

Figure 44 Average number of serious injuries of belted and unbelted occupants in crashes per year by county (2014-2021)

The average number of unbelted occupants involved in a crash is shown in Figure 45. As can be seen, this seems to be a large issue in Philadelphia County, followed by Allegheny County.

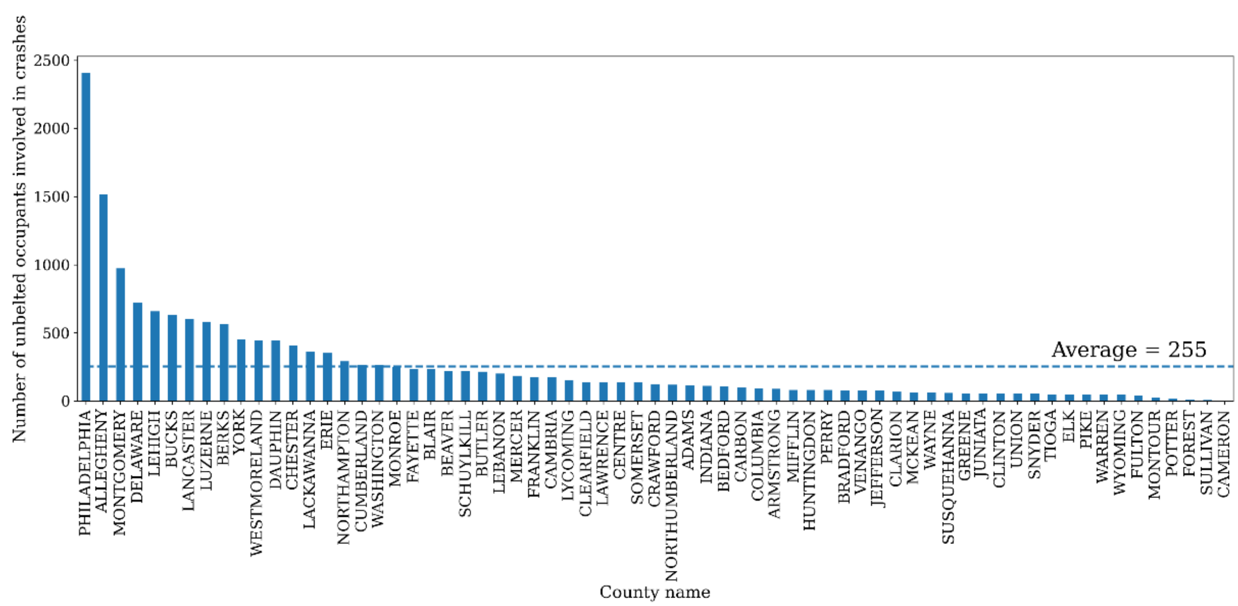

Figure 45 Average number of unbelted occupants involved in crashes per year by county (2014-2021)

When normalizing the average number of unbelted occupants involved in crashes by the number of unbelted citations given (Figure 46), the average number of crashes per citation is larger than one for belting in many counties (e.g., Blair and Montour).

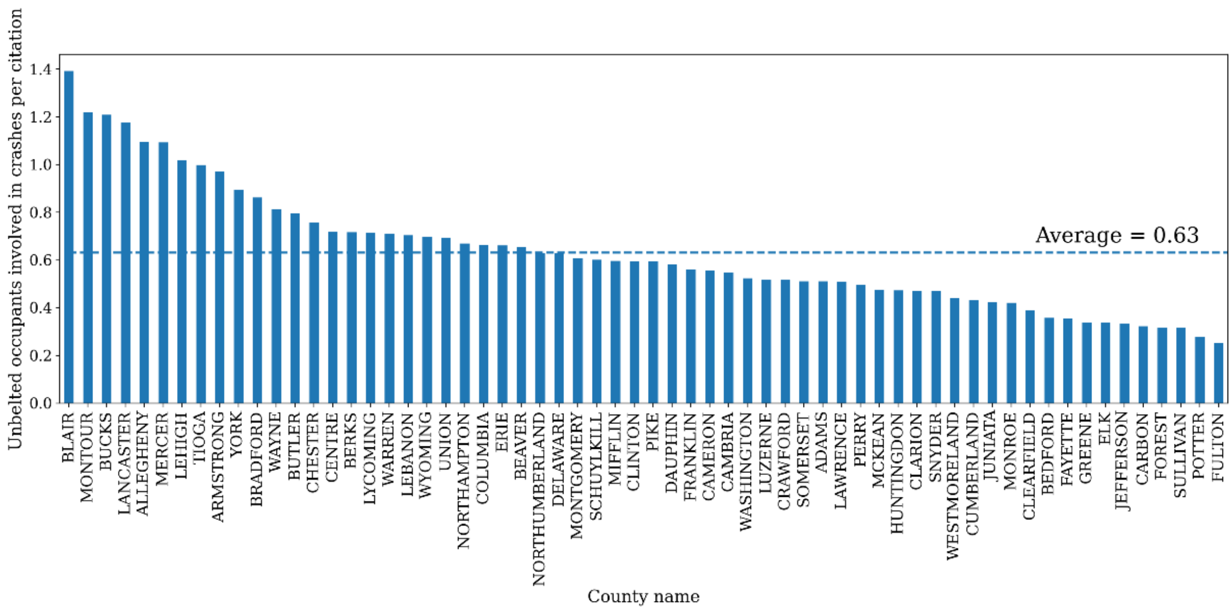

Figure 46 Average number of unbelted occupants involved in crashes per unbelted citations per year by county (2014-2021)

Table 17 shows the average number of belted and unbelted fatalities and serious injuries, the average number of unbelted occupants involved in crashes, and the normalized number of unbelted occupants by the number of unbelted citations in each county. Note that in several counties the unbelted citation data were not available, and hence the unbelted crashes normalized by unbelted crash citations were not computed.

Table 17 Average number of belted and unbelted fatalities and serious injuries, and actual and normalized number (using citations) of unbelted occupancies in each county (2014-2021)

	Average number of:					
County	Belted fatalities	Belted susp serious injuries	Unbelted fatalities	Unbelted susp serious injuries	Unbelted occupants involved in crashes	Unbelted crash per citation
ADAMS	3.5	20.0	3.6	9.1	117.8	0.510
ALLEGHENY	9.8	112.6	21.0	71.0	1516.1	1.100
ARMSTRONG	2.4	8.1	4.6	6.5	91.5	0.970
BEAVER	3.5	18.9	3.4	13.5	220.4	0.650
BEDFORD	2.9	10.1	3.1	6.3	108.0	0.360
BERKS	10.9	59.0	13.3	35.3	565.3	0.720
BLAIR	3.9	17.8	4.0	12.5	237.4	1.390
BRADFORD	3.1	10.6	4.1	8.1	80.0	0.860
BUCKS	10.4	64.5	15.6	34.8	634.1	1.210
BUTLER	4.9	23.4	6.9	15.9	217.4	0.800
CAMBRIA	3.0	14.4	3.1	10.9	174.3	0.550
CAMERON	0.4	0.6	0.3	0.4	5.9	0.560
CARBON	2.0	11.3	4.6	7.8	1.0	0.320
CENTRE	3.8	18.0	3.8	10.9	139.5	0.720

County	Average number of: Belted fatalities	Belted susp serious injuries	Unbelted fatalities	Unbelted susp serious injuries	Unbelted occupants involved in crashes	Unbelted crash per citation
CHESTER	11.1	50.4	9.6	30.0	409.6	0.760
CLARION	1.5	9.1	1.3	7.5	67.6	0.470
CLEARFIELD	3.1	15.6	6.0	14.8	141.1	0.390
CLINTON	1.4	7.0	2.8	4.5	56.3	0.590
COLUMBIA	2.5	13.8	3.6	8.3	96.8	0.660
CRAWFORD	2.4	11.0	4.8	10.0	127.0	0.520
CUMBERLAND	5.6	35.8	6.8	20.4	270.0	0.430
DAUPHIN	7.5	40.3	8.5	24.8	442.5	0.580
DELAWARE	5.0	52.0	7.6	30.8	723.9	0.630
ELK	1.3	5.5	2.4	5.0	50.1	0.340
ERIE	5.3	24.9	8.6	18.8	352.8	0.660
FAYETTE	3.6	17.8	9.0	16.6	237.4	0.360
FOREST	0.0	0.9	1.3	0.6	11.4	0.320
FRANKLIN	7.6	24.8	5.3	14.8	176.0	0.560
FULTON	1.0	4.8	2.0	4.5	41.9	0.250
GREENE	2.1	6.1	2.8	4.8	58.5	0.340
HUNTINGDON	1.1	7.3	3.6	6.6	81.6	0.470
INDIANA	3.3	12.0	5.4	8.0	113.1	
JEFFERSON	2.4	9.9	2.5	8.1	78.9	0.330
JUNIATA	0.8	6.6	2.9	3.4	56.6	0.420
LACKAWANNA	4.4	25.0	6.9	14.4	362.4	
LANCASTER	12.9	82.5	16.5	40.4	605.1	1.180
LAWRENCE	2.4	13.1	4.0	8.5	141.0	0.510
LEBANON	6.1	28.0	6.1	13.8	202.3	0.700
LEHIGH	7.5	39.3	9.9	18.1	660.3	1.020
LUZERNE	5.1	38.8	14.1	28.8	584.3	0.520
LYCOMING	3.8	12.1	5.5	9.8	154.6	0.720
MCKEAN	2.4	4.6	2.6	6.1	67.0	0.480
MERCER	3.6	14.5	4.9	15.8	187.4	1.090
MIFFLIN	1.0	9.0	2.1	6.4	82.8	0.600
MONROE	5.0	35.6	8.9	19.0	248.9	0.420
MONTGOMERY	7.4	76.9	10.5	45.4	975.1	0.610
MONTOUR	1.0	4.0	0.9	2.3	25.9	1.220
NORTHAMPTON	6.5	31.0	5.8	14.1	292.9	0.670
NORTHUMBERLAND	2.3	14.3	3.9	9.3	121.0	0.630
PERRY	1.4	9.8	3.6	9.1	81.6	0.500
PHILADELPHIA	5.1	65.0	13.3	33.1	2408.6	
PIKE	2.4	9.1	3.3	3.6	48.5	0.590
POTTER	0.4	2.1	0.9	1.6	18.8	0.280
SCHUYLKILL	4.4	24.0	8.1	15.6	218.8	0.600

	Average number of:					
County	Belted fatalities	Belted susp serious injuries	Unbelted fatalities	Unbelted susp serious injuries	Unbelted occupants involved in crashes	Unbelted crash per citation
SNYDER	1.4	6.6	2.1	3.8	54.8	0.470
SOMERSET	3.0	11.0	5.1	8.3	136.3	0.510
SULLIVAN	0.3	1.5	0.5	1.4	8.8	0.320
SUSQUEHANNA	2.0	6.1	3.8	4.9	60.1	
TIOGA	3.3	5.4	2.6	3.9	50.1	1.000
UNION	1.8	6.9	1.6	4.5	56.1	0.690
VENANGO	2.4	7.4	2.4	6.6	79.5	
WARREN	1.5	6.0	1.8	5.1	47.5	0.710
WASHINGTON	4.9	28.5	9.8	20.8	265.3	0.520
WAYNE	2.1	5.8	3.4	5.0	65.9	0.810
WESTMORELAND	8.1	45.9	14.6	30.8	444.5	0.440
WYOMING	1.4	4.6	1.4	2.8	46.8	0.700
YORK	10.0	51.6	10.9	25.6	450.9	0.890

Work zone safety

The average number of crashes at works zones is plotted in Figure 47. It can be seen that in Allegheny County the average number of crashes that occur in work zones is 7.7 times greater than the PA average, and in Philadelphia County it is 6.3 times greater than the PA average.

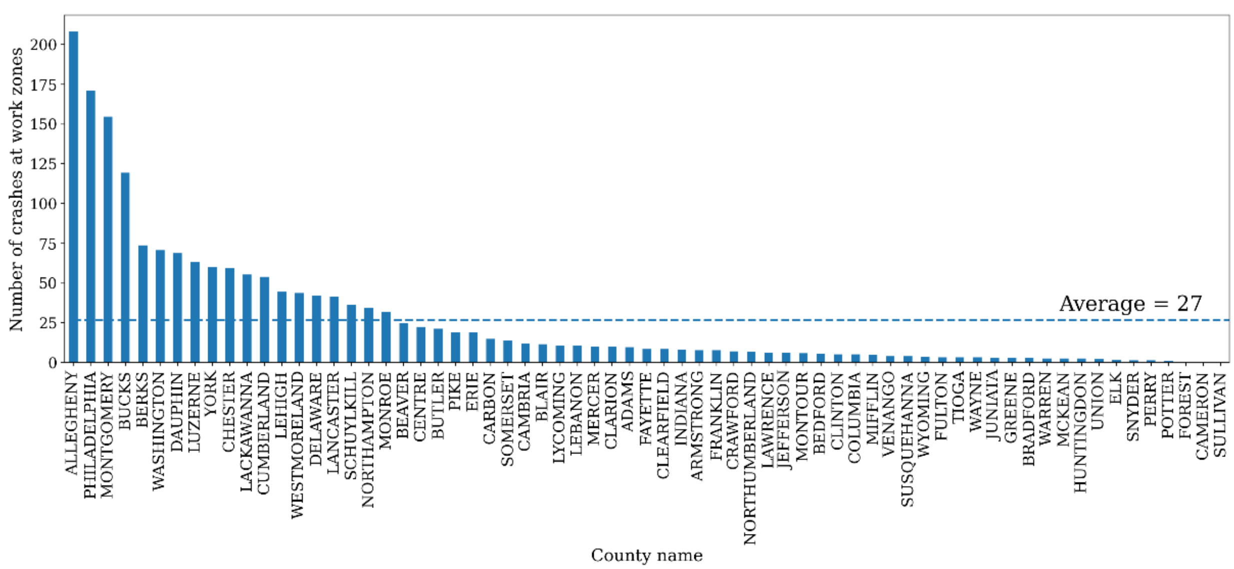

Figure 47 Average number of crashes at work zones per year by county (2014-2021)

Unfortunately, a list of work zones and when they were active from PennDOT's Bureau of Maintenance and Operations was not available. Hence, AOPC work zone citation data were used as a proxy for exposure of work zone crashes (see Figure 48). The average number of crashes per work zone citation in PA was found to be 16 (i.e., for every 1 work zone citation, 16 crashes are observed). As can be seen, Washington and Lackawanna counties appear to have the largest number of work zone crashes per work zone citation.

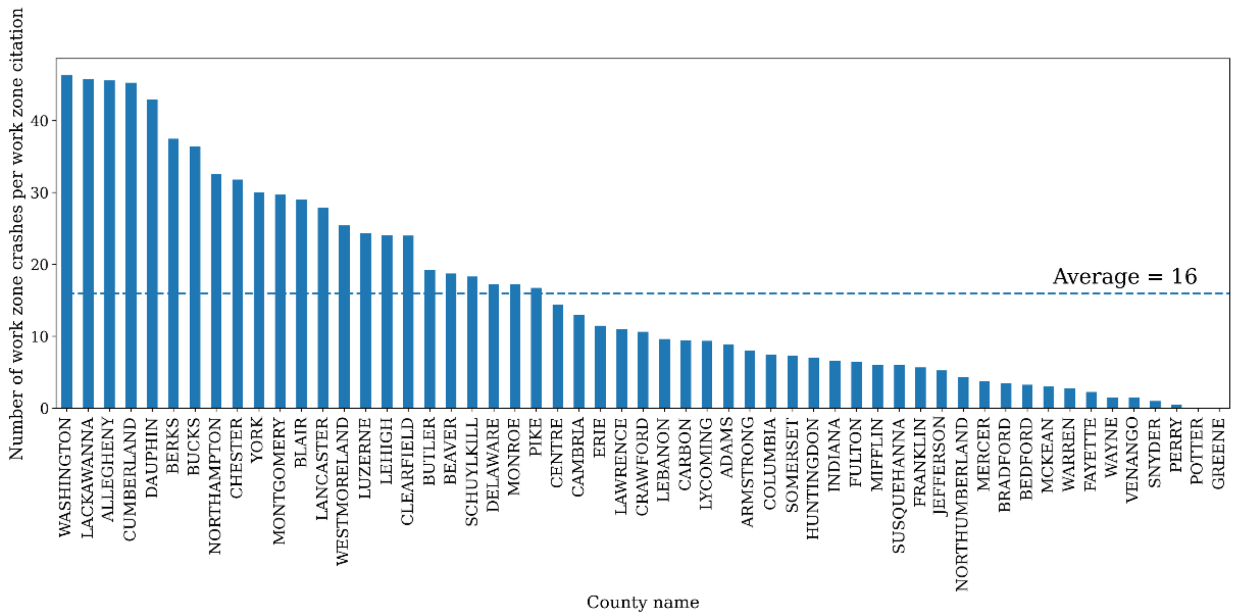

Figure 48 Work zone crashes per number of work zone citations per year by county (2014-2021)

Table 18 provides the average and normalized number of crashes at work zones using the number of citations in each county. Note that in several counties the work zone crash citation data were not available, and hence the normalized number of crashes at work zones using the number of citations were not computed.

Table 18 Average and normalized (by number of citations) crashes at work zones in each county (2014-2021)

County	Work zone crashes	Work zone crashes per citation
ADAMS	9.75	8.88
ALLEGHENY	208.00	45.58
ARMSTRONG	7.88	8.00
BEAVER	24.63	18.75
BEDFORD	5.75	3.25
BERKS	73.88	37.49
BLAIR	11.50	29.00
BRADFORD	2.88	3.50
BUCKS	119.38	36.41
BUTLER	21.25	19.20
CAMBRIA	11.88	13.00
CAMERON	0.38	
CARBON	14.88	9.50
CENTRE	22.50	14.44
CHESTER	59.25	31.79
CLARION	10.13	

County	Work zone crashes	Work zone crashes per citation
CLEARFIELD	8.50	24.00
CLINTON	5.25	
COLUMBIA	5.13	7.50
CRAWFORD	7.13	10.67
CUMBERLAND	53.88	45.30
DAUPHIN	68.75	42.97
DELAWARE	42.13	17.30
ELK	2.00	
ERIE	18.88	11.48
FAYETTE	8.63	2.25
FOREST	0.50	
FRANKLIN	7.88	5.69
FULTON	3.38	6.50
GREENE	2.88	0.00
HUNTINGDON	2.63	7.00
INDIANA	8.13	6.58
JEFFERSON	6.13	5.25
JUNIATA	3.00	
LACKAWANNA	55.38	45.83
LANCASTER	41.38	27.92
LAWRENCE	6.38	11.00
LEBANON	10.88	9.67
LEHIGH	44.38	24.09
LUZERNE	63.25	24.35
LYCOMING	10.88	9.37
MCKEAN	2.63	3.00
MERCER	10.13	3.73
MIFFLIN	4.88	6.00
MONROE	31.63	17.25
MONTGOMERY	154.63	29.71
MONTOUR	6.00	
NORTHAMPTON	34.25	32.58
NORTHUMBERLAND	7.00	4.33
PERRY	1.50	0.50
PHILADELPHIA	171.13	
PIKE	19.13	16.75
POTTER	0.88	0.00
SCHUYLKILL	36.50	18.33
SNYDER	1.50	1.00
SOMERSET	13.75	7.25
SULLIVAN	0.13	
SUSQUEHANNA	4.00	6.00
TIOGA	3.38	

County	Work zone crashes	Work zone crashes per citation
UNION	2.25	
VENANGO	4.13	1.46
WARREN	2.75	2.78
WASHINGTON	70.75	46.33
WAYNE	3.25	1.50
WESTMORELAND	43.88	25.44
WYOMING	3.63	
YORK	60.13	30.03

A number of detailed work zone crash reports were also read to better understand the characteristics of work zone crashes (FHWA, 2014, Pennsylvania Work Zone Safety Implementation Plan). This consisted of all the fatal work zone crashes (a total of 43) in the last three years, 50 randomly chosen serious injury work zone crashes in the last 3 years, and 50 randomly chosen non-injury work zone crashes in the last 3 years. The narrative reports suggest that the work zone contributed to about 50% of the crashes, with the others having to do with impaired drivers, careless lane changing, or distracted driving. Often times the main issue with work zone crashes was vehicles speeding in the work zone.

4. Summary of Findings from Data Analysis

The results of this data analysis suggest the following:

- Speeding is a major driver of behavioral issues that lead to crashes, followed by distracted driving;
- Young drivers are at a higher risk of being involved in a crash than mature drivers (see Figure 49 and Figure 50 for a comparison of average number of young and mature drivers per population, and per licensed drivers, respectively);
- Child passengers are at less danger than the general population in terms of fatalities (see Figure 51 for a comparison of average number of child fatalities per child population to the average number of fatalities per population);
- When considering crashes per population, car crashes have the largest crash rates, followed by motorcycles, pedestrians, and bicycles, which have the lowest crash rates (see Figure 52 for a comparison of the average number of bicycle, pedestrian, motorcycle, and car crashes per population, and Figure 53 for a more detailed plot on the average number of bicycle, pedestrian, and motorcycle crashes);
- When normalized by the percentage of trips taken by different modes, bicycles have the largest crash rate, followed by motorcycles and cars, while pedestrians have the lowest crash rates (see Figure 54 for a comparison of the average number of bicycle, pedestrian, motorcycle, and car crashes per percentage of travel by each mode).

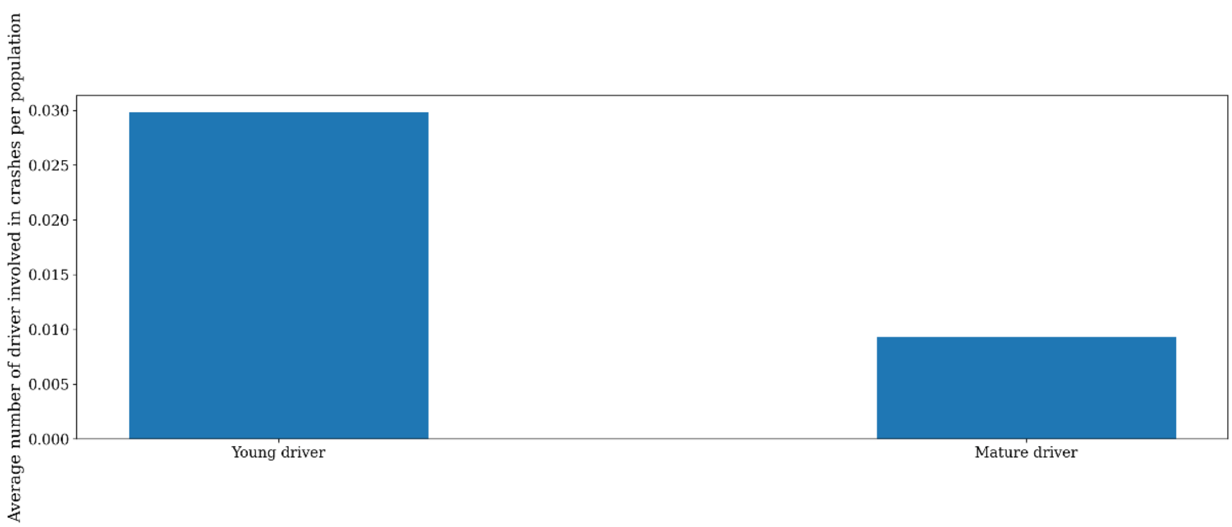

Figure 49 Average number of young and mature drivers involved in crashes per population in PA (2014-2021)

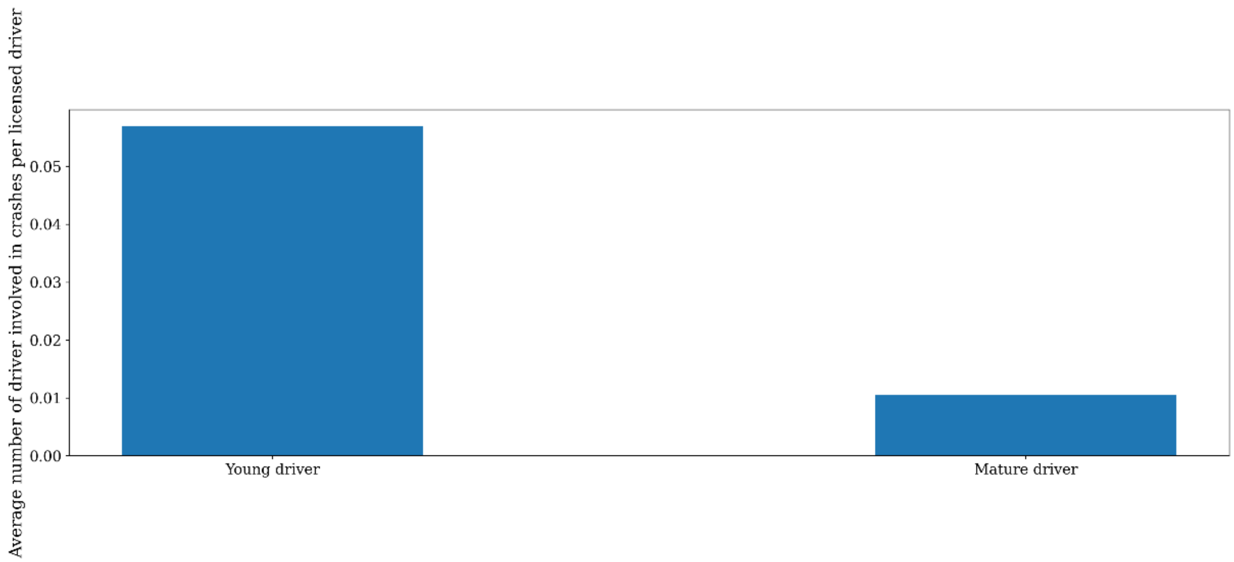

Figure 50 Average number of young and mature drivers involved in crashes per licensed drivers in PA (2014-2021)

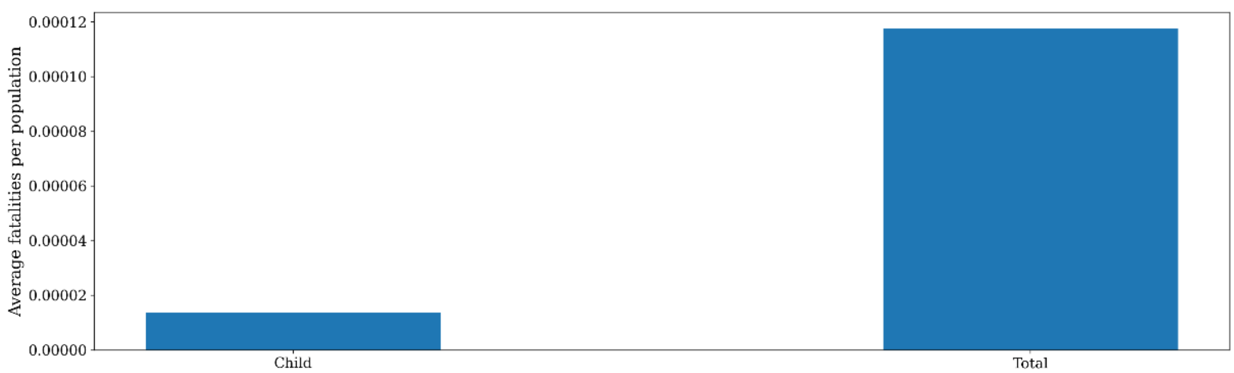

Figure 51 Average child fatalities per child population and general population fatalities per population in PA (2014-2021)

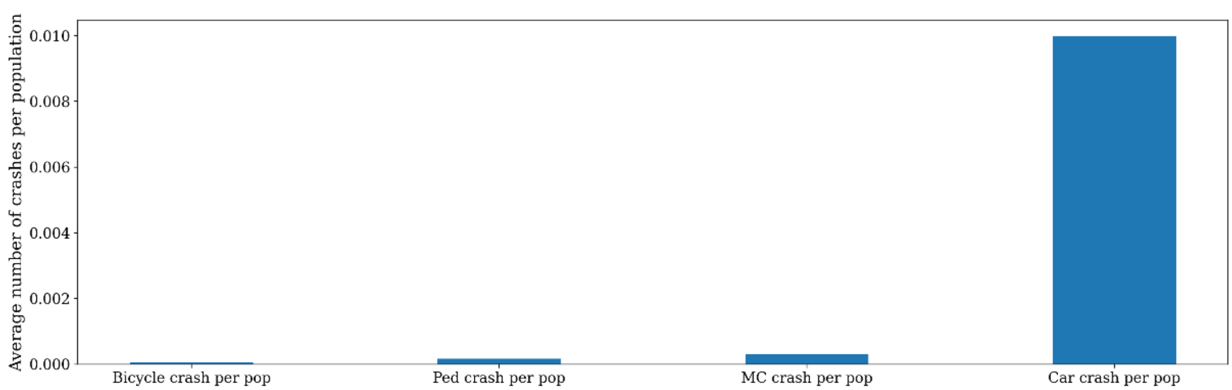

Figure 52 Average number of crashes per population of four travel modes in PA (2014-2021)

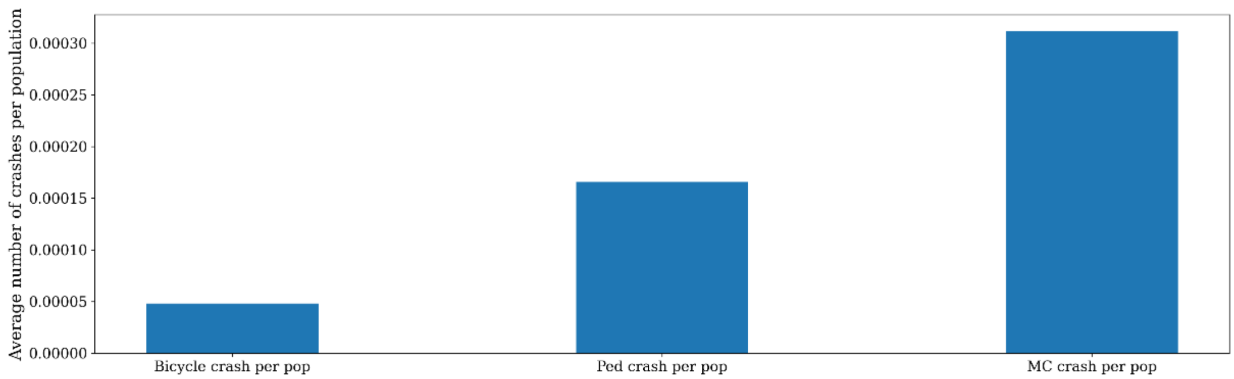

Figure 53 Average number of crashes per population of three travel modes in PA (2014-2021)

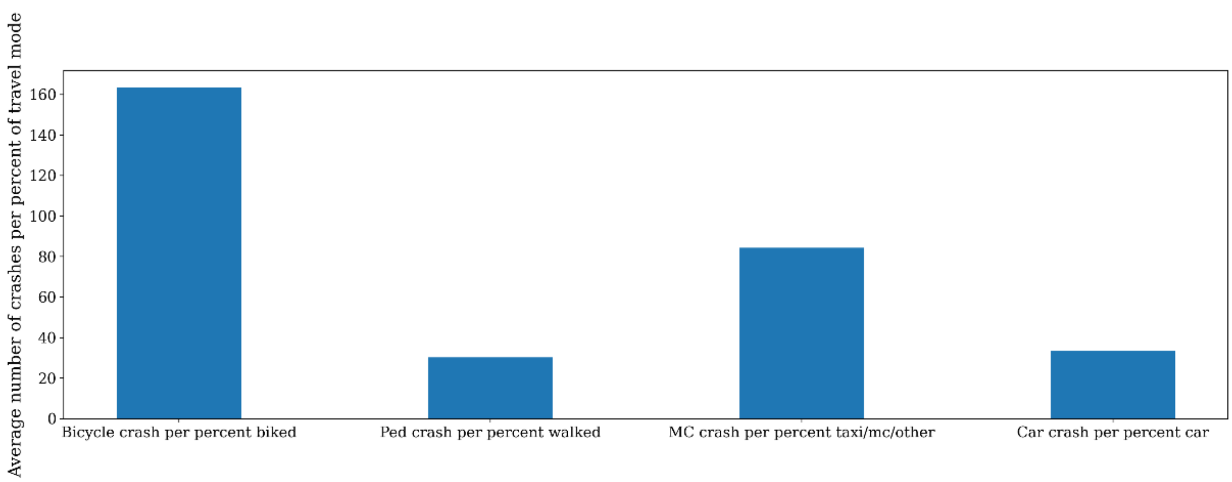

Figure 54 Average number of crashes per percentage of four travel modes in PA (2014-2021)

In the next task, countermeasures that are appropriate to address the behavioral safety issues identified will be investigated. These issues mainly consist of countermeasures for NHTSA aggressive driving, distracted driving, safety of young drivers, and pedestrians. As a starting point, a list of strategies that have been used throughout the United States will be identified through a review of the existing research literature. For each strategy, the conditions under which the countermeasure is applicable will be noted and an assessment of its effectiveness and its relative cost will be determined.

IDENTIFYING POTENTIAL COUNTERMEASURES

Behavioral countermeasures that could be used to reduce the number of crashes are presented next, focusing on areas of concern identified as a result of the data analysis presented above:

1) speeding,
2) distracted driving,
3) young drivers,
4) pedestrians, and
5) motorcycles.

Additionally, behavioral countermeasures for impaired driving are also documented as this is a safety focus area for Pennsylvania. Two major resources are utilized to summarize the proven countermeasures: *Countermeasures that Work: A Highway Safety Countermeasure Guide for State Highway Office* (Venkatraman et al., 2021) and *National Cooperative Highway Research Program (NCHRP) Report No. 622 – Effectiveness of Behavioral Highway Safety Countermeasures (*Preusser et al., 2008). The countermeasures currently used in Pennsylvania are documented from Pennsylvania's 2022 Strategic Highway Safety Plan (Pennsylvania DOT, 2022). Potential novel countermeasures are documented from the Governors Highway Safety Association (*2018 – 2019 Policies and Priorities*, n.d.).

The effectiveness, cost, use, and implementation time of different countermeasures are presented based on (Venkatraman et al., 2021). Specifically, the effectiveness of each countermeasure is rated on the following 1–5 scale:

- an indicator of 4 or 5 means the countermeasure has been determined to be effective;
- an indicator of 3 means the countermeasure is considered promising and likely to be effective;
- an indicator of 2 means the effectiveness has not been determined, since it is still undetermined based on the available evidence; and
- an indicator of 1 means the effectiveness has not been determined, since there has been limited or no high-quality evidence.

The countermeasure effectiveness is assumed to represent the maximum effect that can be realized with high-quality implementation, and the effectiveness ratings are based primarily on demonstrated reductions in crashes. The cost to implement the countermeasure is rated on a 1–3 scale:

- an indicator of 1 means the countermeasure can be implemented with current staff, perhaps with training and limited costs for equipment or facilities;
- an indicator of 2 means the countermeasure requires some additional staff time, equipment, facilities, and/or publicity; and
- an indicator of 3 means the countermeasure requires extensive new facilities, staff, equipment, or publicity, or makes heavy demands on current resources.

The use of a countermeasure is categorized using four levels:

- "High" indicates that the countermeasure is implemented in more than 2/3 of the states or a substantial majority of communities;
- "Medium" means the countermeasure is implemented in less than 2/3 of the states or communities;
- "Low" means the countermeasure is implemented in less than 1/3 of the states or communities; and,
- "Unknown" means data are not available.

Lastly, time to implement, which does not include the time required to enact legislation or establish policies, for a countermeasure is categorized into three levels:

- “Long” indicates it takes more than 1 year to implement;
- “Medium” means it takes between 3 months and 1 year to implement; and
- “Short” means it takes less than 3 months to implement.

The rest of this document is organized as follows. The potential countermeasures for the areas of concern are presented, including discussion on proven countermeasures, countermeasures currently considered in Pennsylvania, and potential novel countermeasures. Next, a summary of findings and recommendations is presented.

5. Potential Countermeasures for the Areas of Concerns

Speeding

Proven Countermeasures

The most common behavioral countermeasure for speeding is law enforcement, since speeding involves traffic law violations. Another critical strategy is to set appropriate speed limits using engineering recommendations and using geometric design to slow vehicles, which is outside the scope of this report. There are eight commonly used countermeasures for speeding behavior, which can be classified into four groups: Laws, Enforcement, Penalties and Adjudication, and Communications and Outreach. Three of these are deemed to be effective, with Penalties and Adjudication being the one ineffective category. Table 19 shows the effectiveness, cost, use, and time to implement for these eight countermeasures documented in (Venkatraman et al., 2021).

Table 19 Countermeasures to reduce speeding

Countermeasure	Effectiveness	Cost	Use	Time
Laws				
Speed limits	5 (+)	1	High	Short
Aggressive Driving and Other Laws	1	1	Low	Short
Enforcement				
Automated Enforcement	5 (+)	3	Medium	Medium
High-Visibility Enforcement	2	3	Low	Medium
Other Enforcement Methods	2	Varies	Unknown	Varies
Penalties and adjudication				
Penalty Types and Levels	2	Varies	High	Low
Diversion and Plea Agreement Restrictions, Traffic Violator School	1	Varies	Unknown	Varies
Communications and Outreach				
Communications and Outreach Supporting Enforcement	3 (+)	Varies	Medium	Medium

The following discusses the effectiveness of the countermeasures shown in Table 19 in more detail.

The effects of maximum speed limits on driving speed, crashes, and fatalities have been studied extensively over the past 40 years (e.g., Fieldwick and Brown, 1987; Preston, 1990; Walz, Hoefliger, and Fehlmann, 1983). In general, these studies have found that reducing speed limits can reduce driving speed, but these reductions are not the same magnitude as the reduction in the speed limit. Further, smaller reductions in speed limit are more likely to be obeyed by drivers than larger reductions (Gayah et al., 2018). Regardless, lowering speed limits (e.g., from 60 km/h to 50 km/h in urban areas) has been found to reduce pedestrian crashes (e.g., by 25–30%) (Preusser et al., 2008). The FHWA CMF Clearinghouse contains several CMFs for reducing speed limits, which suggest a reduction in crash frequency between 6 % and 33%, though some other studies found increased crash frequencies. A more comprehensive effort that includes changes to the roadway geometry (e.g., road diet) and/or enhanced enforcement may be required to reduce travel speeds by the desired amount, especially if the road design does not reflect the desired speed limit and operating speeds.

Aggressive driving laws target drivers who violate traffic laws repeatedly or whose violations lead to crashes producing serious injury or death. There is some evidence that points to small reductions in crashes in relation to license suspension and warning letters (Masten and Peck, 2004); however, these benefits are not always observed (Venkatraman et al., 2021).

Automated enforcement systems function by capturing violations, recording relevant data about the violations, and recording images of the violating vehicles. This strategy is in use across the United States, including Pennsylvania in the form of automated red-light cameras and automated speed-enforcement systems in active work zones. The effectiveness of red-light camera systems has been studied previously, and mixed results with respect to crash type and experience were found. Red-light camera technology can reduce the number of dangerous offset and right-angle crashes at intersections. The most carefully designed studies have found that intersections with high total volumes, higher entering volumes on the main road, longer green (through) cycle lengths, protected left-turn phases, and higher publicity may also increase the safety and cost benefits of red-light camera enforcement (Venkatraman et al., 2021). For example, a study conducted in 2005 found that red-light cameras can reduce all crashes by 16% and specifically right-angle crashes by 24% (Aeron-Thomas and Hess, 2005). These findings are in line with CMFs in the FHWA Clearinghouse, which finds reduction in total crash frequencies of between 2% and 40% (though often associated with an increase in rear-end crash frequencies). Similarly, a study conducted in Canada, Australia, and Europe found that speed cameras can reduce crashes by 20% to 40% (Pilkington and Kinra, 2005). The CMF Clearinghouse contains several CMFs for speed cameras; however, the results vary from decreases in crash frequency of up to 55% to increases in crash frequency of up to 46% for some severe crash types.

High-visibility enforcement (HVE) campaigns have been used to deter speeding and aggressive driving through specific and general deterrence. In the HVE model, law enforcement targets certain high-crash or high-violation geographical areas using either expanded regular patrols or designated aggressive driving patrols. This countermeasure has been examined in several research studies; however, the findings regarding countermeasure effectiveness are inconclusive.

Other enforcement methods, including speed trailers, drone radar, and intelligent speed adaptation, have been recommended to address speeding and aggressive driving. These technological measures have not been adequately studied to reliably determine their effectiveness.

Although implementing penalty types and levels for speeding is widely used, research studies suggest that these types of countermeasures are ineffective in the long term.

There is not sufficient evidence to conclude if "attending traffic violator school" after accumulating a specific number of demerit points on the driver license has positive effects that outweigh the negative effects.

Effective, high-visibility communications and outreach are essential parts of successful speed and aggressive-driving enforcement programs. A meta-analysis of 67 worldwide studies of the effect of road safety campaigns on crashes suggests a general campaign effect of 9%; however, anti-drunk-driving campaigns were considerably more effective than anti-speeding campaigns.

Countermeasures considered for use in Pennsylvania

Currently in Pennsylvania maximum speed limits are utilized. Additionally, Pennsylvania state laws permit speed cameras, speed cameras in active work zones when workers are present, and red-light cameras. Other strategies that are being considered to combat speeding include:

- Increase education and outreach programs,
- Increase enforcement efforts,
- Enact legislation to support enforcement, and
- Increase the use of new technologies.

Potential novel countermeasures

In addition to the countermeasures discussed in (Venkatraman et al., 2021), the Governors Highway Safety Association (GHSA) (*2018 – 2019 Policies and Priorities*, n.d.) also suggests that motor vehicle manufacturers and advertisers should emphasize safety rather than speed in the advertising. Moreover, that document encourages the prohibition of the sale and/or use of speed detection devices by the public because such devices undermine law enforcement efforts to control motor vehicle speeds and enhance highway safety.

Moreover, Fisher et al. (2021) performed a comprehensive review of the effectiveness of dynamic speed feedback signs (DSFS) using published research. The study concludes that DSFS are an effective tool that can provide statistically significant reductions in travel speed at the installation location and downstream of the installation location; these reductions may even last after the DSFS are deactivated. Because a small reduction in speed can significantly reduce injury from crashes, DSFS are recommended as a countermeasure to reduce speeding-related crashes and the severity of these crashes.

Several states have introduced novel approaches to combating speeding on highways. The Maryland Department of Transportation developed a combination of automated enforcement with high-visibility enforcement for work zones. This included an automated speed-enforcement program that also includes advance warning signs and speed display trailers. Citations for speeding are issued if drivers are traveling more than 12 mph over the posted speed limit through the automated speed enforcement device that captures the rear license plates of vehicles in violation. The image is verified by the vendor and matched to a drivers' license database, and then each citation is reviewed and approved or rejected by a law enforcement officer. The long-term program was established after a successful pilot program in 2009–2010. The Michigan Office of Highway Safety Planning (OHSP) developed a teen driver parental toolkit to focus on young drivers and speeding. The toolkit included information about the impact of parental involvement on safe teen driving, the dangers of teen speeding, and teen defensive driving programs, along with resources to assist parent to help their teens develop safe driving behaviors. The toolkit is available on the Michigan OHSP website. This toolkit was promoted through a social media campaign and a 30-second public service announcement, "Put your foot down," which encourages parents to talk to their teen drivers about the dangers of speeding.

Overall, it is believed that speeding legislation should be revenue neutral for it to be the most effective; that is, the goal of speeding legislation should be to reduce speeding and not to gain revenue. Along those lines, the success of implementing automated enforcement depends on it being constantly monitored and being data driven to make it more equitable. For example, a good use of automated enforcement would be to locate the system(s) where there are known speeding issues, and to move them somewhere else once compliance increases and ticketing decreases, in order to solve problems elsewhere.

Distracted driving

<u>*Proven countermeasures*</u>

Although it is difficult to measure or observe, distracted driving is a common driving behavior involved in crashes. There are three types of distraction: visual, manual, and cognitive. Common behaviors that lead to distracted driving include cell phone use, in-vehicle device use, reading or writing, looking at outside object, or eating. However, it is difficult to require drivers to avoid distracted driving because many drivers regard some distractions, such as eating or listening to the radio, to be important and common.

Some states have investigated ways to counter distracted driving, which include laws prohibiting cell phone usage or the development of public educational campaigns. Table 20 shows the most common countermeasures to reduce distracted driving behavior (Venkatraman et al., 2021). Overall, there are six types of countermeasures included, and two of them are found to be effective.

Table 20 Countermeasures to reduce distracted driving

Countermeasure	Effectiveness	Cost	Use	Time
Laws and enforcement				
Graduated Driver Licensing Requirements for Beginner Drivers	5 (+)	1	High	Medium
Cell Phone and Text Messaging Laws	2	1	Medium	Short
High-Visibility Cell Phone/Text Messaging Enforcement	4 (+)	3	Low	Medium
General Distraction Laws	1	Varies	High	Short
Communications and Outreach				
Communications and Outreach on Distracted Driving	1	2	High	Medium
Other				
Employer Programs	1	1	Unknown	Short

Although studies show that young drivers and adults engage in distracted driving at a similar frequency, young drivers are at higher risk for a crash compared to adults (Gerson et al., 2019). Graduated driver licensing (GDL) has been implement in all states in the United States, including Pennsylvania. GDL is a three-phase system for beginning drivers, consisting of a learner's permit, which allows driving while supervised by a fully licensed driver; an intermediate license, which allows unsupervised driving with some restrictions; and a full license, which allows unsupervised driving. The GDL program can include several restrictions, including nighttime driving, passengers, and cell phone and electronic usage, all of which are present in Pennsylvania. These restrictions can reduce the likelihood of distractions for newly licensed drivers. Several studies document that passenger GDL restrictions reduce teenage driver crashes and injuries. It is estimated that this countermeasure can reduce crashes involving young drivers by 20 to 40% (Shope, 2007; Baker, Chen, and Li, 2007). One factor that may undermine the effectiveness of GDL restrictions on cell phone use in teen drivers is the perception that the risk of penalty from not complying with the law is low.

Cell phone and text messaging laws involve legislation to curtail distracted driving or driver cell phone use. The effectiveness of laws banning cell phone use has been examined in several research studies. The results across types of phone use are inconsistent. Specifically, research examining prohibitions on hands-free phone use and texting have yielded mixed results in terms of reductions in phone use while driving and reduced crashes. There is some evidence that banning handheld cell phone use leads to long-term reductions in this behavior; however, it is unknown if drivers are simply switching to hands-free use.

NHTSA conducted a high-visibility enforcement (HVE) demonstration project aimed at reducing cell phone use among drivers in two pilot locations. Results from the program suggest that the handheld cell phone use among drivers dropped 57% in Hartford and 32% in Syracuse. The percentage of drivers observed manipulating a phone (e.g., texting or dialing) also declined. Although these results are encouraging, the effect of HVE campaigns on crashes is not certain. The distracted driving toolkit, which is a document that provides law enforcement with effective strategies to improve distracted driving education and enforcement, also highlights a few case scenarios to improve the effectiveness of enforcement (IACP 2019). For example, channelization, which is creating a safety area with enhanced lights to allow officers to better observe distracted driving, was tested in Montgomery County, Maryland, and was found to be an effective way of enforcing distracted driving. In Ohio, 14 on-ramps and other locations on a corridor were equipped with signage to inform users of the high-enforcement zones and observed that crashes decreased by 38% along this corridor. Although these results are encouraging, the effect of HVE campaigns on crashes is not certain and the relationship between the level of HVE and the safety outcomes for distracted driving has not been identified (Taylor et al., 2022).

General distraction laws would permit distracted drivers who are involved in a crash to be cited for distracted driving. Laws that specifically target distracted drivers are not widely enforced, and this countermeasure has not been systematically examined.

Communications and outreach on distracted driving involve outreach campaigns directed to the general public. Although this countermeasure is widespread, there is little information that exists regarding its effectiveness.

Employer programs involve job-related distracted driving. NHTSA funded the Network of Employers for Traffic Safety (NETS) program aimed at improving the traffic safety of employees. No employer distracted driving program has currently been evaluated.

GHSA (*2018 – 2019 Policies and Priorities*, n.d.) recommends that states prohibit handheld cellphone use by all drivers. GHSA found that the following common elements exist in the most effective laws:

- Unambiguous statutory language that clearly defines when and how a wireless device can and cannot be used
- Penalties and fines in line with other traffic citations
- A combination of high-visibility enforcement of the law and targeted public information, education, and outreach campaigns
- Sustained coalition-building efforts

Countermeasures considered for use in Pennsylvania

Pennsylvania currently has a graduated driver licensing with a minimum duration of 6 months, supervised driving hours, nighttime restrictions, and passenger restrictions. Further, Pennsylvania law prohibits any driver from using wireless communication devices to send, read, or write a text-based communication while the vehicle is in motion. Such violations are treated as a primary offense. Other strategies considered in Pennsylvania to reduce distracted driving include:

- Outreach programs to increase driver awareness of the dangers of distracted driving
- Increase enforcement and enact legislation to address distracted driving
- Implement technology to prohibit or limit the use of cell phone and electronic equipment while a vehicle is in motion

Potential novel countermeasures

In addition to the countermeasures discussed in (Venkatraman et al., 2021), a joint program between End Distracted Driving (EndDD.org) and Safe Roads Alliance (SRA, saferoadsalliance.org) was conducted to investigate the impact of child-to-adult interventions on the distracted driving behavior of the drivers. These aim at teaching elementary and middle school children about the dangers of distracted driving, including providing children with tools to recognize when their drivers are distracted and how to address this (GHSA *2018 – 2019 Policies and Priorities*, n.d.). The results indicated that this program increased the number of children who intervened when their adult driver was engaged in a distracted driving behavior. However, whether the intervention changed the driving behavior is unknown.

Several states recently received a GHSA grant to combat distracted driving (GHSA 2022). Most of the participating states are considering implementing different outreach and awareness programs, many targeted at teens or children. Several will focus on elementary school age kids (e.g., Massachusetts, Missouri) and others on high school ages (e.g., Colorado, Maryland, Missouri, Montana). The Nebraska Department of Transportation is using the funds to team up with a technology company to use digital imaging to collect accurate distracted driving information and analyze the data to understand factors that most contribute to distracted driving.

Furthermore, using higher mounted vehicles (e.g., SUVs or school buses) for enforcement can help improve the detection of distracted driving behavior. Additionally, simply enacting a distracted driving law can improve compliance, even if enforcement is not possible.

Young drivers

<u>*Proven countermeasures*</u>

There are two common reasons for young drivers to have higher crash risks: (1) inexperience and (2) increased novelty-seeking and risk-taking behaviors in adolescents. Table 21 provides a summary of the countermeasures aiming at reducing the number of young drivers involved in traffic crashes documented in (Venkatraman et al., 2021).

Table 21 Countermeasures to reduce number of young drivers involved in crashes

Countermeasure	Effectiveness	Cost	Use	Time
Graduated Driver Licensing				
Graduated Driver Licensing (GDL)	5 (+)	1	High	Medium
Learner's Permit Length, Supervised Hours	5 (+)	1	High	Medium
Intermediate – Nighttime Restrictions	5 (+)	1	High	Medium
Intermediate – Passenger Restrictions	5 (+)	1	High	Medium
Cell Phone Restrictions	2	1	Medium	Medium
Belt Use Requirements	2	1	Low	Medium
Intermediate – Violation Penalties	1	1	High	Medium
Driver Education				
Pre-Licensure Driver Education	2	3	Medium	Long
Post-Licensure Driver Education	1	3	Low	Long
Parents				
Parent Roles in Teaching and Managing Young Drivers	2	2	Medium	Short
Electronic Technology for Parental Monitoring	3 (+)	1	Low	Short
Traffic Law Enforcement				
Enforcement of GDL and Zero-Tolerance Laws	3 (+)	2	Unknown	Short

Many of the countermeasures for young-driver-related crashes focus on driver education that teaches driving skills and safe driving practices. For young drivers, it is found that driver education is more effective if combined with an effective graduated driver licensing program. GDL serves two functions: reducing risk and reducing exposure. GDL's effectiveness in reducing young driver crashes and fatalities has been well-documented. The most restrictive GDL programs are associated with a 38% reduction in fatal crashes and a 40% reduction in injury crashes among 16-year-old drivers. In addition to reducing crashes, GDL is associated with declines in hospitalization rates and citations for 16-year-old drivers.

The available evidence suggests that crash rates decreased after jurisdictions with no learner's permit requirement implemented a 6-month requirement (Preusser et al., 2008). In addition, longer holding periods result in larger crash reductions, since during the learner's permit period crash rates are generally very low. However, the effect of supervised hours is currently unclear.

Nighttime driving restrictions can help reduce the risk for young drivers, since crash rates typically increase for all drivers at night. The restricted hours vary from 1 a.m.–5 a.m. to 6 p.m.–6 a.m.

across the states with GDL programs. Crash reductions resulting from nighttime driving restrictions have been demonstrated, along with evidence to show that larger crash reduction is expected if the night restriction begins earlier. One study found that nighttime crashes could be reduced by over 50% as a result of these nighttime restrictions (Williams, 2007).

Young passengers are also associated with a substantial increase in the risk of a fatal crash for young drivers. To reduce this risk, most states include a passenger restriction in their GDL requirements for intermediate licenses. It has been confirmed by growing evidence that this countermeasure can help reduce young driver crashes. One study has found that passenger restrictions could reduce young driver fatal crashes where a young passenger is injured or killed by approximately 33% (Williams, 2007).

The GDL cell phone restrictions ban all cell phone use. The age group covered by this restriction varies across states. Although it is widely used, its effectiveness remains inconclusive.

The GDL belt use requirements may have more influence on beginning drivers than the state's overall belt use law. To date, there has been only one evaluation for this countermeasure, which found no evidence of its effectiveness.

The GDL intermediate license violation penalties require that an intermediate license holder maintain a violation-free driving record for a specified amount of time before they can obtain a full license. The available data are insufficient to conclude that this countermeasure is effective.

Pre-licensure driver education involves some form of driver education before licensure, typically for drivers younger than 18. Several research studies showed that this countermeasure is ineffective in the long term.

Post-licensure driver education involves post-licensure driver education curricula that are integrated with driver education included in GDL. There are insufficient evaluation data available to conclude that the countermeasure is effective.

Parental roles in teaching and managing young drivers involve interaction and engagement with parents to supervise their teen's driving during the GDL phase. The effectiveness of this countermeasure remains inconclusive.

Electronic technologies have been developed for parents to monitor the driving behaviors and performance of their teenagers. For example, the smartphone-based Teen Driver Support System (TDSS) has been used to provide real-time feedback to teen drivers about unsafe driving behaviors. If a monitored driver does not stop the unsafe behavior, text notifications are used to report the behavior to parents. Many studies have reported positive benefits due to electronic monitoring of teen drivers in both learner and early post-licensure periods.

Enforcement of GDL and zero-tolerance laws prohibit drivers under 21 from having blood alcohol concentrations (BACs) of .02 g/dL or greater. High-visibility enforcement of GDL provisions is found to be most effective if compliance with nighttime and passenger restrictions are included as part of the zero-tolerance efforts. A study in New Jersey has found increases in citations for violations and decreases in crash rates among intermediate license holders in the year after the requirement went into effect.

Countermeasures considered for use in Pennsylvania

Pennsylvania currently has a graduated driver licensing with a minimum duration of 6 months, supervised driving hours, nighttime restrictions, and passenger restrictions. Further, Pennsylvania is considering the following strategies to ensure safety of young drivers:

- Increase education efforts for young and inexperienced drivers, and parents of young drivers;
- Pursue partnerships with non-traditional organizations, such as vehicle manufacturers, travel and vehicle mobile applications, and insurance companies; and
- Increase enforcement efforts for younger driver safety, including stricter graduated driver licensing law requirements.

Potential novel countermeasures

The Ford Motor Company Fund has developed the Ford Driving Skills for Life program, which teaches newly licensed teen drivers the skills for safe driving beyond what is taught in driver education programs. This includes sessions on protecting pedestrians, bicyclists and scooter riders (GHSA *2018 – 2019 Policies and Priorities*, n.d.).

Pedestrian Safety

Proven countermeasures

Factors that contribute to pedestrian crashes include distraction of pedestrians, distraction of drivers, driver's speed, alcohol use by driver or pedestrian, vehicle type and design, roadway design, etc. Basic countermeasure principles for pedestrian crashes include reducing vehicle speed, conducting speed enforcement, reducing exposure to risky situations, increasing enforcement of pedestrian-friendly laws, reducing distracted walking or driving behaviors, decreasing impaired walking or driving, educating pedestrians on required safety behaviors, etc. Table 22 provides a list of countermeasures to reduce pedestrian crashes documented in (Venkatraman et al., 2021). Many of the countermeasures to improve pedestrian safety target children and impaired pedestrians. Almost none of these are found to be effective.

Table 22 Countermeasures to reduce pedestrian crashes

Countermeasure	Effectiveness	Cost	Use	Time
Preschool-Age Children				
Children's Safety Clubs	1	Varies	Unknown	Unknown
Child Supervision	1	1	Unknown	Short
School-Age Children				
Elementary-Age Child Pedestrian Training	3 (+)	1	Unknown	Short
Safe Routes to School	3 (+)	1	High	Short
Walking School Buses	3 (+)	1	Low	Short
Child School Bus Training	2	1	High	Short
Impaired Pedestrians				
Communications and Outreach Addressing Impaired Pedestrians	2	Varies	Low	Medium
"Sweeper" Patrols of Impaired Pedestrians	1	2	Low	Medium
All Pedestrians				
Pedestrian Safety Zones	4 (+)	3	Low	Medium
Reduce and Enforce Speed Limits	3 (+)	1	High	Varies
Conspicuity Enhancement	3 (+)	1	Low	Medium
Enforcement Strategies	3 (+)	2	Low	Short
Driver Training	1	1	Low	Medium
Pedestrian Gap Acceptance Training	1	2	Unknown	Medium
University Educational Campaign	1	1	High	Medium

There are two countermeasures targeted at preschool-age children. Children's safety clubs involve sponsoring safety clubs into which parents can enroll children as young as age three. Children regularly receive books or electronic media from these clubs to improve their walking safety consciousness. The research suggests that this countermeasure does not translate into crash and injury reductions. The countermeasure of child supervision requires training for parents, babysitters, teachers, day care workers, and others licensed to care for children to increase caregiver supervision of children when they are exposed to traffic. This countermeasure has not been systematically examined. There are insufficient evaluation data available to conclude that the countermeasure is effective.

There are four countermeasures that are targeted at school-age children, which are found to be somewhat more effective than those targeted at preschool-age children. Elementary school pedestrian training equips school-age children with knowledge and practices to enable them to walk safely in environments with traffic and other safety hazards. Child pedestrian training programs have been shown to increase knowledge; however, long-lasting behavioral improvements may be harder to achieve. In addition, studies showed that repetition in school-based trainings is important for effectiveness. Numerous studies suggest that knowledge and behaviors of young children may be improved through education and training programs.

The goal of Safe Routes to School Programs (SRTS) is to increase the amount of walking and bicycling trips to and from school while simultaneously improving safety for children walking or bicycling to school. The CDC has identified SRTS programs as one of eight non-clinical, contextbased, community-wide interventions that have the potential to improve population health. A growing body of evidence suggests SRTS programs are effective in reducing injuries.

"Walking school buses" use volunteer adults, usually parents, to walk a group of students on a specific route to and from school, collecting or dropping off children on the way. Studies show that the students with walking school buses are more likely to cross at the intersection or crosswalk (rather than at midblock locations) as opposed to children at schools without walking school buses.

School bus training for children aims at teaching children how to approach, board, disembark, and walk away from school buses safely. There are no evaluation studies showing reductions in crashes or injuries from this countermeasure.

There are two countermeasures targeted at impaired pedestrians. Although communications and outreach can be directed at a variety of audiences, including law enforcement, drivers, alcohol servers and vendors, etc., impaired pedestrians are viewed as a difficult audience for communications because their decision-making is compromised. There are insufficient evaluation data available to conclude that the countermeasure is effective. "Sweeper" patrols of impaired pedestrians aim to keep alcohol-impaired pedestrians off the streets. This countermeasure has not been systematically examined, and there is insufficient evaluation data available to conclude that the countermeasure is effective.

Pedestrian safety zones aim to induce large decreases in pedestrian crashes and injuries by targeting education, enforcement, and engineering measures to geographic areas and audiences where significant portions of the pedestrian crash problem exist (Blomberg and Cleven, 1998). Properly designed and implemented pedestrian zone programs have been shown to be effective in reducing crashes and injuries for older pedestrians, impaired pedestrians, and for child and adult pedestrian crashes. Several implementations of pedestrian safety zones resulted in reductions in pedestrian crashes; for example, an 8–13% reduction in pedestrian crashes was observed in Miami-Dade County, Florida (Zeeger et al., 2008), a reduction of up to 40% of pedestrian crashes was observed (Dunckel et al., 2014) in Montgomery County, Maryland, and mixed results were observed but overall compliance with pedestrian safety zones increased in urban locations and at intersections in nine communities across New Jersey (Gonzales 2017).

Reducing and enforcing speed limits can increase available reaction time for both drivers and pedestrians to avoid crashes. Reduced speed limits with enforcement can reduce vehicle speeds and all types of crashes and crash severity. Although the actual speed reduction is only a fraction of the reduction in speed limits, even 1–2 mph reductions in average speed are estimated to yield substantial fatal and injury crash reductions overall.

Enhancing conspicuity for pedestrians increases the opportunity for drivers to see and avoid pedestrians, particularly when it is dark, since 75% of pedestrian fatalities nationally occur in dark lighting conditions. Widespread use of retroreflective materials would increase the ability of drivers to detect pedestrians at night in time to avoid crashes.

The purpose of enforcement strategies is to increase compliance with the pedestrian and motorist traffic laws that are most likely to enhance the safety of pedestrians in areas where crashes happen or are most likely to happen due to increased pedestrian and motorist exposure. Studies showed that drivers' yielding behaviors were modestly improved only in areas with the highest enforcement, while yielding behaviors in other areas did not change. A NHTSA study that implemented two pedestrian-oriented enforcement campaigns at Wayne State University showed pedestrian violations (walking outside the crosswalk or against the signal) decreased between 17% and 27% immediately after the campaign, with sustained reductions of between 8% and 10% several weeks after active enforcement ceased (Savolainen et al., 2011).

Driver training aims to increase the sensitivity of drivers to the presence of pedestrians and their shared responsibility as drivers to prevent crashes. There is no evidence indicating that this countermeasure is effective.

Pedestrian gap acceptance training, which includes video-based training and feedback geared toward improving pedestrian judgment of speed and/or distance of oncoming traffic, seeks to help pedestrians learn to make better road crossing decisions. While there is some evidence that certain approaches may lead to limited positive outcomes, there is insufficient evaluation data available to conclude that the countermeasure is effective.

University educational campaigns involve conducting educational campaigns targeted at new students and staff that may be unfamiliar with walking and driving in the campus environment to improve their safety. This countermeasure has not been systematically examined. There are insufficient evaluation data available to conclude that the countermeasure is effective.

GHSA (*2018 – 2019 Policies and Priorities*, n.d.) urges local jurisdictions to implement special pedestrian safety programs for groups making up a large percentage of fatalities and injuries (e.g., young children and older adults). In addition, it also supports enforcement of traffic laws to protect pedestrians crossing roadways at crosswalks.

Countermeasures considered for use in Pennsylvania

Strategies being considered in Pennsylvania to improve pedestrian safety include:

- Implementing legislative changes to promote increased pedestrian safety, including enacting and enforcing traffic laws applicable to motor vehicle operators and pedestrians, such as automated speed enforcement, red-light enforcement, pedestrian plazas, and sideguards on trucks.
- Increasing pedestrian safety education and outreach materials for all modes of travel, including education programs such as Safe Routes to School, education on right-of-way at crosswalks, modifying the driver's licensing exam to reflect design standards, and legislative changes, with increased emphasis on education and outreach where pedestrian exposure is greater.

Potential novel countermeasures

An educational program called the Safety City Program was developed in New York City. This program consists of a full-scale city block with working traffic devices, pavement markings etc. that can be used as a training site for elementary age students. This real-size intersection provides hands-on education on the dangers of crossing the street and how to safely navigate intersections.

These locations are typically built on city-owned property; however, despite being an effective program, it has suffered from budget cuts[4].

Motorcycle safety

<u>Proven countermeasures</u>

Motorcycles are generally riskier to operate than passenger vehicles, since motorcycles require more physical strength to operate and do not provide protection in the case of a crash.

Different strategies have been proposed to improve safety for motorcyclists. The most demonstrably effective objectives are to increase helmet use and reduce impaired riding, which are difficult to realize. Another objective is to increase other motorists' awareness of motorcyclists by increasing the visibility of motorcyclists and educating drivers on the importance of sharing the road with motorcycles. Table 23 provides a list of countermeasures to reduce motorcycle crashes documented in (Venkatraman et al., 2021). Note that only one strategy has been deemed effective.

Table 23 Countermeasures to reduce motorcycle crashes

Countermeasure	Effectiveness	Cost	Use	Time
Motorcycle Helmets				
Universal Motorcycle Helmet Use Laws	5 (+)	1	Medium	Short
Motorcycle Helmet Use Promotion Programs	1	Varies	Low to Medium	Varies
Motorcycle Helmet Law Enforcement: Noncompliant Helmets	1	1	Unknown	Medium
Alcohol Impairment				
Alcohol-Impaired Motorcyclists: Detection, Enforcement, and Sanctions	3 (+)	Varies	Unknown	Varies
Alcohol-Impaired Motorcyclists: Communications	1	2	Medium	Medium
Motorcycle Rider Licensing and Training				
Motorcycle Rider Licensing	1	1	High	Medium
Motorcycle Rider Training	2	2	High	Varies
Communications and Outreach				
Conspicuity and Protective Clothing	1	Varies	High	Medium
Motorist Awareness of Motorcyclists	1	Varies	High	Medium

Studies in states that enacted universal helmet laws observed use rates of 90% or higher immediately after the laws became effective, compared to 50% or lower before the laws. The use of the motorcycle helmet aims at protecting riders' heads in crashes. Research indicates that helmets reduce motorcycle rider fatalities by 22 to 42% and brain injuries by 41 to 69%. It can also reduce the hospital treatment cost and lower the insurance claims.

[4] http://bronxjournal.com/?p=22351

There appear to be no formal evaluations of the effect of helmet use promotion programs in states without universal helmet laws.

Motorcycle helmet law enforcement involves legislation and enforcement of laws that require motorcyclists to wear helmets. The effectiveness of an enforcement program on noncompliant helmet use has not been evaluated.

Law enforcement officers on traffic patrol use characteristic driving behaviors, or cues, to identify drivers who may be impaired by alcohol. Vehicle impoundment or forfeiture can be a more effective deterrent to drinking and driving for motorcyclists than the riders for other vehicle types. Research has found that motorcycle drivers do not think fines and license suspension are a deterrent to impaired riding, however, they are highly concerned for the safety and security of their motorcycles (Becker et al., 2003). Sobriety checkpoints and saturation patrols have demonstrated effectiveness in reducing impaired driving and crashes generally.

A literature search found no evaluations of the safety effectiveness of any drinking and riding campaigns.

Licensing aims at ensuring that motorcyclists have the minimum skills needed to operate a motorcycle. This countermeasure has been widely employed; however, the effectiveness of current licensing and testing on crashes and safety has not been evaluated.

Motorcycle ride training is widely used; however, the evidence regarding effectiveness remains inconclusive.

Conspicuity and protective clothing involves communications and outreach campaigns promoting the use of protective clothing and measures that increase rider conspicuity, such as clothing and auxiliary devices. The countermeasure is widely used; however, there is insufficient evaluation data to determine the extent of effectiveness.

Motorist awareness of motorcyclists involves communications and outreach campaigns to increase other drivers' awareness of motorcyclists. Typical themes are "Share the Road" or "Watch for Motorcyclists." Although this countermeasure is widely used, no evaluations of the effectiveness of campaigns to increase driver awareness of motorcyclists are available.

Countermeasures considered for use in Pennsylvania

The universal helmet law was repealed in 2003.

Potential novel countermeasures

The Michigan Office of Highway Safety Planning (OHSP) initiated an outreach program for "unendorsed" motorcycle operators after discovering that many motorcycle crashes were attributed to unendorsed operators. Hence, the Michigan OHSP reached out to known unendorsed operators by mailing a postcard to encourage them to obtain proper training and become an endorsed motorcyclist.

Impaired driving

Impaired driving is discussed for completeness of the proven countermeasures, since this is a safety focus area for Pennsylvania, even though impaired driving was not identified as an area of concern in Task 1. Hence, only the proven countermeasures are discussed in this section.

<u>*Proven countermeasures*</u>

Impaired drivers are defined as the motor vehicle operators with blood alcohol concentrations of >.08 g/dL. Four basic strategies that are used to reduce crashes involving impaired driving include: deterrence, prevention, communications and outreach, and alcohol and drug treatment. Table 24 provides a list of countermeasures to reduce motorcycle crashes documented in (Venkatraman et al., 2021).

Table 24 Countermeasures to reduce crashes involving impaired driving

Countermeasure	Effectiveness	Cost	Use	Time
Deterrence: Laws				
Administrative License Revocation or Suspension	5 (+)	3	High	Medium
Open Container	3 (+)	1	High	Short
High-BAC Sanctions	3 (+)	1	Medium	Short
BAC Test Refusal Penalties	3 (+)	1	Unknown	Short
Alcohol-Impaired Driving Law Review	2	2	Unknown	Medium
Deterrence: Enforcement				
Publicized Sobriety Checkpoints	5 (+)	3	Medium	Short
High-Visibility Saturation Patrols	4 (+)	2	High	Short
Preliminary Breath Test Devices	4 (+)	2	High	Short
Passive Alcohol Sensors	4 (+)	2	Unknown	Short
Integrated Enforcement	3 (+)	1	Unknown	Short
Deterrence: Prosecution and Adjudication				
DWI Courts	4 (+)	3	Low	Medium
Limits on Diversion & Plea Agreements	4 (+)	1	Medium	Short
Court Monitoring	3 (+)	1	Low	Short
Sanctions	2	Varies	Varies	Varies
Deterrence: DWI Offender Treatment, Monitoring, and Control				
Alcohol Problem Assessment and Treatment	5 (+)	Varies	High	Varies
Alcohol Ignition Interlocks	5 (+)	2	Medium	Medium
Vehicle and License Plate Sanctions	4 (+)	Varies	Medium	Medium
DWI Offender Monitoring	4 (+)	3	Unknown	Varies
Lower BAC Limit for Repeat Offenders	4 (+)	1	Low	Short
Prevention, Intervention, Communications and Outreach				
Alcohol Screening and Brief intervention	5 (+)	2	Medium	Short
Mass-Media Campaigns	3 (+)	3	High	Medium
Responsible Beverage Service	2	2	Medium	Medium
Alternative Transportation	3 (+)	2	Unknown	Short
Designated Drivers	2	1	Medium	Short

Countermeasure	Effectiveness	Cost	Use	Time
Underage Drinking and Drinking and Driving				
Minimum Drinking Age 21 Laws	5 (+)	3	High	Low
Zero-Tolerance Law Enforcement	3 (+)	1	Unknown	Short
Alcohol Vendor Compliance Checks	3 (+)	2	Unknown	Short
Other Minimum Legal Drinking Age 21 Law Enforcement	3 (+)	2	Varies	Varies
Youth Programs	2	Varies	High	Medium
Drug-Impaired Driving				
Enforcement of Drug-Impaired Driving	3 (+)	2	Unknown	Short
Drug-Impaired-Driving Laws	1	Unknown	Medium	Short
Education Regarding Medication	1	Unknown	Unknown	Long
Enforcement of Drug-Impaired Driving	3 (+)	2	Unknown	Short

Administrative license revocation or suspension (ALR or ALS) laws allow law enforcement and driver licensing authorities to suspend driver licenses if drivers fail or refuse to take blood alcohol concentration (BAC) tests. Many states have had ALR and ALS laws in place for decades. Studies have shown that these laws can effectively reduce the fatalities and injuries from crashes involving impaired driving (Wagenaar et al., 2000; Wagenaar and Maldonado-Molina, 2007).

Open-container laws prohibit possession of any open alcoholic beverage container and the consumption of alcoholic beverages by drivers or passengers. A study of four states that enacted these laws in 1999 found the proportion of alcohol-involved fatal crashes appeared to decline in three of the four states during the first 6 months after the laws were implemented; however, the reductions were not statistically significant (Stuster et al., 2002). In general, the proportion of alcohol-involved fatal crashes was higher in states with no open-container laws than in states with laws. In addition, active enforcement of open container laws is important for open container laws to be effective.

Based on the observation that many high-BAC drivers are habitual impaired-driving offenders, some states have increased the penalties for drivers with high BACs. A study on the evaluation of high-BAC sanctions in Minnesota demonstrated that it has increased the severity of case dispositions for high-BAC offenders, although the severity apparently declined somewhat over time (McCartt and Northrup, 2004).

All states have established separate penalties for BAC test refusal, typically involving administrative license revocation or suspension. It has been found that test refusal rates appear to be lower if the consequences of test refusal are greater than the consequences of test failure (Zwicker et al., 2005). No study has examined whether stronger test refusal penalties are associated with reduced alcohol-impaired crashes.

Many states have modified their laws to incorporate new ideas such as new definitions of the offense of driving while impaired and new technology and methods for determining impairment. There are insufficient evaluation data available to evaluate if the countermeasure is effective.

Sobriety checkpoints indicate law enforcement officers stopping every vehicle or stopping vehicles at some regular interval at predetermined checkpoints to check for driver impairment. Checkpoints should be highly visible, publicized extensively, and conducted regularly. The CDC's systematic review of 15 high-quality studies found that checkpoints reduce alcohol-related fatal crashes by 9%. Other studies also found that checkpoints can reduce crashes involving impaired driving (Erke et al., 2009).

A saturation patrol consists of a large number of law enforcement officers patrolling a specific area looking for impaired drivers, usually taking place at times and locations where impaired-driving crashes commonly occur (e.g., nights and weekends). A demonstration program in Michigan, where sobriety checkpoints are prohibited by state law, revealed that saturation patrols can be effective in reducing alcohol-related fatal crashes when accompanied by extensive publicity (Fell et al., 2008).

Law enforcement officers use breath test devices in the field to help establish probable cause for a driving while intoxicated (DWI) arrest. Law enforcement officers generally agree that breath test devices are useful. There is some evidence that breath test devices use increases DWI arrests and reduces alcohol-involved fatal crashes.

A passive alcohol sensor (PAS) detects alcohol presence in the air. It is used by an officer to measure alcohol presence in the air where the driver is breathing. PAS units are typically used at the vehicle window after a traffic stop or at a checkpoint. Results showed that a PAS score was a strong predictor of a driver's BAC status (Voas et al., 2006).

Impaired drivers are detected and arrested through regular traffic enforcement and crash investigations as well as through special impaired-driving checkpoints and saturation patrols. This offers extra opportunities to detect impaired drivers. This countermeasure has been demonstrated to be effective in reducing fatal crashes involving impaired driving (Jones et al., 1995).

DWI courts are specialized courts dedicated to changing the behavior of DWI offenders through providing a systematic and coordinated approach to prosecuting, sentencing, monitoring, and treating DWI offenders. DWI courts usually target the enrollment, treatment, and supervision of drivers with prior DWI offenses or those with BACs of .15 g/dL or higher. A meta-analysis of 28 studies suggests DWI courts reduce recidivism among DWI offenders by approximately 50% compared to traditional court programs; however, more rigorous evaluations are still needed (Mitchell et al., 2012).

Diversion programs defer sentencing while a DWI offender participates in some form of alcohol education or treatment. If the education or treatment is completed satisfactorily, charges are dropped or the offender's DWI record is erased in many states. A review of 52 studies of plea agreement restrictions applied in combination with other DWI control policies found an average reduction of 11% across outcome measures such as rates of crashes/fatalities/injuries, alcohol-involved crashes, and roadside BACs (Wagenaar et al., 2000).

In court monitoring programs, people observe, track, and report on DWI court or administrative hearings. A study found that officials in 51 communities believed that court monitoring programs helped increase DWI arrests, decrease plea agreements, and increase guilty pleas (Probst et al., 1987).

Sanction countermeasures involve standard court sanctions for DWI offenses, which include driver's license suspension or revocation, fines, jail, community service, and victim impact panels. Most of these measures are widely used. Their effectiveness has been examined in research studies. Despite some positive findings, the balance of evidence regarding the effectiveness of these countermeasures remains inconclusive.

It is recognized that many DWI first offenders and most repeat offenders will continue to drink and drive unless their alcohol abuse problems are addressed. DWI arrests provide opportunities to refer them to appropriate treatment, ranging from classroom alcohol education programs to long-term inpatient facilities. Studies have found that treatment reduced DWI habits and alcohol-related crashes (Wells-Parker et al., 1995).

An alcohol ignition interlock prevents a vehicle from starting unless the driver provides a breath sample with a BAC lower than a pre-set level. Interlocks are highly effective in allowing vehicles to be started by sober drivers, but not by alcohol-impaired drivers. A review of 15 studies of interlock effectiveness found that offenders who had interlocks installed in their vehicles had arrest recidivism rates that were 75% lower than drivers who did not have interlocks installed (Elder et al., 2011). Also, studies showed that alcohol-related crashes can be decreased while interlocks are installed in vehicles.

The vehicle and license plate sanctions, including special license plates, license plate impoundment, vehicle immobilization, vehicle impoundment, and vehicle forfeiture, are intended to prevent the offender from driving the vehicle while the sanctions are in effect. It indicates that the sanctions can reduce the corresponding recidivism and driving.

DWI offender monitoring, including formal intensive supervision programs, home confinement with electronic monitoring, and dedicated detention facilities, is the common feature of the most successful methods for controlling convicted DWI offenders and reducing recidivism. Intensive supervision, home confinement with electronic monitoring, and dedicated detention facilities all have been evaluated in individual settings and show substantial reductions in DWI recidivism.

Except for Utah, all states have illegal BAC limits of .08 g/dL. Studies show this decreased BAC level contributed to a reduction in the proportion of repeat offenders in fatal crashes.

Alcohol screening uses a few questions to estimate the level and severity of alcohol use and to determine whether a person may be at risk of alcohol misuse or dependence. Brief interventions focus on awareness of the problem and motivation toward behavior change and are short, one-time encounters with people who may be at risk of alcohol-related injuries or other health problems. The combination of these two strategies is most commonly used with injured patients in hospital emergency departments and trauma centers. Many show that alcohol screening and brief interventions in medical facilities can reduce drinking and self-reported driving after drinking studies (D'Onofrio and Degutis, 2002; Moyer et al., 2002).

A mass media campaign, which is a standard part of every state's efforts to reduce alcohol-impaired driving, consists of intensive communication and outreach regarding alcohol-impaired driving using radio, television, print, social, and other mass media. A study indicated that mass media campaigns were associated with a 13% reduction in alcohol-related crashes (Elder et al., 2004).

The countermeasure of responsible beverage service covers alcohol sales policies and practices that prevent or discourage restaurant/bar patrons from driving while impaired by alcohol. This countermeasure is widely used; however, evidence regarding countermeasure effectiveness remains inconclusive.

Alternative transportation describes methods people can use to get to and from places where they drink without having to drive. It includes both for-profit, including transportation network companies, and nonprofit safe rides, which often operate in specific regions such as university campuses. Studies indicate this countermeasure can reduce impaired driving-related crashes (Lacey et al., 2000).

Designated drivers are people who agree not to drink so they can drive home their friends who have been drinking. The countermeasure effectiveness has been examined in a few research studies; however, evidence regarding countermeasure effectiveness remains inconclusive.

The minimum age to buy alcohol is 21 in all 50 states and the District of Columbia. Studies indicate that crashes decrease when the minimum legal drinking age is raised (Shults et al., 2001).

Zero-tolerance laws set a maximum BAC of less than .02 g/dL or less for drivers under 21. Violators have their driver licenses suspended or revoked. However, usually this law is not actively enforced or publicized. Studies show that alcohol-involved crashes for drivers under 21 dropped after the law was implemented (Blomberg, 1992).

Although alcohol venders must verify the age of young customers to be sure they are at least 21 in all 50 states, studies indicate that young buyers successfully purchased alcohol in 44% to 97% of attempts without showing identification (Goodwin et al., 2005). To reduce the likelihood that alcohol vendors sell alcohol to underage people, law enforcement officers can conduct frequent compliance checks. Several studies document that well-publicized and vigorous compliance checks reduce alcohol sales to youth (Elder et al., 2007).

Minimum legal drinking age law enforcement can take several forms, such as actions directed at alcohol vendors, youth, and adults. Studies indicate this countermeasure can reduce fatal crashes among underage drivers.

Youth programs seek to motivate youth not to drink, not to drink and drive, and not to ride with drivers who have been drinking. However, the evidence regarding their effectiveness remains inconclusive.

Enforcement of drug-impaired driving laws can be difficult. Although several devices are available that allow officers to screen suspects for illegal drug use at point-of-contact, none have been proven to be accurate and reliable. To date there have been no studies examining the effectiveness of enforcement in reducing drug-impaired driving or crashes.

The drug-impaired-driving law countermeasure involves laws that prohibit the use of impairing drugs by drivers. To date there have been no evaluations of the effect of drug-impaired-driving laws on the prevalence of drug-impaired driving or crashes.

The countermeasure of education regarding medications involves providing education to physicians, pharmacists, and patients about the potential risk of motor vehicle crashes associated with certain prescription medications. This countermeasure has only been examined in a few studies. Overall, there are insufficient evaluation data available to conclude that the countermeasure is effective.

In addition to the countermeasures mentioned above, (*2018 – 2019 Policies and Priorities*, n.d.) suggested several other countermeasures that have the potential to reduce impaired driving, such as self-sufficient impaired driving programs, alcohol advertising, taxes on alcoholic beverages, and alcohol equivalency. However, the effectiveness of these countermeasures is not clear.

6. Summary and Recommendations

As a result of the literature review on potential countermeasures for identified areas of concern, the following countermeasures appear to have the most promise in terms of a combination of effectiveness and cost:

- Speeding
  - Speed limits
  - Automated enforcement of speed limits (e.g., focused on work zones)
  - Communication and outreach supporting enforcement (e.g., the teen driver parental toolkit available from the Michigan OHSP website)
- Distracted driving
  - Graduated driver licensing requirements for beginner drivers
  - High-visibility cell phone/text messaging enforcement
- Young drivers
  - GDL requirements for beginner drivers, specifically focusing on:
    - Longer learner's permit period
    - Nighttime driving restrictions
    - Passenger restrictions
  - Enforcement of GDL and zero-tolerance laws
- Pedestrians
  - Pedestrian safety zones (i.e., targeted geographic areas where significant portions of the pedestrian crash problem exist for education, enforcement, and engineering measures)
  - Elementary-age child pedestrian training
  - Safe routes to school
  - Walking school buses
  - Reduced speed limits
  - Enforcement of reduced speed limits
  - Conspicuity enhancements
- Motorcycles
  - Universal motorcycle helmet use laws
  - Alcohol-impaired motorcyclists: detection, enforcement, and sanctions
  - Licensing unendorsed drivers

7. Implementation Plan

This section explores the implementation of the above-mentioned countermeasures given the applicable laws, regulations, and policies in Pennsylvania.

Speeding

<u>Reduced Speed Limits</u>

Within Pennsylvania, procedures to reduce speed limits are dictated by Pennsylvania Statues Title 75 Section 3362 and 3363 and are reiterated within PennDOT Publication 212. The procedures are as follows:

"Engineering and traffic studies are not required for statutory speed limits, but documentation should be on file for urban districts and residence districts to show that the requirements defined in the Vehicle Code are satisfied. The speed limit may be established in multiples of 5 miles per hour up to the maximum lawful speed. The speed limit should be within 5 mph of the average 85th percentile speed or the safe-running speed on the section of highway, except the speed limit may be reduced up to 10 mph if one or more of the following conditions are satisfied: major portion of the highway has inefficient stopping sight distance if traveling at the 85th percentile speed or the safe-running speed, available corner sight distance on side roads is less than the necessary stopping sight distance values for through vehicles, the majority of crashes are related to excessive speed and the crash rate during a minimum 12-month period is greater than the applicable rate in the most recent high-crash rate or high-crash severity rate table included in the appendix of Official Traffic-Control Devices."[5]

The National Highway Traffic Safety Administration (NHTSA) suggests that roadway design changes may be considered to reduce speed limits on a road in which the procedures do not warrant a change on its own. Such design changes include road diets, roundabouts, and traffic calming.

In short, using a reduced speed limit as a stand-alone treatment in an attempt to lower speeds on a specific street or road could prove difficult given these guidelines. It is likely that other countermeasures would need to be employed, such as traffic calming, which would lower the 85^{th} percentile speed, which in turn would allow for a lower posted speed limit.

<u>Automated Enforcement</u>

Automated enforcement authorization in Pennsylvania began with Act 86 of 2018, which authorized a five-year pilot program of the automated speed enforcement in active work zones (AWZSE). Improvements to the program and required legislative action in 2023 to permit the use of AWZSE in Pennsylvania after February 2024 is discussed in PennDOT's 2023 *Automated Work Zone Speed Enforcement Annual Report*. [6]

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[5] Chapter 212. *Official Traffic Control Devices*. Commonwealth of Pennsylvania Department of Transportation, https://www.dot.state.pa.us/public/PubsForms/Publications/PUB%20212.pdf.

[6] 2023 *Annual Report Automated Work Zone Speed Enforcement*. https://workzonecameras.penndot.gov/wp-content/uploads/2023/04/2023PennDOT-AWZSE-Report_033023.pdf.

Also authorized in Act 86 of 2018 was automated speed enforcement on Roosevelt Boulevard (US 1) in Philadelphia, which is managed by the Philadelphia Parking Authority. The automated speed enforcement program began in June of 2020. Philadelphia Parking Authority's 2023 Speed Camera Report highlights that total crashes have declined by 36% and that there has been reduced speeding in the corridor. Legislative action will need to be taken to expand the program on US 1 or to other locations in Pennsylvania.[7]

Other automated traffic enforcement efforts include the Red-Light Camera program, which was enacted in 2005 by the Pennsylvania State Legislature for Philadelphia.[8] Then, a bill in 2010 authorized 19 of PA's most populated cities to install red-light cameras.[9] Currently, Title 75 Section 3117 of the PA General Assembly authorizes automated red-light enforcement systems in certain municipalities. The general rule is as follows:

"A municipality, upon passage of an ordinance, is authorized to enforce section 3112(a)(3) (relating to traffic-control signals) by recording violations using an automated red light enforcement system approved by the department."

The applicability, from Title 75 Section 3117 is as follows:

"(1) This section shall only be applicable at intersections in a municipality designated by the municipality with the approval of the secretary under the requirements of paragraph (2).
(2) No automated red-light system shall be installed until the municipality provides notice to the department of the location of each intersection. After receiving notice and before the system may be installed, the department shall have 60 days to review each proposed intersection and to issue a recommendation to the municipality which shall include all of the following:
(i) A statement on whether the proposed intersection is an appropriate location for an automated red light enforcement system.
(ii) The data on which the department based the recommendation.
(3) No system shall be installed if the department does not issue a recommendation approving the location to the municipality.
(4) The department may identify the location of an alternate intersection in the municipality that it determines is appropriate for an automated red light enforcement system."

To summarize, Pennsylvania already has legislation allowing some limited automated enforcement activities. It is presumed that expansion of these efforts would need to be passed by the state legislature and governor's office.

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[7] *Roosevelt Boulevard Automated Speed Camera Annual Report*. Philadelphia Parking Authority, Apr. 2023 https://philapark.org/wp-content/uploads/2023-Speed-Camera-Report-Final-32023.pdf.
[8] Red Light Cameras | The Philadelphia Parking Authority. 10 Mar. 2014, https://philapark.org/red-light-cameras/
[9] Pa. Senate Approves Red-Light Cameras In 19 Cities. 25 Oct. 2011 https://www.cbsnews.com/philadelphia/news/pa-senate-approves-red-light-cameras-in-19-cities/.

<u>*Communication and Outreach Supporting Enforcement*</u>

Four strategies were identified under the heading of communication and outreach supporting enforcement. Each is discussed separately below.

1. Anti-Speeding Campaigns

It is assumed that this would be a media-based campaign that follows the format of other PennDOT-based public service announcements (PSAs). In this particular case, the PSA would target speeding. It is worth noting that PennDOT currently has a "Be Safe PA" that addresses aggressive driving, which is presumed to have overlap with anti-speeding[10].

2. Dynamic Speed Feedback Signs

PennDOT and municipalities can and do place dynamic speed feedback signs. Most implementations are temporary unless the location is deemed appropriate for permanent installation. The *Manual on Uniform Traffic Control Devices* (MUTCD) provides guidance on the design characteristics of the signs; however, there is no guidance on placement or installation. Chapter 2B.13 of MUTCD states:

"A changeable message sign that displays to approaching drivers the speed at which they are traveling may be installed in conjunction with a Speed Limit sign. If a changeable message sign displaying approach speeds is installed, the legend YOUR SPEED XX MPH or such similar legend should be displayed. The color of the changeable message legend should be a yellow legend on a black background or the reverse of these colors." (FHWA 2009, MUTCD)

There is also no guidance provided on placement or installation of dynamic speed feedback signs within Publications 212 or 236; however, FHWA indicates the following:

"Speed feedback signs may be permanent or temporary installations. However, permanent installations are usually restricted to selected locations since a proliferation of speed feedback signs could lessen the effectiveness of the sign when they are needed most."[11]

Previously, PennDOT had eight dynamic speed feedback signs that were temporarily deployed as needed (Donnell and Cruzado, 2008). The status of these eight temporary dynamic feedback signs is unknown at this time.

In summary, the usage of these signs is considered to be routine at this point. Further implementation would likely only involve finding additional funding at the state and local levels for the procurement and deployment of these devices.

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[10] "Aggressive Driving." Pennsylvania Department of Transportation https://www.penndot.pa.gov/TravelInPA/Safety/TrafficSafetyAndDriverTopics/Pages/Aggressive-Driving.aspx. Accessed 30 May 2023.

[11] "Speed Limit Sign and Placement." Federal Highway Administration. https://highways.dot.gov/safety/speed-management/methods-and-practices-setting-speed-limits-informational-report/speed-1.

3. Advertising of New Vehicles for Sale

To encourage advertising safety instead of speed for new vehicles for sale, the Governors Highway Safety Association (GHSA) *"offers to work with other organizations in the transportation and highway safety communities to develop plans and support for responsible corporate advertising."* (*2018 – 2019 Policies and Priorities*, n.d.). PennDOT could work with the GHSA to develop the plans and support. Otherwise, legislation would need to pass at a national level, similar to that which has been established for the advertisement of cigarettes or alcohol, to regulate vehicle advertisements promoting speeding.

4. Radar Detectors

The Pennsylvania state government would need to pass a bill that makes radar detectors illegal in Pennsylvania. Currently radar detectors are illegal in Virginia and Mississippi.

Distracted Driving

<u>*Graduated Driver Licensing for Beginner Drivers*</u>

Graduated driver licensing is in place in Pennsylvania but could be made more stringent through future acts of the state legislature. For example, Act 81 of 2011 in PA increased learning permit hours from 50 to 65 hours with 10 at nighttime and 5 in poor weather conditions and placed restrictions in which a driver must not have more than one passenger under the age of 18 who is not an immediate family member.[12] In Pennsylvania, further study to determine how the existing system is deficient and what changes could be implemented would be required.

<u>*High-Visibility Cellphone and Text-Messaging Enforcement*</u>

Local or state police can receive money from NHTSA to perform a high-visibility enforcement campaign on a temporary basis.[13] To do this on a more permanent basis or without NHTSA funding locally or statewide will require an increase in budget.

The goal of High Visibility Enforcement (HVE) is to increase awareness of enforcement efforts and create deterrents. The locations are chosen based on safety data. NHTSA highlights visibility elements that can be used such as: road signs, specially marked squads, magnetic HVE signs on patrol vehicles, specially marked BATmobiles, specially marked vests, flyers/brochures, or business cards handed out to drivers.[14] The NHTSA "U Drive. U Text. U Pay." High-Visibility Enforcement Campaign *"reminds drivers of the deadly dangers and the legal consequences - including fines - of texting behind the wheel."*[15] In our research, we found at least one documented

[12] "2011 Act 81." The Official Website for the Pennsylvania General Assembly. https://www.legis.state.pa.us/cfdocs/legis/li/uconsCheck.cfm?yr=2011&sessInd=0&act=81.
[13] "Statewide Distracted Driving Enforcement and Awareness Campaign." *Trentonian*, 29 Mar. 2023 https://www.trentonian.com/2023/03/29/statewide-distracted-driving-enforcement-and-awareness-campaign-3.
[14] High Visibility Enforcement (HVE) Toolkit. NHTSA. https://www.nhtsa.gov/enforcement-justice-services/high-visibility-enforcement-hve-toolkit.
[15] Distracted Driving | NHTSA. https://www.nhtsa.gov/campaign/distracted-driving.

case at a local municipality in Pennsylvania that participated temporarily in this campaign (Lower Moreland Township, Montgomery County).[16]

Pennsylvania vehicle code prohibits texting while driving. This includes sending, reading, or writing a text-based communication while the vehicle is in motion. A $50 fine plus court costs could be assessed if stopped for this violation.[17] Increased enforcement occurs, but it is typically temporary.

Young Drivers

GDL for Beginner Drivers with Longer Learning Permit, Night-time Driving Restrictions, and Passenger Restrictions

As noted previously, Pennsylvania's GDL could be made more stringent regarding longer learning permits, night-time driving restrictions, and passenger restrictions through an act in the state legislature and governor.

Enforcement of GDL and Zero-Tolerance Laws

New Jersey requires a decal to indicate the vehicle is driven by a driver with a probationary driver's license to help with enforcement of the GDL.[18] An act of state legislature would need to pass to make the decal required in Pennsylvania. To increase enforcement, the police budget may need to increase.

Pedestrians

Pedestrian Safety Zones

NHTSA states the objective of pedestrian safety zones is *"to increase cost-effectiveness of interventions by targeting education, enforcement, and engineering measures to geographic areas and audiences where significant portions of the pedestrian crash problem exist"* (Venkatraman et al., 2021, Chapter 4.1). Once a local champion is identified for a pedestrian safety zone, a study needs to be established to start implementing engineering changes. Of all strategies identified in this research, this one is anticipated to follow an implementation plan that would most closely resemble that of a typical transportation improvement project.

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[16] "NEWS POST: U Drive. U Text. U Pay." CRIMEWATCH https://montgomery.crimewatchpa.com/lowermorelandpd/6381/post/u-drive-u-text-u-pay.

[17] "Distracted Driving." Pennsylvania Department of Transportation https://penndot.pa.gov/TravelInPA/Safety/TrafficSafetyAndDriverTopics/Pages/Distracted-Driving.aspx.

[18] Section 39:3-13.8 - Fine for Violations of Special Learner's Permit, Examination Permit, or Probationary Driver's License, N.J. Stat. § 39:3-13.8. Casetext Search + Citator. https://casetext.com/statute/new-jersey-statutes/title-39-motor-vehicles-and-traffic-regulation/chapter-393-certain-vehicles-excepted-from-chapter/section-393-138-fine-for-violations-of-special-learners-permit-examination-permit-or-probationary-drivers-license#:~:text=Section%2039%3A3-13.8%20-%20Fine%20for%20violations%20of%20special,driver%27s%20license%3A%20a.%20supervision%20requirements%20for%20permit%20holders%3B.

Elementary-Aged Child Pedestrian Training

PennDOT or local municipalities can create or share an elementary-aged child pedestrian training program and share information with parents, caregivers, and educators. Sessions can be held by the school district, police, or local municipalities. The Office of Transportation, Infrastructure, and Sustainability (OTIS) of Philadelphia created a youth bicycle and pedestrian safety education program by sharing educational resources and hosting events with parents, caregivers, and educators.[19] NHTSA has "Child Pedestrian Safety Curriculum" publicly available as well. [20]

Safe Routes to School (SRTS)

Safe Routes to School is a *"national and international movement to create safe, convenient, and healthy opportunities for children to walk and bicycle to school."*[21] Communities can apply for grants to receive money for Safe Routes to School, although it is important to note that Safe Routes to School is not itself a grant program. Implementation at a specific location may require a study to identify the particular improvements that are required. PennDOT's website identifies applicable grant programs.[22]

Walking School Buses

According to NHTSA, *"'walking school buses' use volunteer adults, usually parents, to walk a group of students on a specific route to and from school, collecting or dropping off children on the way."* (Venkatraman et al., 2021, Chapter 2.3) Implementation could start with a group of parents, the school district or the municipality planning the walking school bus routes and recruiting volunteers to lead the students.

Reduced Speed Limits

See the Reduced Speed Limit section above for the procedures and limitations regarding reducing speed limits to improve safety. Additionally, note that PennDOT Pub 212 does not include mention of "pedestrian safety" when considering speed limits.[23]

Enforcement of Reduced Speed Limits

Most likely an increase in enforcement of reduced speed limits will result in a request for an increased budget for the police. Depending on the program, enforcement could include communications, outreach, and engineering changes as well.

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[19] "Start Teaching Youth Traffic Safety with Safe Routes Philly! | Office of Transportation, Infrastructure, and Sustainability." City of Philadelphia, 4 Aug. 2022, https://www.phila.gov/2022-08-04-start-teaching-youth-traffic-safety-with-safe-routes-philly/.

[20] Child Pedestrian Safety Curriculum | NHTSA. https://www.nhtsa.gov/pedestrian-safety/child-pedestrian-safety-curriculum. Accessed 30 May 2023.

[21] "Safe Routes to School." Pennsylvania Department of Transportation https://www.penndot.pa.gov:443/ProjectAndPrograms/Planning/Pages/safe-routes-to-school.aspx.

[22] "SRTS-Apply." Pennsylvania Department of Transportation https://www.penndot.pa.gov:443/ProjectAndPrograms/Planning/Pages/SRTS/SRTS-Apply.aspx. Accessed 30 May 2023.

[23] Chapter 212. Official Traffic Control Devices. Commonwealth of Pennsylvania Department of Transportation, https://www.dot.state.pa.us/public/PubsForms/Publications/PUB%20212.pdf.

Conspicuity Enhancement

Pedestrians can increase their conspicuity by wearing retroreflective materials. Education on retroreflective materials can be provided to the community. NHTSA suggests the following regarding retroreflective material:

"Devices designed to be semi-permanently fastened to children's clothing can be provided to parents through schools, group activities, or health care providers. Light sticks and reflective bands can be supplied with new cars or distributed by automobile clubs or insurance companies for use during vehicle breakdowns or emergencies." (Venkatraman et al., 2021, Chapter 4.3).

Motorcyclists

Universal Motorcycle Helmet Use Laws

Pennsylvania's Universal Helmet Law was repealed in 2003.[24] An act of the state legislature and governor would be needed to bring back this law.

Alcohol-Impaired Motorcyclists: Detection, Enforcement, and Sanctions

Changes in state law would be required to increase sanctions, such as vehicle impoundments. Detection and enforcement can be improved through increased training to recognize alcohol-impaired motorcyclists and increasing enforcement in target areas. It is assumed that these additional efforts would result in a request for an increased budget for the police.

Pennsylvania has the Advanced Roadside Impaired Driving Enforcement and the Drug Recognition Expert programs for all motorists (not specific to motorcycles).[25]

Licensing Unendorsed Drivers

Based on a program in Michigan, this initiative would provide outreach to unendorsed motorcycle drivers, such as via a postcard, to encourage them to obtain the proper training to become an endorsed motorcyclist. In Pennsylvania, all residents that operate a motorcycle are legally required to obtain a Class M license. Obtaining the license includes a vision test, a knowledge test, the issuance of a learner's permit, and a final test of driving skills. A Motorcycle Safety Program is offered by PennDOT for those with a learner's permit. At the end of the program, the skills test can be administered by the Rider Coach. If the test is passed, there is no need for additional skills testing at the Driver's License Center.

The PennDOT website has all of the necessary information for those interested in obtaining the Class M license. The maximum penalty for driving a motorcycle without a Class M license is $200 and a license suspension. There may be some motorists that are unaware of the need for a motorcycle-specific drivers license that could be reached with a postcard outreach program. It is unsure if these can be targeted to households with a registered motorcycle, or somehow connected to the purchase or registration of a motorcycle. However, it should be noted that a quick search on

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[24] GHSA. https://www.ghsa.org/state-laws/issues/Motorcyclists.

[25] "Impaired Driving." Pennsylvania Department of Transportation https://penndot.pa.gov/TravelInPA/Safety/TrafficSafetyAndDriverTopics/Pages/Impaired-Driving.aspx. Accessed 30 May 2023.

the internet of whether motorcycle-specific licenses are required in Pennsylvania quickly reveals that they are and includes the applicable penalties for noncompliance.

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APPENDIX A – DISTRICT-LEVEL SUMMARY

The following shows the data summary by district. Both crash counts and exposure metrics for each district in each year are computed as the sum of the associated values over all counties in the same district and year. If an exposure metric is missing, the associated crash counts in the same county and the same year are removed before the aggregation. Since the missing value for different exposure metrics occurs in different counties and different year, this process is conducted for all exposure metrics separately. Similar to the results for each county, the **average** annual counts (averaged over the years) or the **average** normalized annual counts (averages of normalized annual counts by exposure) for all districts are shown.

Results for total crashes

Figure 55shows the annual number of crashes (bicycle, motorcycle, pedestrian and commercial vehicles) per district. It can be seen that while District 6 and District 8 have the largest total crash counts.

Figure 55 Average number of crashes per year by district (2014-2021)

Figure 56 provides the number of crashes normalized using total population (i.e., annual crashes per person), while Figure 57 shows the number of crashes normalized by VMT. When normalized by total population District 5 and District 4 have the largest crash rates when normalized by total population. However, District 6 still has the largest crash rate when normalized by VMT.

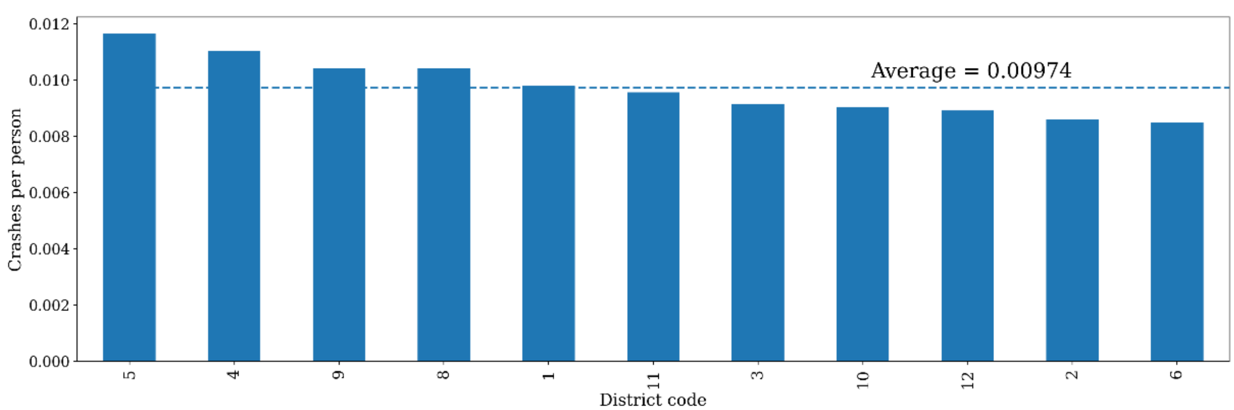

Figure 56 Average number of crashes per person per year by district (2014-2021)

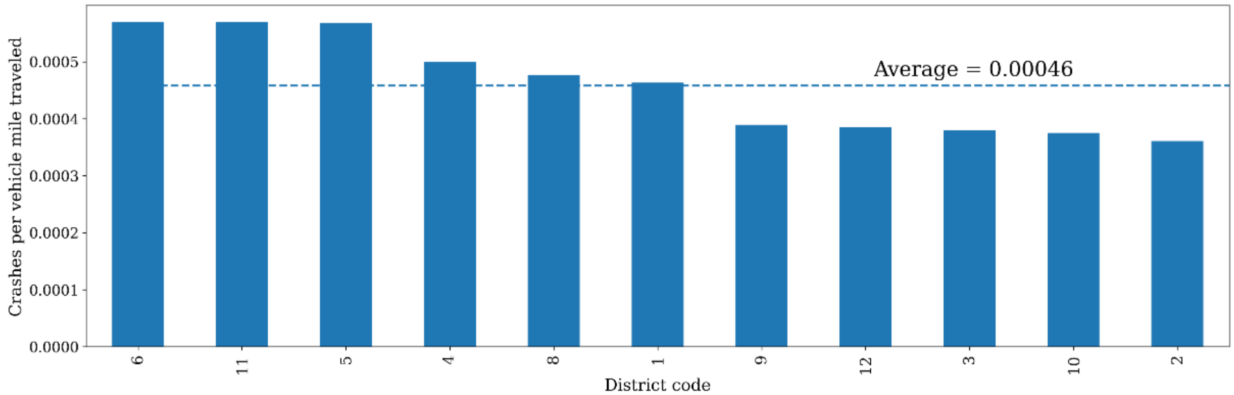

Figure 57 Average number of crashes per VMT per year by district (2014-2021)

Figure 58 provides the fraction of crashes involving four travel modes of interest (bicycle, commercial vehicle, motorcycle and pedestrian). t is found that overall; bicycles have the lowest crash ratio and commercial vehicle have the highest. In most districts, the ratio of motorcycle crashes is greater than pedestrian crashes. In general, crashes involving pedestrians and bicyclists seems to be a significant issue in District 6, as these ratios are much higher relatively to other counties

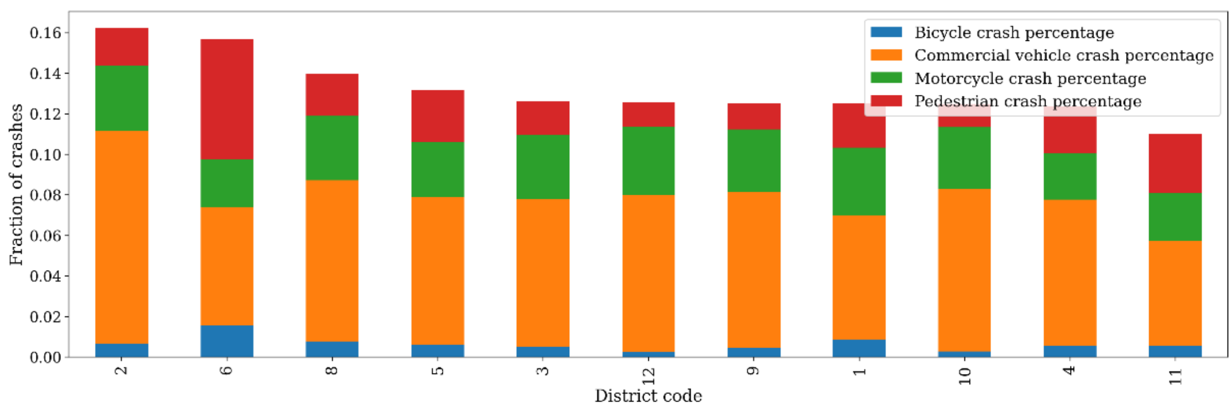

Figure 58 Fraction of crashes involving bicycles, commercial vehicles, motorcycles and pedestrians by district (2014-2021)

Table 25 provides the detailed crash data shown in Figure 49 through Figure 52 for each district.

Table 25 Total, bicycle, commercial, motorcycle and pedestrian crashes by district (2014-2021)

District code	Total crash count	Total crash per population	Total crash per VMT	Bicycle crash fraction	Commercial vehicle crash fraction	Motorcycle crash fraction	Pedestrian crash fraction	Passenger car crash fraction
1	5644	0.0098	0.00046	0.0085	0.0550	0.0320	0.0210	0.684
2	3831	0.0086	0.00036	0.0065	0.0900	0.0310	0.0170	0.645
3	4465	0.0092	0.00038	0.0051	0.0670	0.0310	0.0160	0.662
4	7814	0.0111	0.00050	0.0055	0.0670	0.0220	0.0220	0.714
5	16971	0.0117	0.00057	0.0061	0.0660	0.0260	0.0240	0.734

District code	Total crash count	Total crash per population	Total crash per VMT	Bicycle crash fraction	Commercial vehicle crash fraction	Motorcycle crash fraction	Pedestrian crash fraction	Passenger car crash fraction
6	34780	0.0085	0.00057	0.0156	0.0560	0.0230	0.0570	0.721
8	20225	0.0104	0.00048	0.0077	0.0720	0.0310	0.0200	0.694
9	4636	0.0104	0.00039	0.0044	0.0690	0.0300	0.0130	0.687
10	3825	0.0091	0.00038	0.0028	0.0710	0.0300	0.0110	0.666
11	14167	0.0096	0.00057	0.0056	0.0490	0.0230	0.0280	0.735
12	6551	0.0089	0.00039	0.0026	0.0710	0.0330	0.0110	0.672

NHTSA aggressive driving, speeding related, distracted driving and impaired driving

Considering each district, it can be seen that the general trends of speeding related driving being the top contributor to crashes holds, see Figure 59.

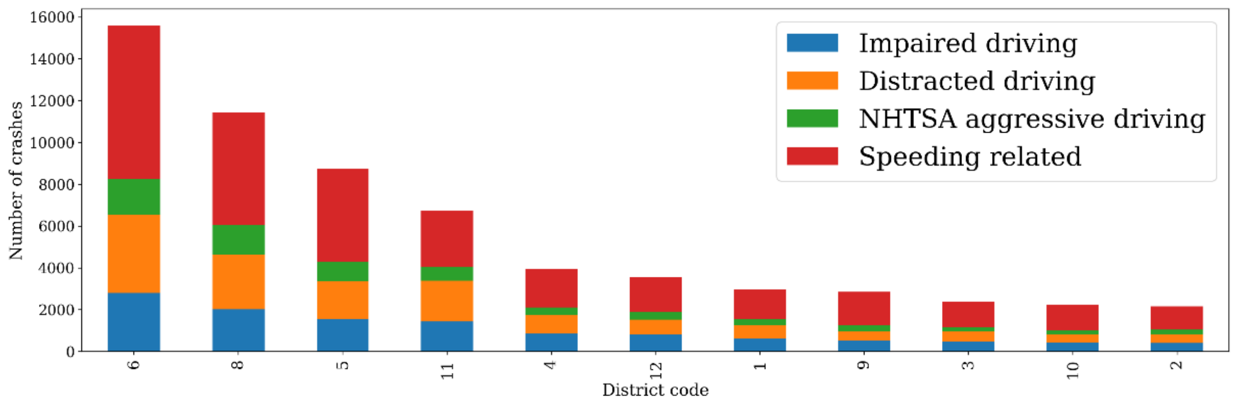

Figure 59 Average number of NHTSA aggressive driving, distracted driving, impaired driving or speeding related crashes per year by district (2014-2021)

Table 26 shows the number of crashes involving each of the four driving behavior in Figure 59 in each district.

Table 26 Number of crashes involving impaired, distracted, NHTSA aggressive and speeding related driving in each district (2014-2021)

District code	Impaired	Distracted	NHTSA Aggressive Driving	Speeding related
1	622	639	291	1429
2	406	434	206	1126
3	465	499	217	1212
4	849	909	360	1817
5	1540	1823	927	4468
6	2804	3745	1690	7358
8	2023	2606	1419	5381
9	526	462	277	1589
10	449	364	218	1200
11	1449	1937	658	2694
12	841	685	355	1664

Figure 60 provides the rates of crashes involving NHTSA aggressive driving, distracted driving, impaired driving or speeding related per total VMT.

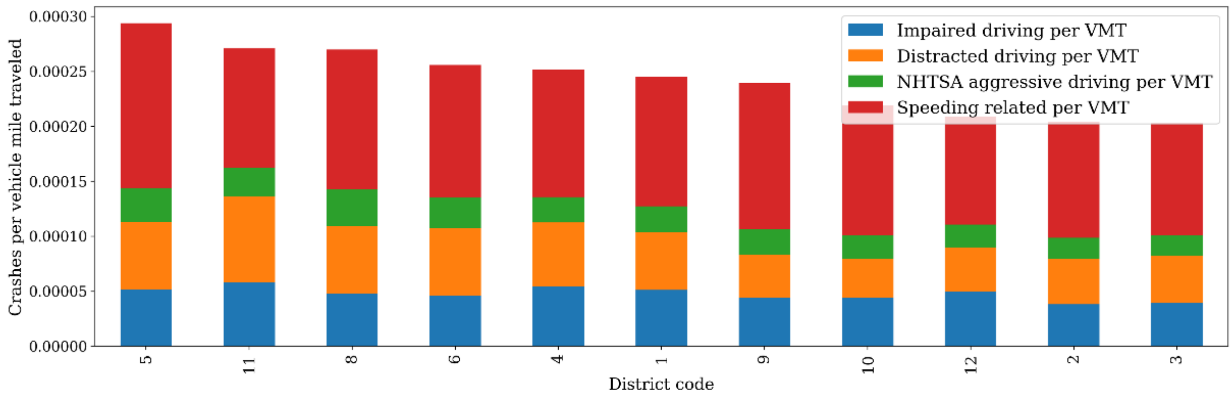

Figure 60 Average number of NHTSA aggressive driving, distracted driving, impaired driving or speeding related crashes per VMT by district (2014-2021)

Figure 61 provides crash rates for NHTSA aggressive driving categories normalized by total population in each county. Note that the conclusions do not change much with this normalization compared to VMT.

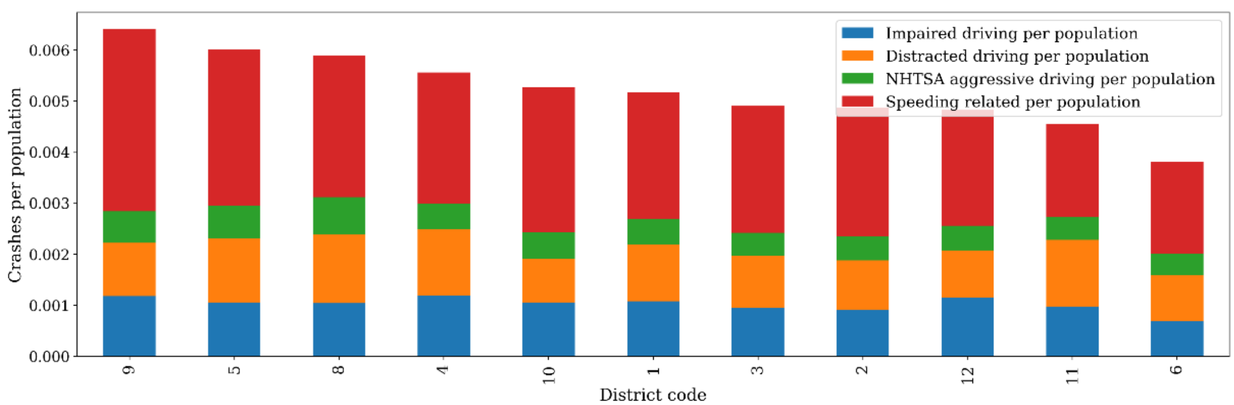

Figure 61 Average number of NHTSA aggressive driving, distracted driving, impaired driving or speeding related crashes per population by district (2014-2021)

Table 27provides the normalized number of crashes involving impaired, distracted, NHTSA aggressive and speeding related driving behavior by VMT and population in each district.

Table 27 Normalized number of each type of crashes by VMT and population in each district (2014-2021)

District code	Normalized by VMT				Normalized by population			
	Impaired	Distracted	NHTSA aggressive driving	Speeding Related	Impaired	Distracted	NHTSA aggressive driving	Speeding Related
1	0.0000511	0.0000525	0.0000239	0.000117	0.00108	0.00111	0.00051	0.00248
2	0.0000382	0.0000409	0.0000193	0.000106	0.00091	0.00097	0.00046	0.00253

District code	Normalized by VMT				Normalized by population			
	Impaired	Distracted	NHTSA aggressive driving	Speeding Related	Impaired	Distracted	NHTSA aggressive driving	Speeding Related
3	0.0000396	0.0000425	0.0000184	0.000103	0.00095	0.00102	0.00045	0.00249
4	0.0000543	0.0000582	0.0000230	0.000116	0.00120	0.00128	0.00051	0.00257
5	0.0000516	0.0000612	0.0000311	0.000150	0.00106	0.00125	0.00064	0.00307
6	0.0000460	0.0000615	0.0000277	0.000121	0.00069	0.00092	0.00041	0.00180
8	0.0000478	0.0000615	0.0000335	0.000127	0.00104	0.00134	0.00073	0.00278
9	0.0000442	0.0000388	0.0000233	0.000134	0.00118	0.00104	0.00062	0.00357
10	0.0000440	0.0000357	0.0000214	0.000118	0.00106	0.00086	0.00052	0.00284
11	0.0000583	0.0000778	0.0000264	0.000109	0.00098	0.00131	0.00045	0.00182
12	0.0000495	0.0000403	0.0000208	0.000098	0.00115	0.00093	0.00048	0.00227

Figure 62 to Figure 65 provides each considered type of behavioral issue associated with a crash as a rate normalized by the number of citations or arrests associated with that type of behavior. Comparing the magnitudes of the different types of behavioral issues normalized by their respective citation or arrest types, it can be concluded that distracted driving has few citations per crash compared to the other types of crashes, especially in District 1. The behavioral issue with the largest citation per crash appears to be NHTSA aggressive driving.

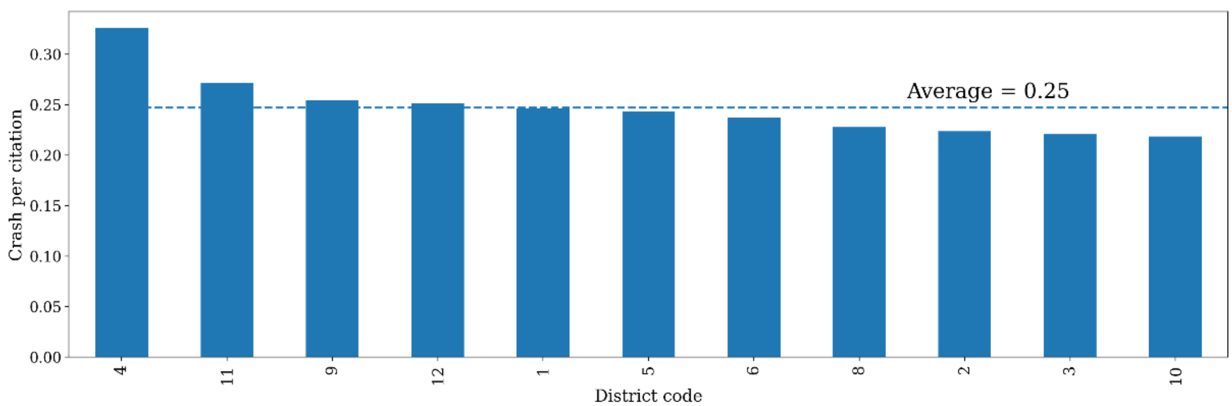

Figure 62 Average number of impaired driver crashes per impaired driver citations by district (2014-2021)

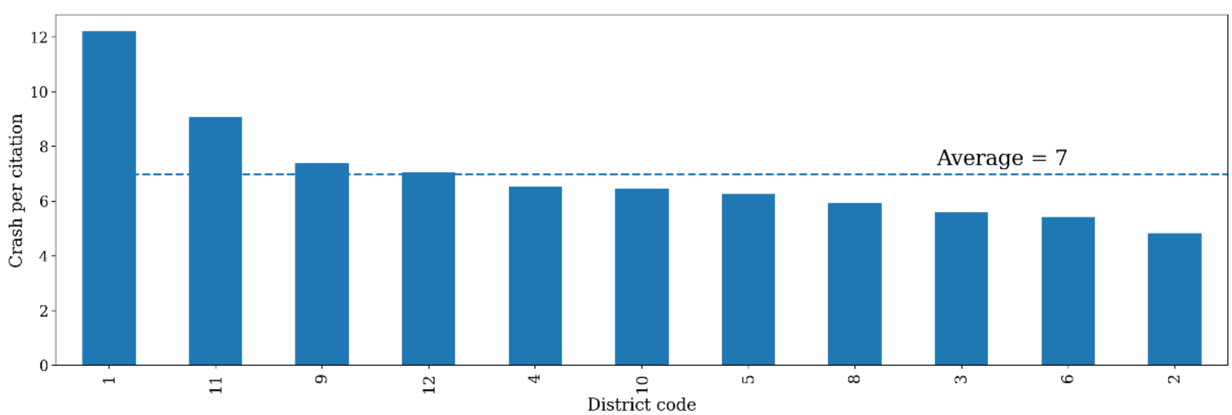

Figure 63 Average number of distracted driver crashes per distracted driver citations by district (2014-2021)

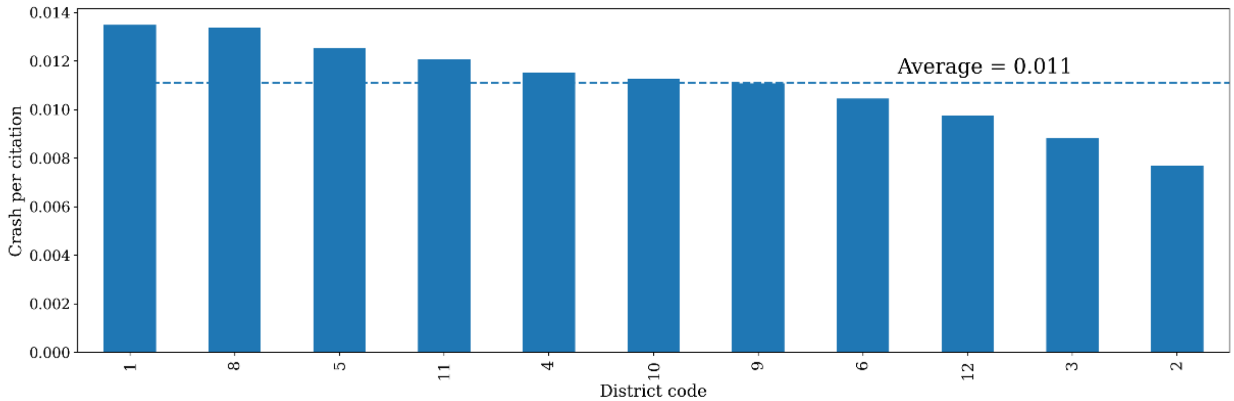

Figure 64 Average number of NHTSA aggressive driver crashes per NHTSA aggressive driver citations by district (2014-2021)

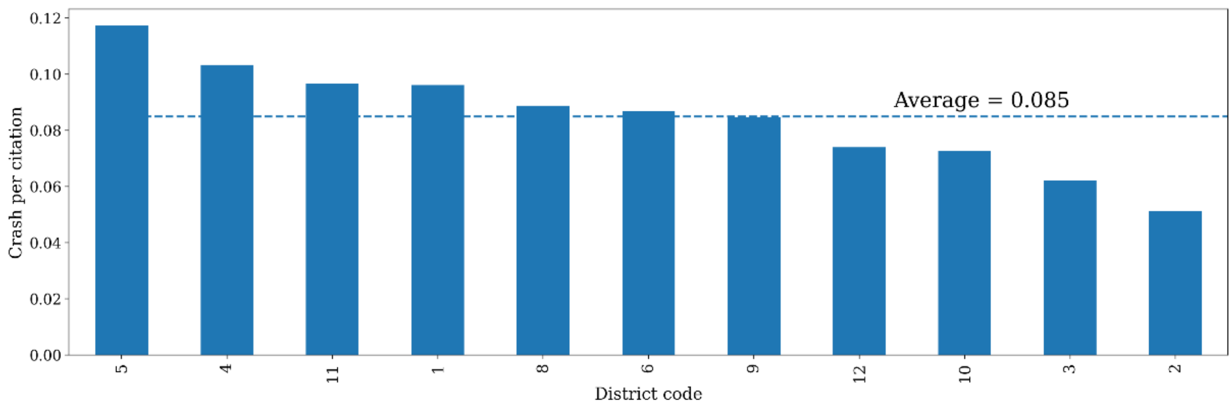

Figure 65 Average number of speeding related crashes per speeding citations by district (2014-2021)

Table 28 provides the normalized number of crashes involving impaired, distracted, NHTSA aggressive and speeding related driving using the number of citations in each district.

Table 28 Normalized number of crashes for four types of driving behavior using citations in each district (2014-2021)

District code	Impaired	Distract	NHTSA Aggressive Driving	Speeding Related
1	0.246	12.200	0.0135	0.096
2	0.224	4.820	0.0077	0.051
3	0.221	5.590	0.0088	0.062
4	0.326	6.540	0.0115	0.103
5	0.243	6.260	0.0125	0.117
6	0.237	5.420	0.0105	0.087
8	0.228	5.920	0.0134	0.089
9	0.254	7.390	0.0111	0.085
10	0.219	6.460	0.0113	0.073
11	0.272	9.070	0.0121	0.097
12	0.251	7.040	0.0098	0.074

Bicycle safety

Figure 66 provides the total crashes involving bicycles per county. It can be seen that District 6 has by far the largest number of crashes involving bicycles.

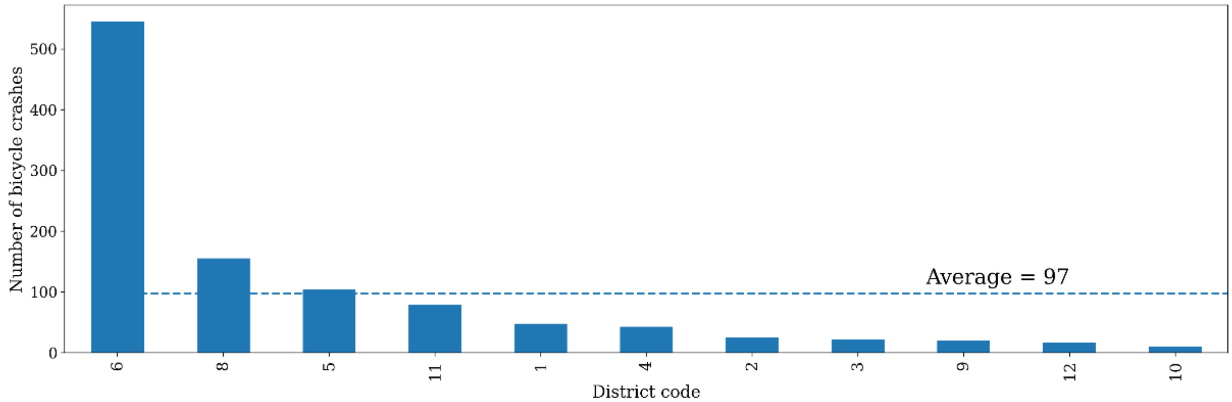

Figure 66 Average number of bicycle crashes per year by district (2014-2021)

The number of deaths and serious injuries in crashes involving bicycles are shown in Figure 67. District 6 has the largest fatalities and serious injuries as well.

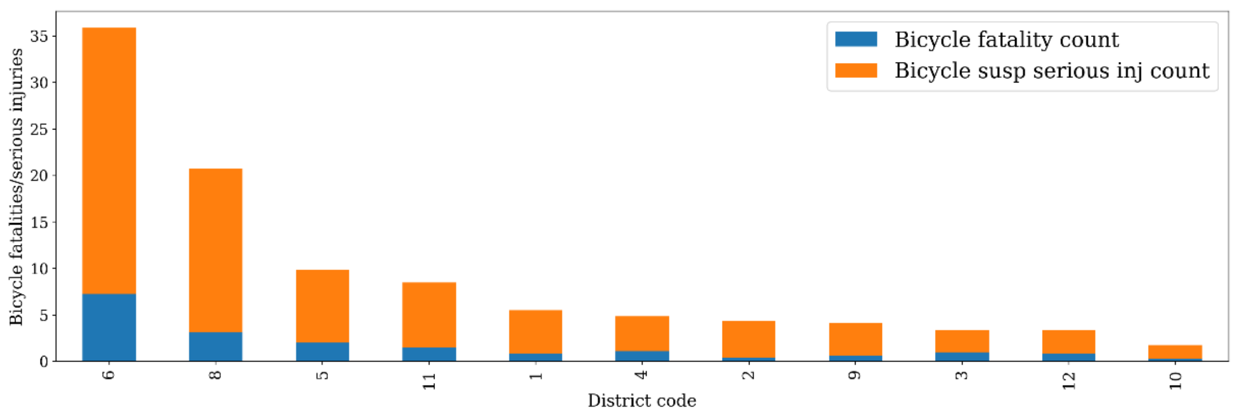

Figure 67 Average number of bicycle fatalities and serious injuries per year by district (2014-2021)

Table 29 provides the number of bicycle crashes, fatalities and suspicious serious injuries in each district.

Table 29 Number of bicycle crashes, fatalities and suspicious serious injuries in each district (2014-2021)

District code	Bicycle crash count	Bicycle fatality count	Bicycle susp serious inj count
1	48.00	0.88	4.63
2	25.75	0.38	4.00
3	22.63	1.00	2.38
4	43.00	1.13	3.75
5	105.00	2.00	7.88
6	547.75	7.25	28.63

District code	Bicycle crash count	Bicycle fatality count	Bicycle susp serious inj count
8	157.13	3.13	17.63
9	20.50	0.63	3.50
10	10.75	0.25	1.50
11	79.88	1.50	7.00
12	17.13	0.88	2.50

Figure 68 to Figure 71 provides rates of crashes involving bicycles (both total and those with fatalities or serious injuries) normalized using the total population, population density and the percentage of trips using bicycles. As can be seen, District 6 still remains as one of the riskiest places for bicycle trips even after normalized considering population. However, District 8 and District 2 have the largest number bicycle crashes per population density.

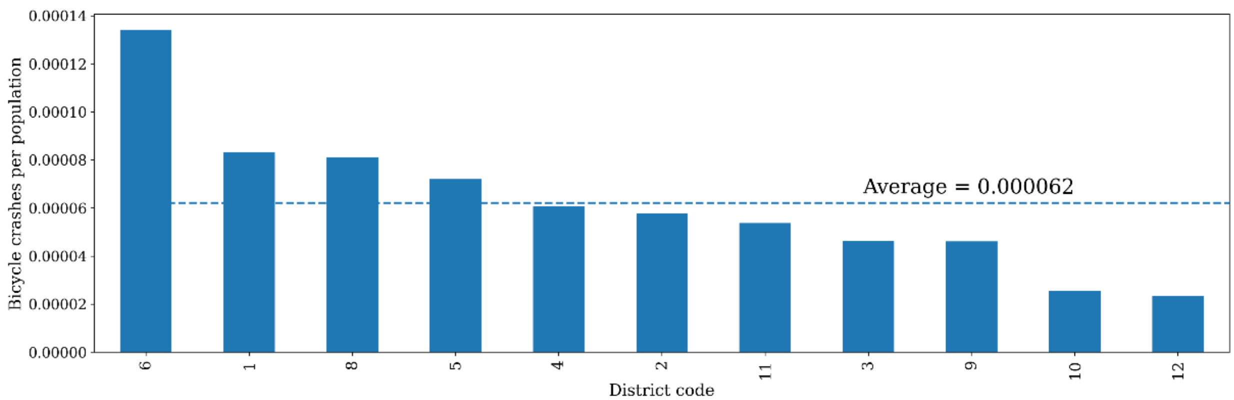

Figure 68 Average number of bicycle crashes per population per year by district (2014-2021)

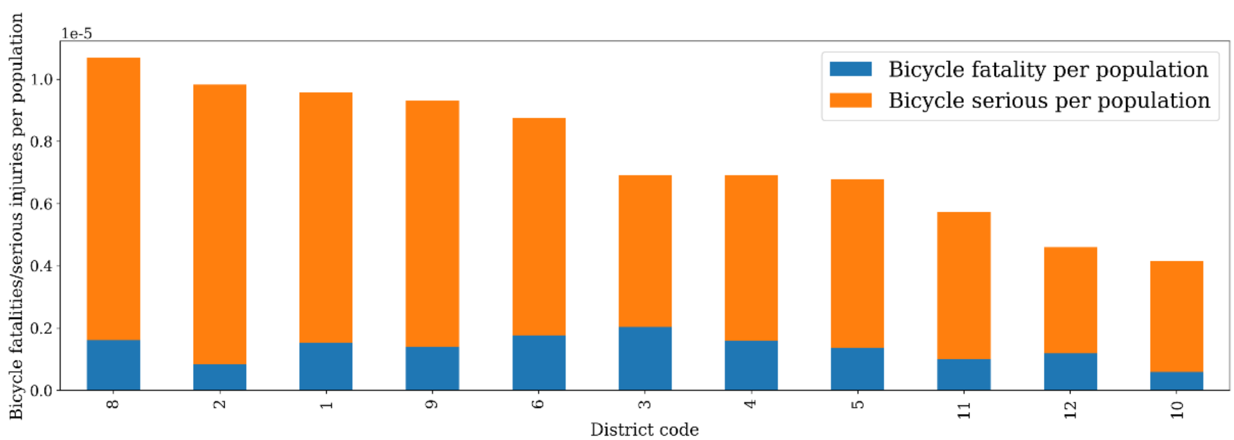

Figure 69 Average number of bicycle fatalities and serious injuries per population per year by district (2014-2021)

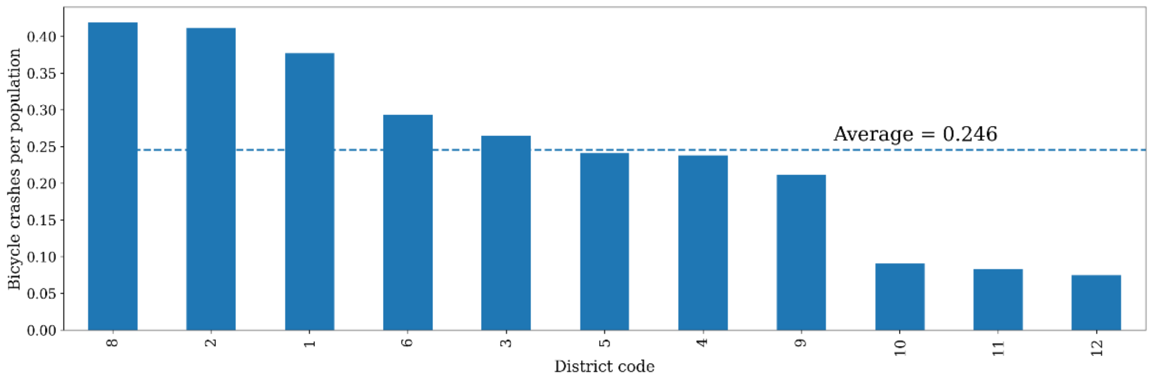

Figure 70 Average number of bicycle crashes per population density per year by district (2014-2021)

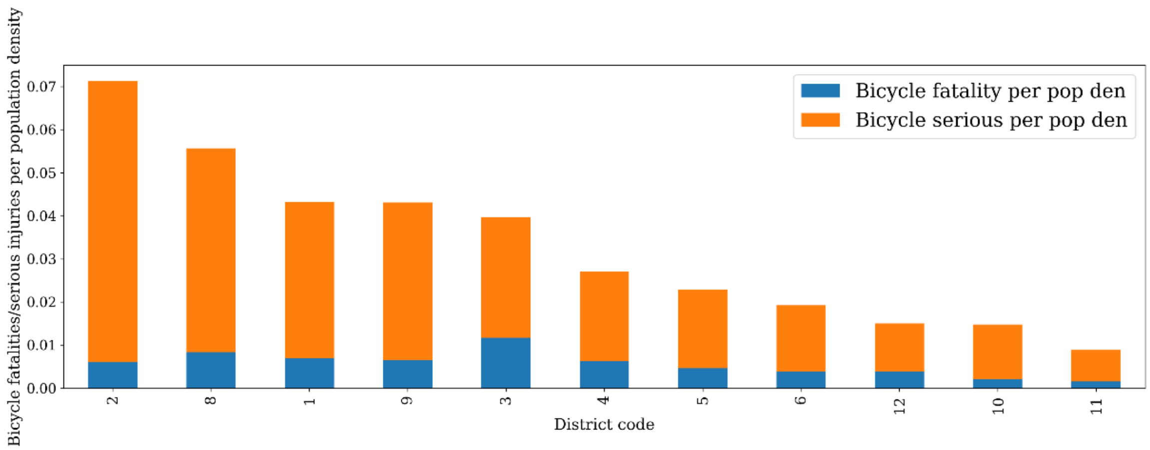

Figure 71 Average number of bicycle fatalities and serious injuries per population density per year by district (2014-2021)

Table 30 provides the normalized number of bicycle crashes, fatalities and serious injuries in each district by using population and population density, respectively.

Table 30 Normalized number of bicycle crashes, fatalities and serious injuries in each district (2014-2021)

District code	Per population			Per population density		
	Total	Fatality	Serious	Total	Fatality	Serious
1	0.000083	0.00000153	0.00000803	0.377	0.00694	0.0364
2	0.000058	0.00000084	0.00000899	0.420	0.00612	0.0653
3	0.000046	0.00000204	0.00000488	0.266	0.01170	0.0280
4	0.000061	0.00000160	0.00000532	0.239	0.00627	0.0209
5	0.000072	0.00000137	0.00000540	0.243	0.00463	0.0182
6	0.000134	0.00000177	0.00000699	0.295	0.00390	0.0154
8	0.000081	0.00000161	0.00000907	0.423	0.00841	0.0473
9	0.000046	0.00000141	0.00000789	0.214	0.00654	0.0366
10	0.000025	0.00000059	0.00000356	0.090	0.00211	0.0127
11	0.000054	0.00000101	0.00000473	0.084	0.00157	0.0073
12	0.000023	0.00000119	0.00000342	0.076	0.00390	0.0112

Figure 72 and Figure 73 provides average rates of crashes involving bicycles (both total and those with fatalities or serious injuries) normalized by the percentage of bicycle trips. District 6 has the largest bicycle crashes or bicycle fatalities and serious injuries per bicycle trip percentage, followed by District 8.

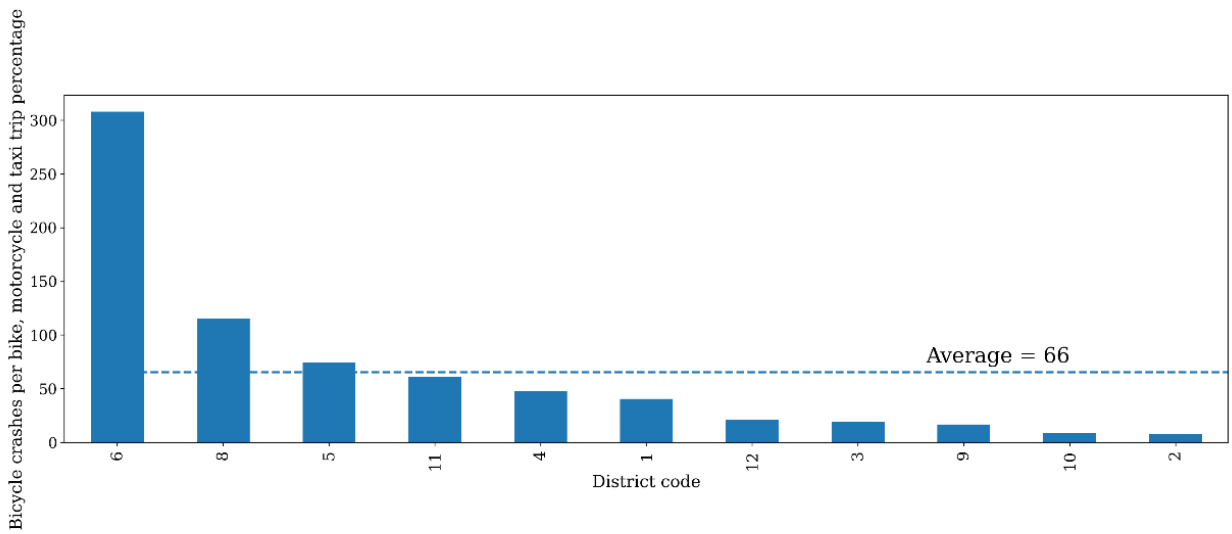

Figure 72 Average number of bicycle crashes per bicycle trip percentage by district(2014-2021)

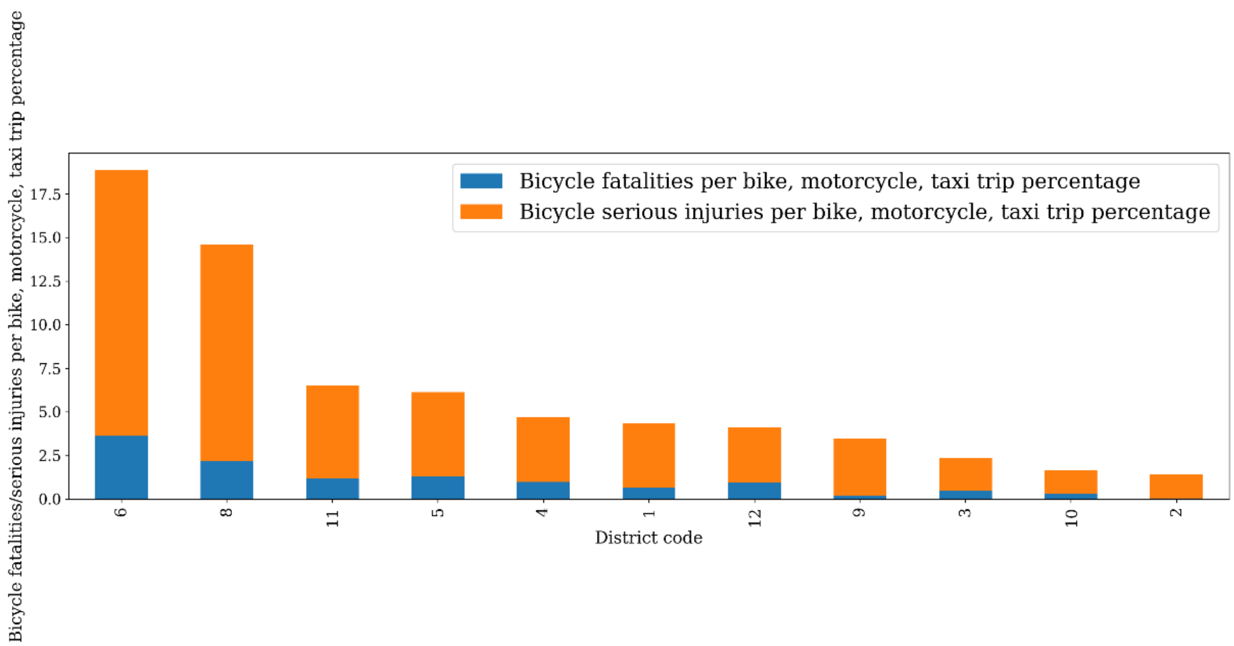

Figure 73 Average number of bicycle fatalities and serious injuries per bicycle trip percentage by district (2014-2021)

Table 31 provides the normalized number of bicycle crashes, fatalities and serious injuries using the percentage of combined bicycle, motorcycle and taxi trip percentage in each district.

Table 31 Normalized average number of bicycle crashes by bicycle, motorcycle and taxi trip percentage in each district (2014-2021)

District code	Crashes	Fatalities	Serious injuries
1	40.73	0.66	3.68
2	7.95	0.04	1.38
3	19.74	0.46	1.91
4	47.56	0.98	3.72
5	74.15	1.29	4.85
6	307.97	3.62	15.28
8	115.20	2.20	12.42
9	16.85	0.20	3.25
10	9.18	0.30	1.38
11	61.00	1.19	5.31
12	21.44	0.96	3.17

Pedestrian safety

The average number of crashes that involve pedestrians is shown in Figure 74. As can be seen, District 6 has a disproportionally high level of crashes that involve pedestrians.

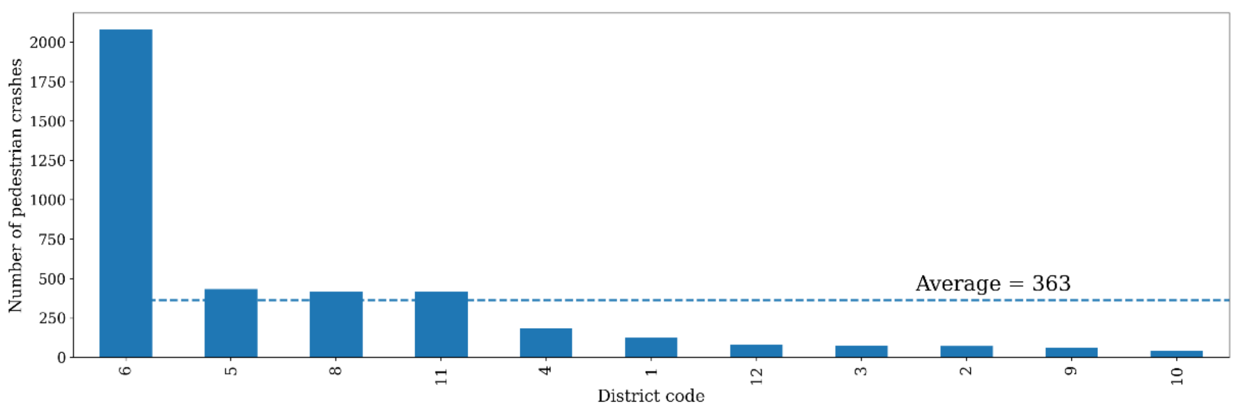

Figure 74 Average number of crashes involving pedestrians per year by district (2014-2021)

District 6 also has the largest average number of crashes that involve pedestrians per total population, see Figure 75. However, District 2 and District 8 have the largest number of crashes that involve pedestrians per population density, see Figure 76. Notice that pedestrians have a larger average number of crashes per percentage of trips than bicyclists, see Figure 77.

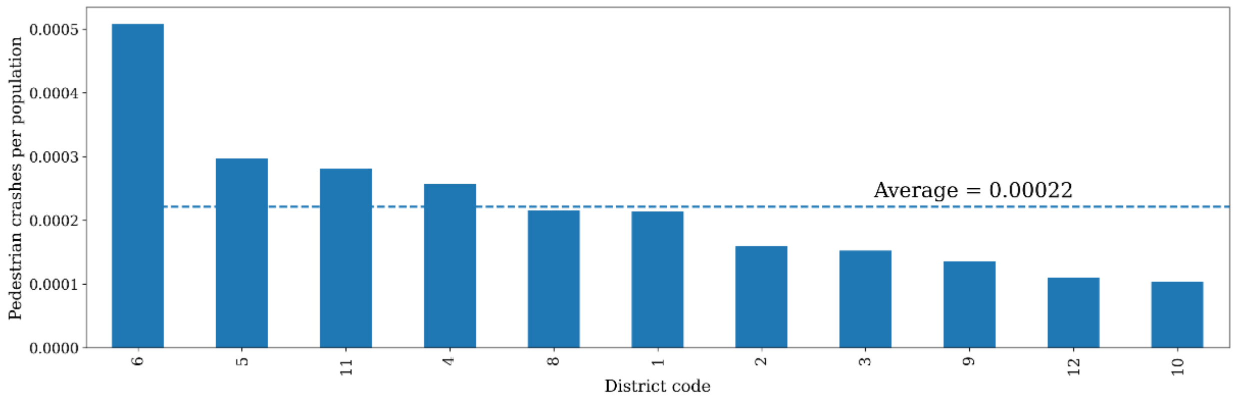

Figure 75 Average number of crashes involving pedestrians per population per year by district (2014-2021)

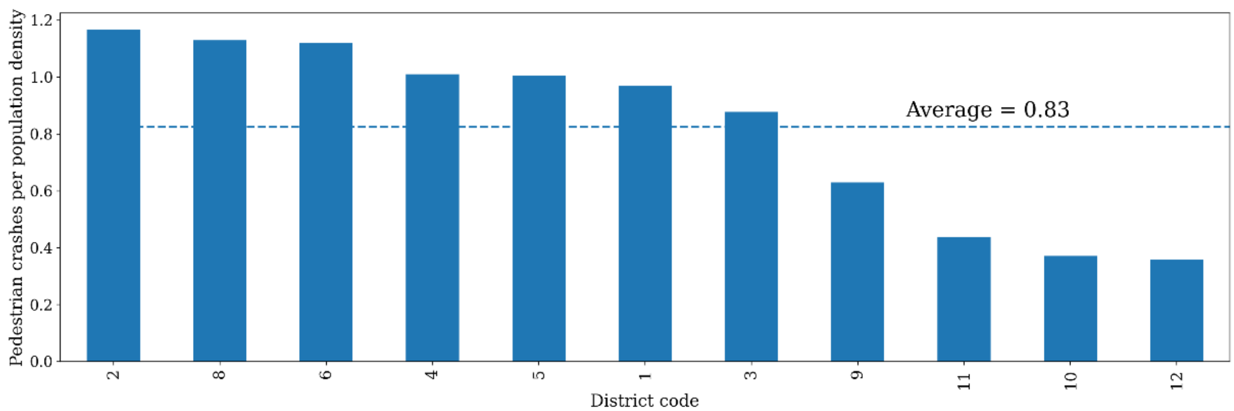

Figure 76 Average number of crashes involving pedestrians per population density per year by district (2014-2021)

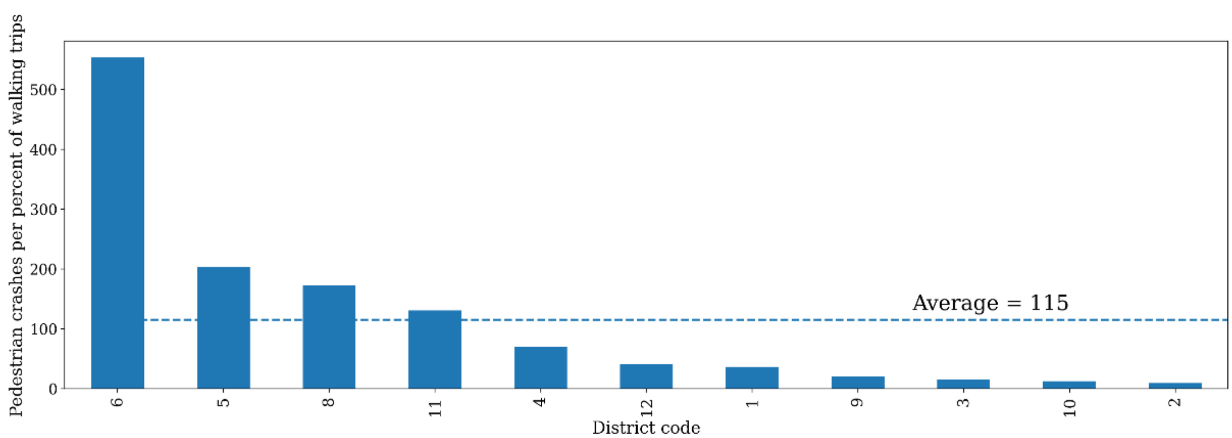

Figure 77 Average number of crashes involving pedestrians per percentage of walking trips by district (2014-2021)

Table 32 provides the average number and normalized number of pedestrian crashes using population, population density and percent of walking trips, respectively, in each district.

Table 32 Average and normalized pedestrian crashes in each district (2014-2021)

District code	Ped crash	Ped crash per pop	Ped crash per pop den	Ped crash per percent walked
1	123.500	0.000214	0.971	36.377
2	71.500	0.000160	1.166	9.525
3	74.500	0.000153	0.878	15.980
4	182.000	0.000257	1.011	70.131
5	433.400	0.000298	1.005	203.672
6	2080.600	0.000509	1.120	553.442
8	419.500	0.000217	1.129	172.366
9	60.300	0.000136	0.630	20.803
10	44.100	0.000104	0.371	12.869
11	417.600	0.000282	0.437	131.146
12	80.800	0.000110	0.360	41.421

Child passenger safety

The average number of child fatalities and suspected serious injury counts are shown in Figure 78.

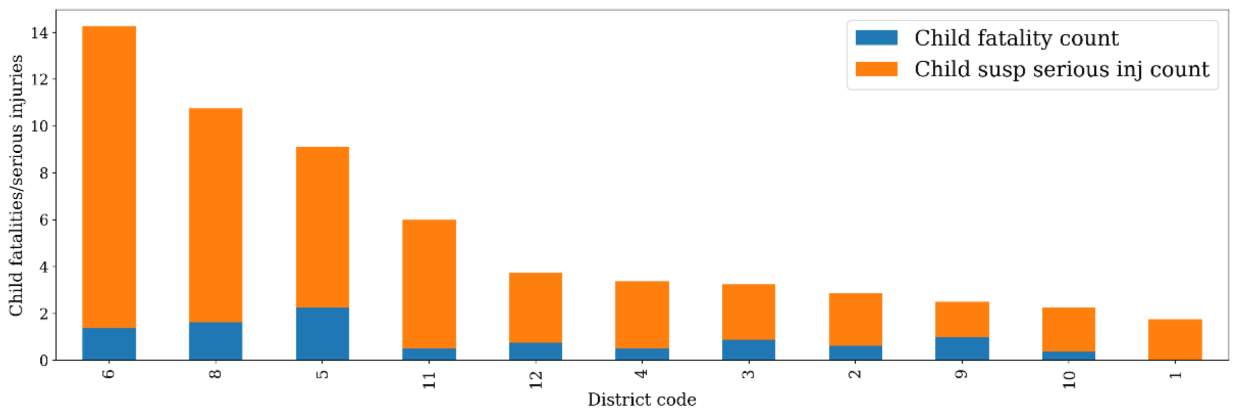

Figure 78 Average number of child passenger fatalities and serious injuries per year by district (2014-2021)

The average number of child deaths and suspected serious injury counts normalized by the population at or under the age of eight is shown in Figure 79.

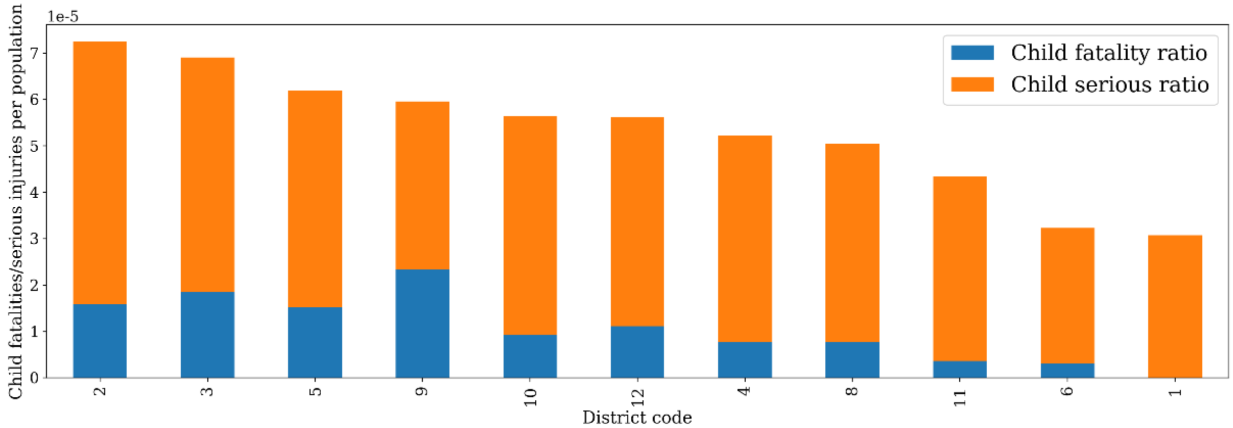

Figure 79 Average number of child fatalities and suspected serious injury counts per population at or under the age of eight per year by district (2014-2021)

Table 33 provides the average and normalized child fatalities and serious injuries by population at or under the age of eight in each district.

Table 33 Average and normalized child fatalities and serious injuries by population in each district (2014-2021)

District code	Fatalities	Serious inj	Fatality ratio	Serious inj ratio
1	0.000	1.750	0.0000000	0.000031
2	0.625	2.250	0.0000159	0.000057
3	0.875	2.375	0.0000186	0.000051
4	0.500	2.875	0.0000077	0.000045
5	2.250	6.875	0.0000153	0.000047
6	1.375	12.875	0.0000031	0.000029
8	1.625	9.125	0.0000076	0.000043
9	1.000	1.500	0.0000234	0.000036
10	0.375	1.875	0.0000093	0.000047
11	0.500	5.500	0.0000036	0.000040
12	0.750	3.000	0.0000112	0.000045

Next, the average number of children fatality normalized using total children population is compared to the average number of total fatality normalized using total population by plotting the two separately in Figure 80 and plotting the ratio of the two in Figure 81. As can be seen, in every district the normalized children fatality is smaller than the total fatality.

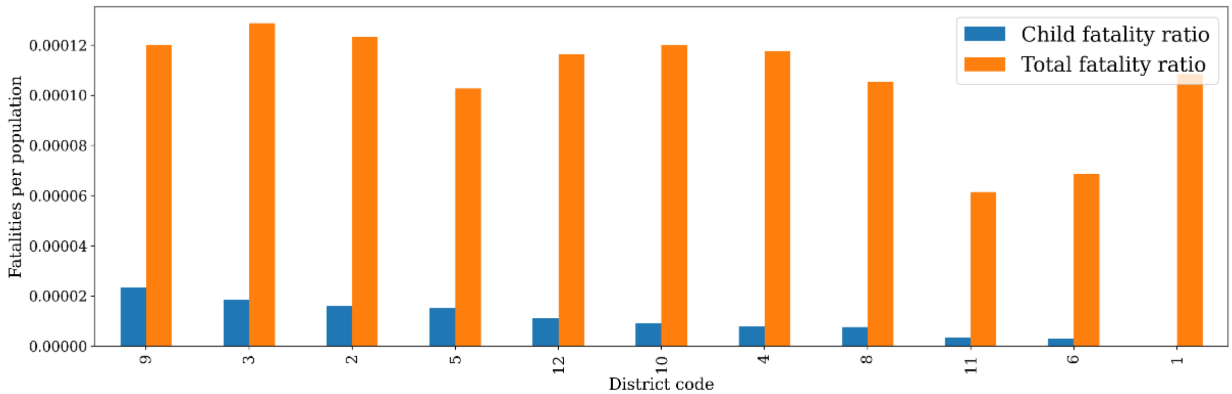

Figure 80 Average number of children fatality per total child population vs. average number of total fatality per total population per year by district (2014-2021)

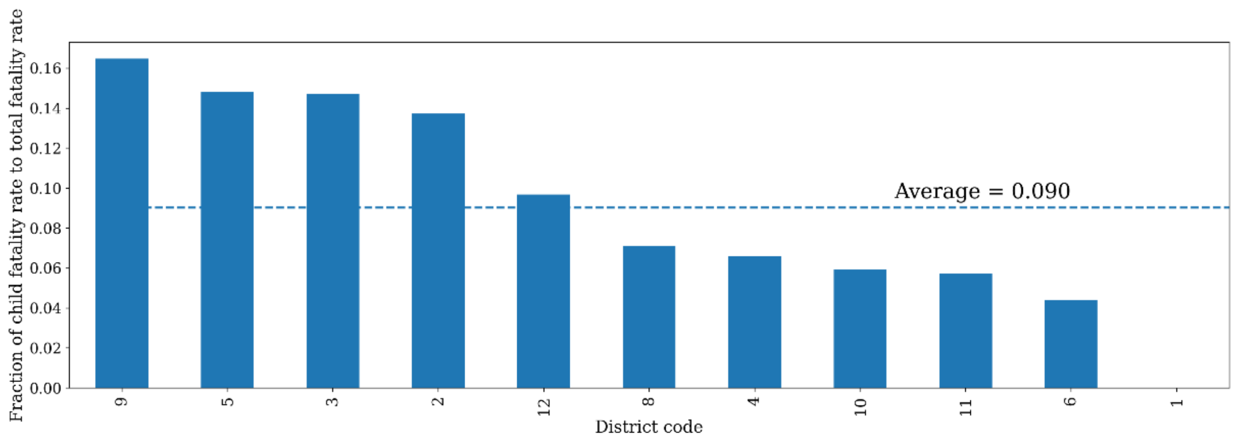

Figure 81 Ratio of average number of children fatality per total child population to average number of total fatality per total population by district (2014-2021)

Table 34 shows the average child fatality rate, average total fatality rate and the fraction of child fatality rate to total fatality rate in each district.

Table 34 Comparison between average child fatality ratio and average total fatality ratio in each district

District code	Child fatality rate	Total fatality rate	Fraction
1	0.0000000	0.000108	0.000
2	0.0000159	0.000123	0.137
3	0.0000186	0.000129	0.147
4	0.0000077	0.000118	0.066
5	0.0000153	0.000103	0.148
6	0.0000031	0.000069	0.044
8	0.0000076	0.000105	0.071
9	0.0000234	0.000120	0.165
10	0.0000093	0.000120	0.059
11	0.0000036	0.000062	0.057
12	0.0000112	0.000116	0.097

Commercial motor vehicle safety

The average number of commercial vehicle crashes is shown in Figure 82. District 6 and District 8 are the top two districts with commercial vehicle crashes.

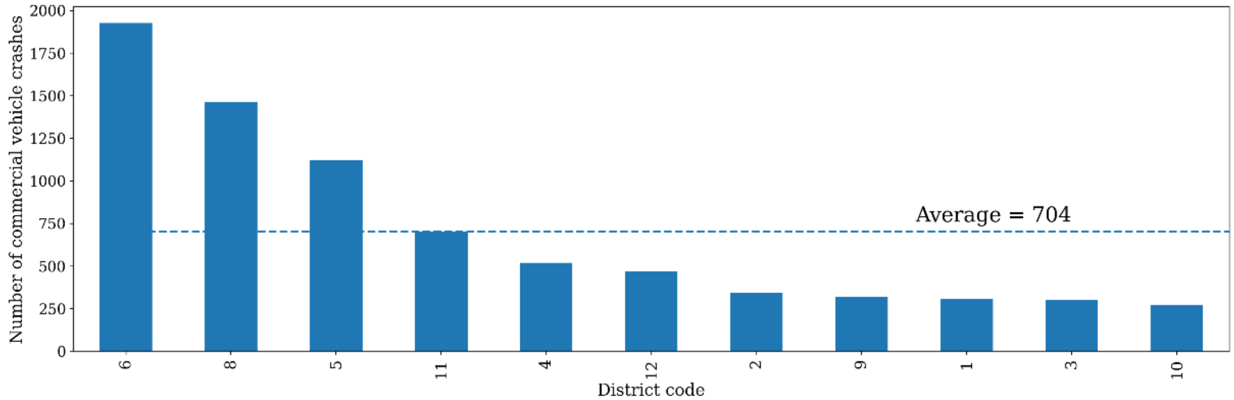

Figure 82 Average number of commercial vehicle crashes per year by district (2014-2021)

Figure 83 provides the average commercial vehicle crash rate normalized by the truck VMT. District 6 remains the location with the largest number of commercial vehicle crashes per truck VMT.

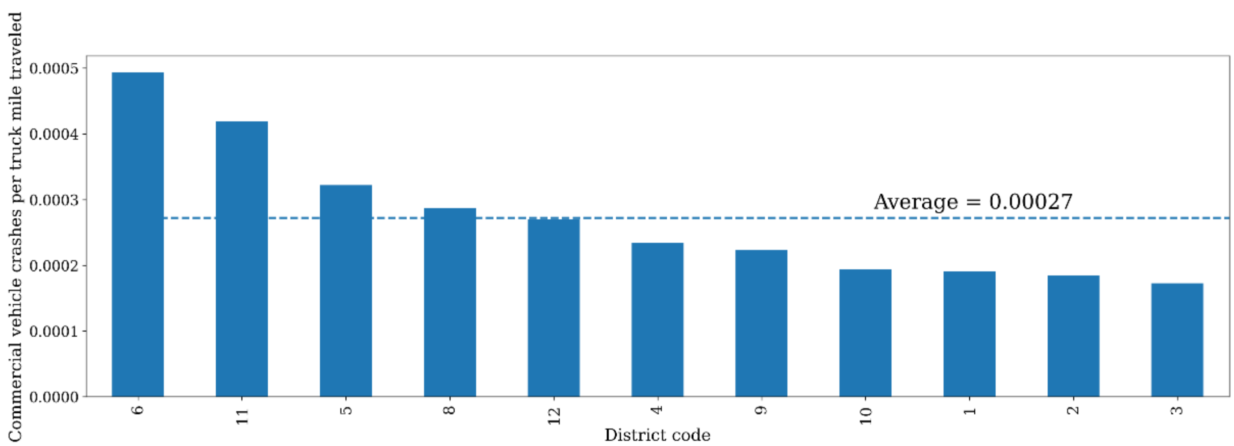

Figure 83 Average number of commercial vehicle crashes per truck VMT per year by district (2014-2021)

Table 35 provides the average and normalized commercial vehicle (using truck VMT) crashes in each district.

Table 35 Average and normalized commercial vehicle (per truck VMT) crashes in each district (2014-2021)

District code	Commercial crashes	Comme crashes per VMT
1	347.130	0.00022
2	400.130	0.00022
3	326.000	0.00019
4	563.750	0.00026
5	1236.750	0.00036
6	2022.500	0.00052

District code	Commercial crashes	Comme crashes per VMT
8	1607.130	0.00032
9	357.130	0.00025
10	306.880	0.00022
11	732.630	0.00044
12	509.380	0.00029

Young and mature drivers

The average number of young (16-20) and mature (65+) drivers involved in crashes per county per year is plotted in Figure 84. The average number of young drivers involved in crashes is similar to the number of mature drivers involved in crashes. In some districts, e.g., District 6 and District 11, more mature drivers are involved in crashes than young drivers. In others, e.g., District 8 and District 5, more young drivers are involved in crashes than mature drivers.

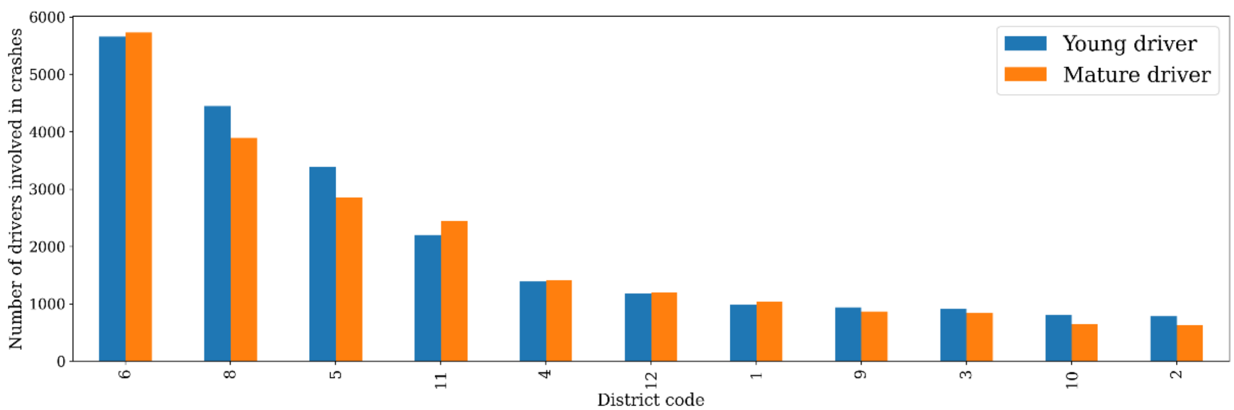

Figure 84 Average number of young (16-20) and mature (65+) drivers involved in crashes per year by district (2014-2021)

When normalized by the actual population in each group (see Figure 85), it can be seen that young drivers have a larger risk of being involved in a crash compared to mature drivers.

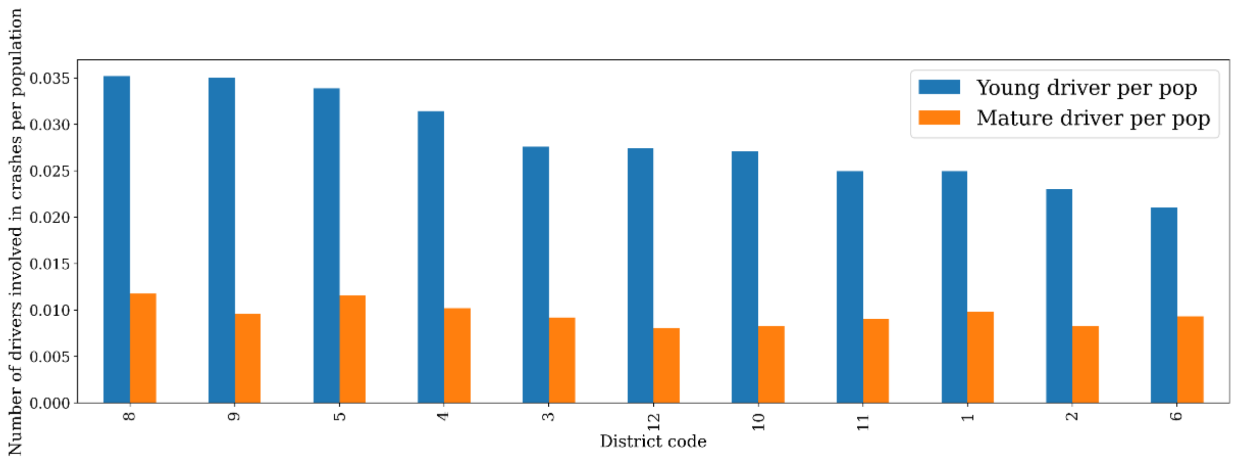

Figure 85 Average number of young (16-20) and mature (65+) drivers involved in crashes per population in each group per year by district (2014-2021)

A similar conclusion is found when normalizing by the number of licensed drivers in each age group, see Figure 86.

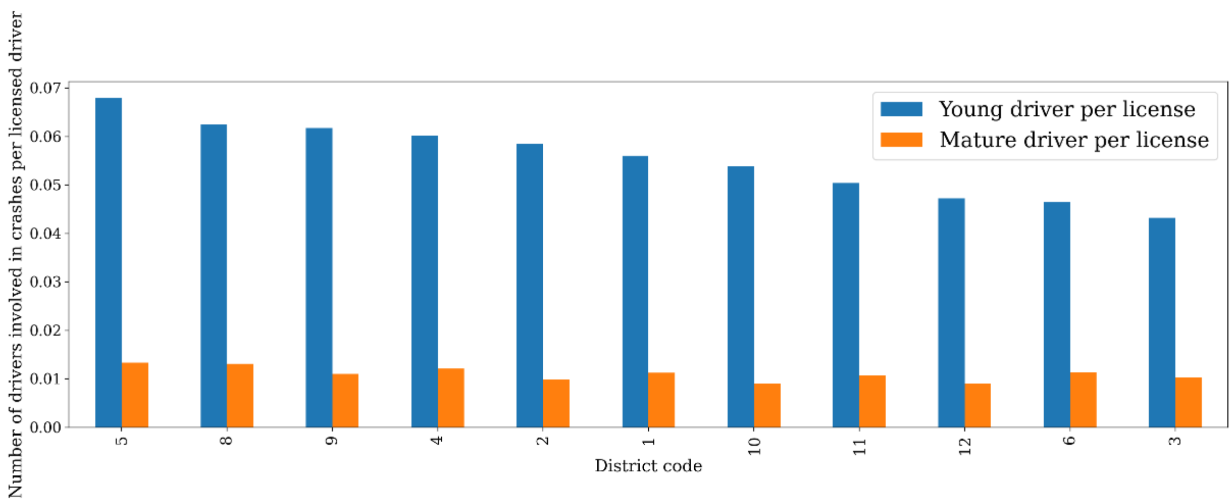

Figure 86 Average number of young (16-20) and mature (65+) drivers involved in crashes per licensed drivers in each group per year by district (2014-2021)

Table 36 shows the average number, and the normalized number using population and number of licenses within the corresponding age groups of crashes involving young and mature drivers in each district.

Table 36 Average and normalized (using population and number of licenses) number of crashes involving young and mature drivers in each district (2014-2021)

District code	Young	Mature	Young per pop	Mature per pop	Young per license	Mature per license
1	993.500	1046.800	0.0250	0.0099	0.0561	0.0112
2	786.600	636.100	0.0230	0.0083	0.0584	0.0099
3	914.000	848.600	0.0276	0.0092	0.0433	0.0104
4	1388.400	1416.900	0.0314	0.0102	0.0602	0.0121

District code	Young	Mature	Young per pop	Mature per pop	Young per license	Mature per license
5	3386.400	2857.500	0.0339	0.0116	0.0680	0.0134
6	5665.400	5732.600	0.0211	0.0093	0.0466	0.0114
8	4453.400	3894.300	0.0352	0.0118	0.0625	0.0132
9	940.900	869.800	0.0351	0.0096	0.0618	0.0110
10	803.600	645.100	0.0271	0.0083	0.0539	0.0091
11	2204.000	2450.900	0.0250	0.0090	0.0504	0.0107
12	1187.400	1200.400	0.0275	0.0080	0.0472	0.0091

Motorcycle safety

The average number of motorcycle crashes per district is shown in Figure 87. District 6 and District 8 are the top two districts that experience motorcycle crashes.

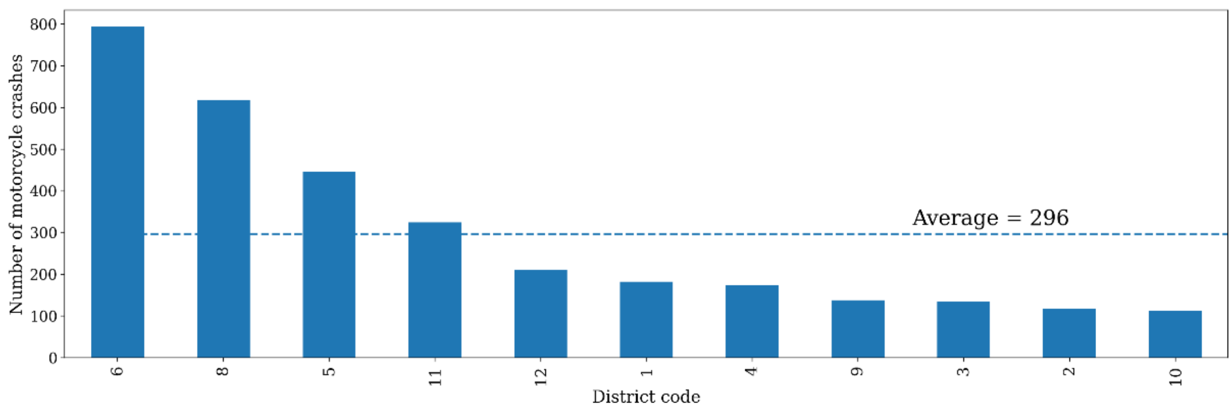

Figure 87 Average number of motorcycle crashes per year by district (2014-2021)

The average motorcycle crashes per motorcycle licenses is more evenly distributed across districts, see Figure 88.

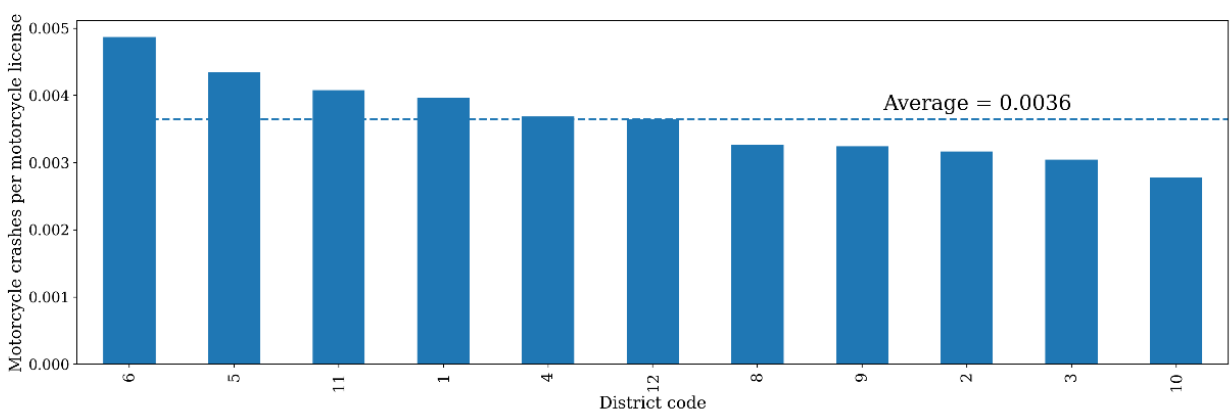

Figure 88 Average number of motorcycle crashes per motorcycle licenses per year by district (2014-2021)

A similar conclusion is obtained considering the number of registered motorcycles, see Figure 89.

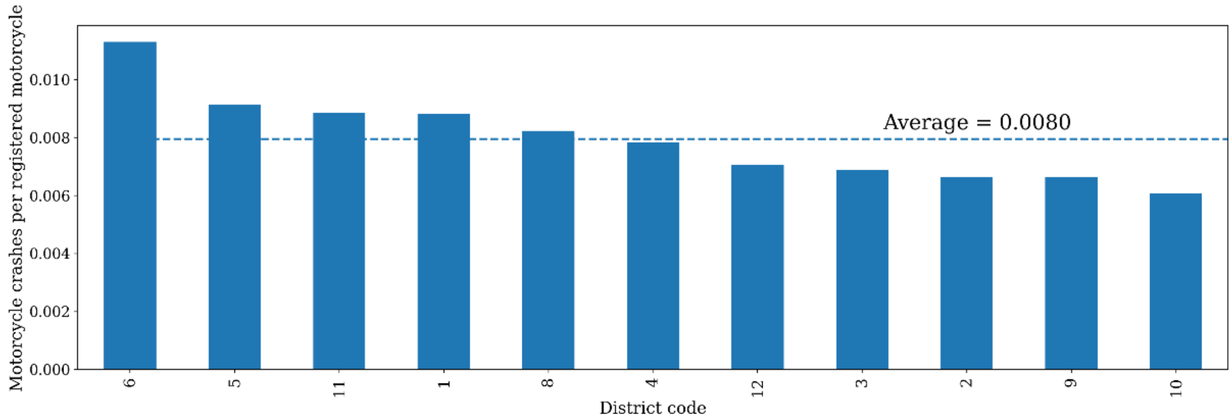

Figure 89 Average number of motorcycle crashes per registered motorcycles per year by district (2014-2021)

Table 37 shows the average and normalized number of motorcycle crashes using number of licenses and registrations, respectively, in each district.

Table 37 Average and normalized (using number of licenses and registrations) number of motorcycle crashes in each district (2014-2021)

District code	Actual crashes	Crashes per license	Crashes per registration
1	182.500	0.00382	0.0088
2	117.375	0.00303	0.0066
3	135.625	0.00293	0.0069
4	173.125	0.00359	0.0078
5	447.000	0.00422	0.0091
6	793.625	0.00476	0.0113
8	617.750	0.00376	0.0082
9	138.625	0.00317	0.0066
10	112.000	0.00269	0.0061
11	325.000	0.00399	0.0088
12	211.250	0.00355	0.0071

Seat belt use

Figure 90 shows the average number of fatalities and serious injuries of belted occupants that were involved in a crash. Figure 91 shows the average number of fatalities and serious injuries of unbelted occupants that were involved in a crash. It can be seen that while the total magnitude of fatality and injury is similar, the proportion of fatalities is greater for the unbelted occupants compared to the belted occupants.

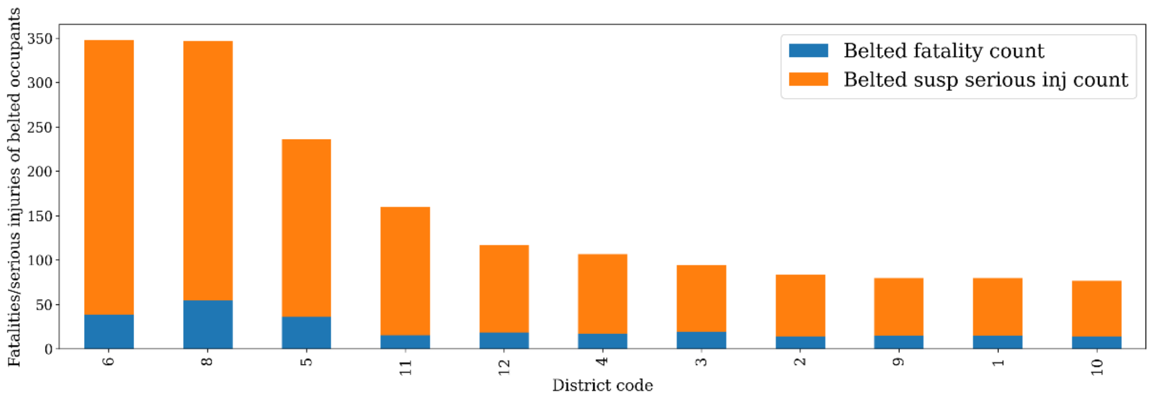

Figure 90 Average number of fatalities and serious injuries of belted occupants in crashes per year by district (2014-2021)

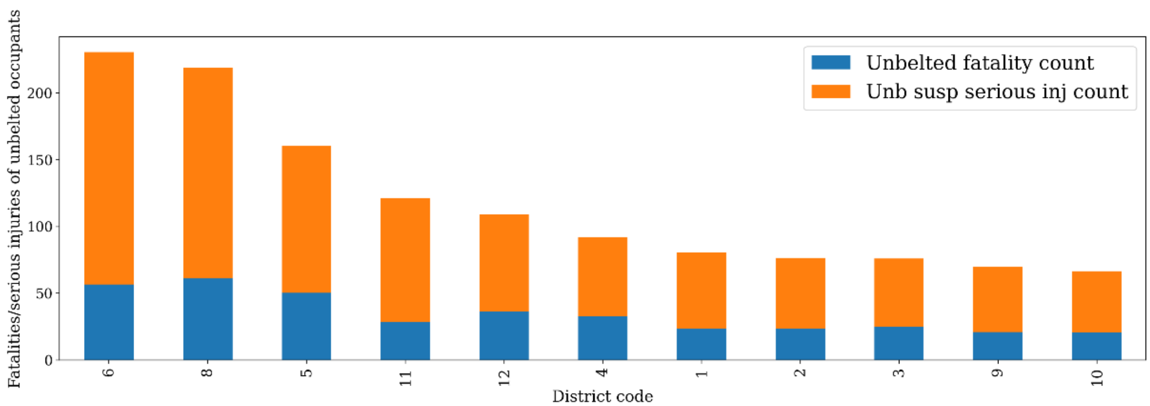

Figure 91 Average number of fatalities and serious injuries of unbelted occupants in crashes per year by district (2014-2021)

The total number of unbelted occupants involved in a crash is shown in Figure 92. As can be seen, this seems to be a large issue in District 6, followed by District 8.

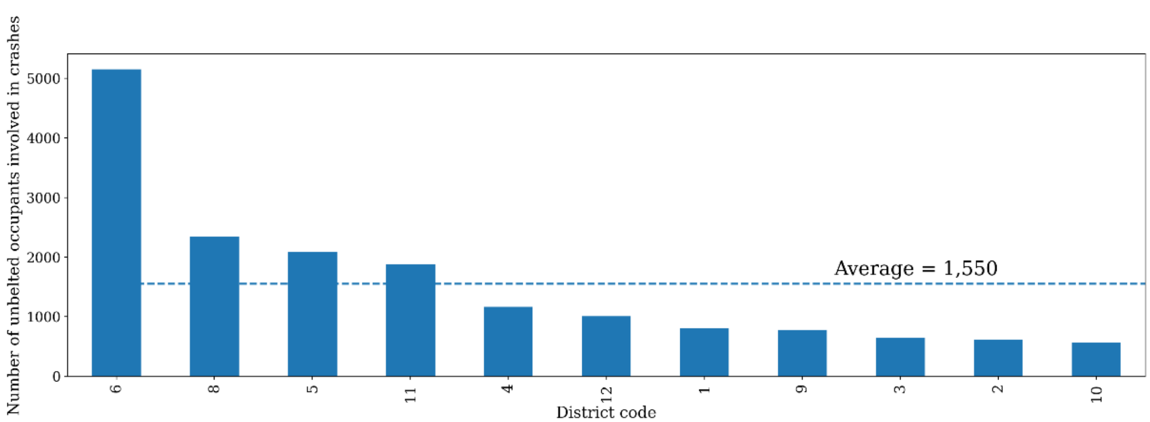

Figure 92 Average number of unbelted occupants involved in crashes per year by district (2014-2021)

When normalizing the average number of unbelted occupants involved in crashes by the number of unbelted citations given, see Figure 93, it can be seen that the number of crashes per citation is rather large in some districts, e.g., District 11 and District 6.

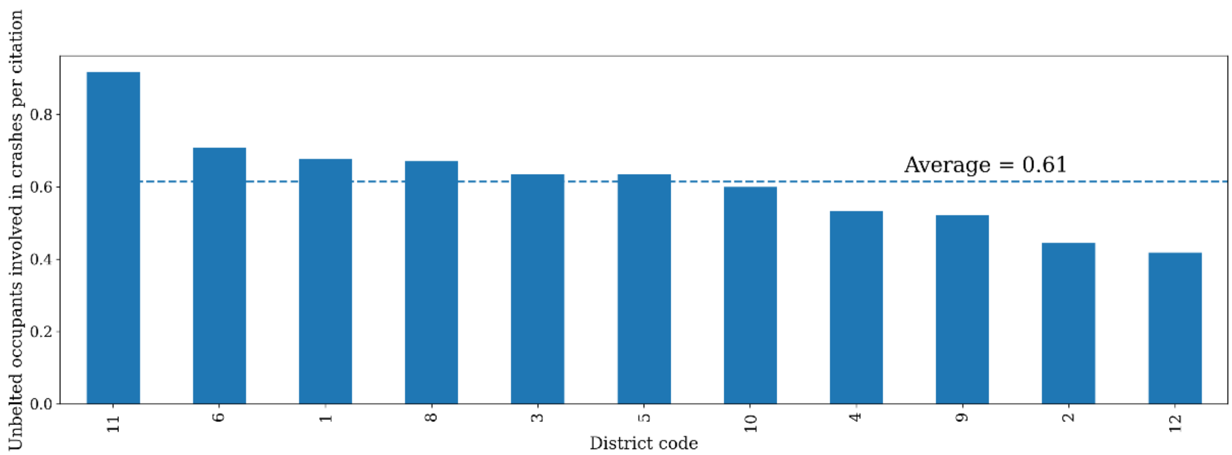

Figure 93 Average number of unbelted occupants involved in crashes per unbelted citations per year by district (2014-2021)

Work zone safety

The average number of crashes at works zones is plotted in Figure 94. This appears to be a larger problem at District 6.

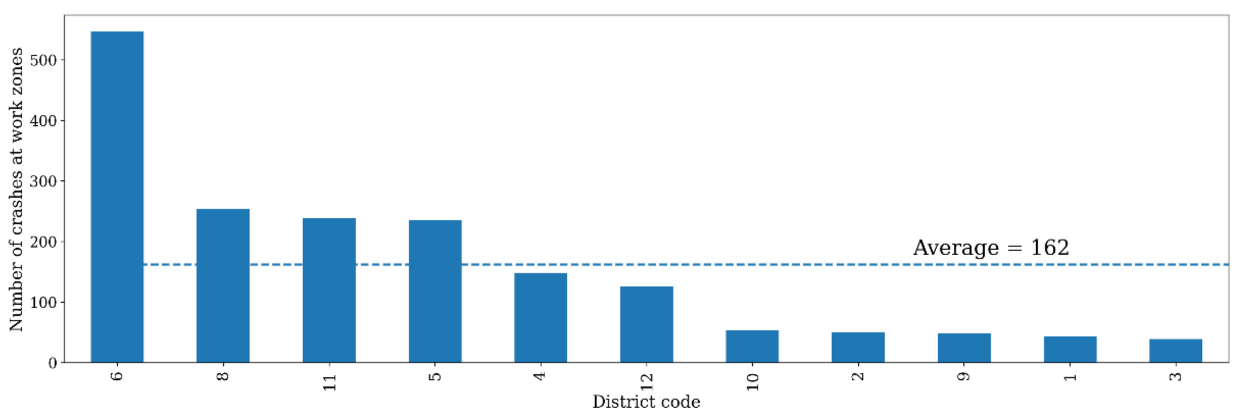

Figure 94 Average number of crashes at work zones per year by district (2014-2021)

Unfortunately, a list of work zones and when they were active from PennDOT's Bureau of Maintenance and Operations was not available. Hence, AOPC work zone citation data was used as a proxy for exposure of work zone crashes, see Figure 95. As can be seen, District 4 and District 11 appear to have the largest number of work zone crashes per work zone citation.

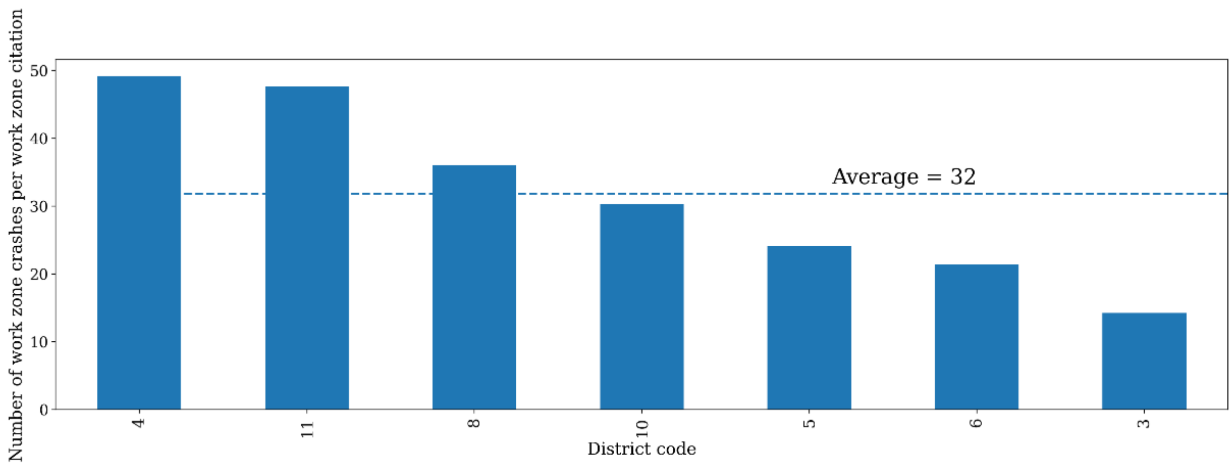

Figure 95 Average number of work zone crashes per number of work zone citations per year by district (2014-2021)

Table 38 shows the average number of belted and unbelted fatalities and serious injuries, and the actual number and normalized number of unbelted occupancies using the number of citations in each district.

Table 38 Average number of belted, unbelted, fatalities and serious injuries, and actual and normalized number (using citations) of unbelted occupancies in each district (2014-2021)

District code	Belted fatality count	Belted susp serious inj count	Unbelted fatality count	Unb susp serious inj count	Unbelted occupancy count	Unbelted per citation
1	15.1	64.6	23.6	56.9	805.5	0.68
2	14.4	69.1	23.6	53	618	0.44
3	19.3	75.1	24.9	51.1	648	0.64
4	17.4	89.4	32.8	59.4	1167.9	0.53
5	36.3	200.1	50.5	109.9	2086	0.63
6	39	308.8	56.6	174	5151.4	0.71
8	54.6	292.6	61.3	157.9	2346.1	0.67
9	14.9	65.3	21	49	779.4	0.52
10	14.4	62.5	20.6	46	568.5	0.6
11	15.6	144.6	28.4	93	1877.5	0.92
12	18.8	98.3	36.1	72.9	1005.6	0.42