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Motor Vehicle Crashes among the Older Population

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16. Abstract

Adults aged 65 or older form a vulnerable population that is susceptible to road traffic injuries. Motor vehicle crashes are among the leading causes of unintentional injury deaths for the older population. There has been an increasing trend in the percentage of fatalities involving older people among the total fatalities. As the older population continues to increase, agencies are facing more challenges in improving older people's safety. Studies have examined the correlation of aging-related physical and medical conditions with crashes in the older population. However, research on how sociodemographic characteristics, driving exposure and habits, as well as physical and medical conditions are associated with older people's crash risks in different roadway geometric, traffic operational, and environmental conditions has been extremely limited. The objectives of this project were to examine fatality and severe injury risks of motor vehicle crashes among older people, identify specific areas where crash risks may be mitigated, and make recommendations for improved safety while promoting mobility and independence among older people. The researchers conducted a literature review, statistical analyses of Illinois crash data and county-level socioeconomic data from 2011 to 2016, and a senior driver survey in Illinois. The study identified several roadway geometric, traffic operational, and environmental features that significantly affected older people's severe injury risk. These include traffic control device, roadway alignment, light and surface condition, and vehicle defect. Household income, minority and uninsured populations, physician care availability, and prescription drug use were significantly associated with severe crashes or crash risk. Recommendations were made to mitigate motor vehicle injuries and enhance safety in the older population, including updating design guides, reviewing traffic control devices at high-crash locations, and fostering a safety culture. Joint efforts from multiple agencies are needed, as the safety of older people is not merely an engineering or a safety issue.

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EXECUTIVE SUMMARY

Adults aged 65 or older form a vulnerable population that is susceptible to roadway traffic injuries. Motor vehicle crashes are among the leading causes of unintentional injury deaths for the older population. The fatality rate among older pedestrians, pedalcyclists, and drivers has risen continuously in the United States. Compared to younger people, older people face additional crash risks resulting from aging-related physical/medical conditions and prescription medications. As the older population keeps increasing, agencies are facing more challenges in improving older people's safety. It is critical to understand how demographic characteristics, physical/medical conditions, and driving habits of older people affect their crash risks under different roadway and environmental conditions. Previous research in this regard has been extremely limited. To address this need, IDOT initiated this research project. The objectives of the project were to examine fatality and severe injury risks of motor vehicle crashes among older people, identify areas where motor vehicle crash risks may be mitigated, and make recommendations for improved safety while promoting mobility and independence among older people.

Crash data over 2011–2016 were acquired from IDOT and Illinois county-level demographic data, and socioeconomic data over the same study period were retrieved from the US Census Bureau. In addition to screening, joining, and compiling, the data were categorized into different age groups for comparison. Descriptive analyses of the crash data and socioeconomic data were conducted to reveal the relation between crash frequency, type, and severity with roadway geometry, traffic operation, environment, and socioeconomic characteristics. The causation analyses were used to identify conditions where older people were prone to motor vehicle crashes. Further, multiple logistic regression analyses and hierarchical linear model analyses were performed to test if the impacts of crash data variables and socioeconomic variables on severe older people crashes are significant.

To complement the crash data and socioeconomic data, a mail-in survey was conducted to gather information on driving exposure, habits, physical/medical conditions, prescription medicine usage of older drivers in Illinois, along with their perception of roadway safety and suggestions to improve safety. A proportional sampling method was employed in identifying mail recipients. Responses were converted into a digital Excel file format and coded before data analyses. Besides frequency analyses of survey response, odds ratio and multiple logistic analyses were conducted to model the association between older driver crash/near crashes and different survey variables.

The descriptive data analysis found that the percentage of older people in the total number of people involved in crashes has been increasing over the study period in Illinois. Older people are more vulnerable than other age groups in motor vehicle crashes, particularly fatal crashes. Older non-motor-vehicle users are more likely to get injured in motor vehicle crashes compared to older motor vehicle drivers and passengers. Using reflective material or a light source is more effective in increasing older non-motorists' visibility. Compared to younger groups, obscured vision adversely impacts older people more when there are parked vehicles and trees/plants on the roadside and when they are blinded by sunlight. Older people's relative involvement is higher for rear-end, turning, or same-direction sideswipe collisions compared to other collision types. Most crashes involving older

people occurred during daylight in good weather. DUIs were not a frequent occurrence for older people.

The causation analysis focused on older people's crash data and socioeconomic characteristics to identify conditions where older people were prone to motor vehicle crashes. Moving vehicles were found to be the largest vision-obstructing parameter in severe injuries involving older people. Older males were involved in more fatalities than females, although the older male population is lower than the female. Top collision types involving older people were rear-end, turning, and angle collisions for both total crashes and severe crashes. Most total injuries and severe injuries among the older population also occurred during daylight in good weather and along straight and level roadways. This may be because older people drive mostly in the daytime and clear weather and most roadways are straight and level in Illinois. Socioeconomic data showed that crashes involving older people had a negative relationship with African American and Hispanic populations and older people education level, and a positive relationship with older population under poverty level older people employment rate.

Multiple logistic regression analyses and hierarchical linear model analyses were conducted to identify significant factors that affected older people's severe injury risk. The analyses were done using both all age and older group data for comparison. Overall, the results from the two models were similar and consistent with the findings from the causation analysis. The regression analysis showed that median household income, percentage of African Americans, and unemployment rate were negatively associated with severe crash risk involving older people. Both models also found that the higher the average number of people served by one physician, the higher the risk for severe motor vehicle crash injury. Severe injury risk increases for older people in dark conditions, along curves, and when driving vehicles with defects. At wet or snowy roadway surface conditions, the chance for older people to get severe injuries is lower than at dry surfaces. Older people avoid driving during unfavorable roadway surface conditions and when they do, they are more careful and focus on the primary driving task. Traffic control devices did not work for protecting older people; the existence of yield signs, railroad crossing signs, etc. increase severe injury risk for older people.

The older driver survey found that it is common for older people to experience driving difficulty and take prescription drugs. Medicine use significantly increases older drivers' crash/near-crash risk, but a physician warning of the side effects of prescription drugs marginally increases older drivers' crash risk. Crash risk increases as driving exposure increases. To reduce crash risk, older drivers tend to drive on local roads with low traffic volume and speed and try to avoid driving at night and in bad weather conditions. Consistent results were obtained regarding the impacts of gender and education on crash risk.

Based on the study's findings, collaborative efforts are required to mitigate motor vehicle crashes among the older population. The current roadway and traffic sign design guides appear to not fully consider the older population's needs due to declines in their sensory, perceptual, cognitive, and motor function. Reduced severe motor vehicle crashes among the older population are achievable through enhancing traffic control at high-risk locations and reducing their driving exposure.

Considering the results of the crash data statistical analysis and older driver survey, several recommendations were offered. First, the results indicate a need for special consideration of older population's needs in road design guides. Older driver safety could be improved with additional sight distance along roadways, more restrictive on-street parking, or larger sign text. The results also indicate a need for further investigation of traffic control devices at locations with a high number of severe-crash incidents involving older people. Chapter 3 identifies high-risk crash locations to consider, and Chapter 7 proposes a method for this safety investigation. Last, the recommendations include fostering a traffic-safety culture in Illinois that respects older motorists, pedestrians, and pedalcyclists. Activities could include educational outreach, coalition building, and public service announcements.

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CHAPTER 1: INTRODUCTION

BACKGROUND

Adults aged 65 or older form a vulnerable population that is susceptible to road traffic injuries. Motor vehicle crashes are among the leading causes of unintentional injury deaths for the older population. From 2006 to 2015, the fatality rate among older pedestrians, pedalcyclists, and drivers increased by 10%, 12%, and 3%, respectively, in the United States (IDOT, 2015; National Center for Statistics and Analysis, 2017; NHTSA, 2015). In 2015, older people made up 15% (47 million) of the US population, while 17.6% (6,615) of motor vehicle fatalities involved people aged 65 or older (NHTSA, 2015). With an expected older population of 72 million (20%) by 2030 (Ortman et al., 2014), agencies are facing more challenges in improving the safety of older people. The Illinois Department of Transportation (IDOT) has identified older drivers as an emphasis area in the Illinois Strategic Highway Safety Plan (IDOT, 2018).

Besides the normal risks associated with roadways, drivers, and vehicles, there are a few other reasons that make older people one of the most critical special population groups in terms of roadway safety. Compared to younger people, older people face additional crash risks resulting from physical/medical conditions and prescription medications. Over 75% of drivers aged 65 and older report using one or more medications, but less than one-third acknowledge awareness of the potential impact of medications on driving performance (MacLennan et al., 2009). In addition, due to the natural aging process, older drivers experience decreased mental and physical capabilities compared to younger people. Cognitive impairment, especially related to dementia, is associated with higher motor vehicle crash rates among older people (American Geriatrics Society & Pomidor, 2016).

In recent years, the number of motor vehicle crashes in Illinois has risen continuously. In 2011, the total number of crashes was 282,188, while in 2016 that number went up 23% to 324,499 (IDOT, 2012, 2017). In Illinois, the percentage of crashes involving older people among total crashes has also increased from 13.6% in 2011 to 14.9% in 2016 (IDOT, 2012, 2013, 2014, 2015, 2016, 2017). Figure 1 shows the increasing trend in total crashes and crashes involving older people in Illinois from 2011 to 2016.

Many studies have been conducted on motor vehicle crashes among the older population; however, they mainly focused on the correlation/association of aging-related physical and medical conditions with crashes. For example, Foley et al. (1995) found that back pain and anti-inflammatory drugs were related to severe traffic accidents. Cicchino and McCartt (2015) reported that 97% of crashes involving older drivers were due to driver error, such as misjudgment of a gap, medical event, daydreaming, etc. Similar studies also found visual impairment (Owsley et al., 1998; Rubin et al., 2007), medication use (LeRoy et al., 2008), as well as sensory, perceptual, cognitive, and motor declines (Lombardi et al., 2017) affected crash risk among older drivers. However, research has been limited on how sociodemographic characteristics, driving exposure and habits, and physical/medical conditions are associated with older people’s crash risk in different roadway geometric, traffic operational, and environmental conditions. In this context, this research project was initiated to better understand characteristics and associated factors of crashes involving older people in Illinois.

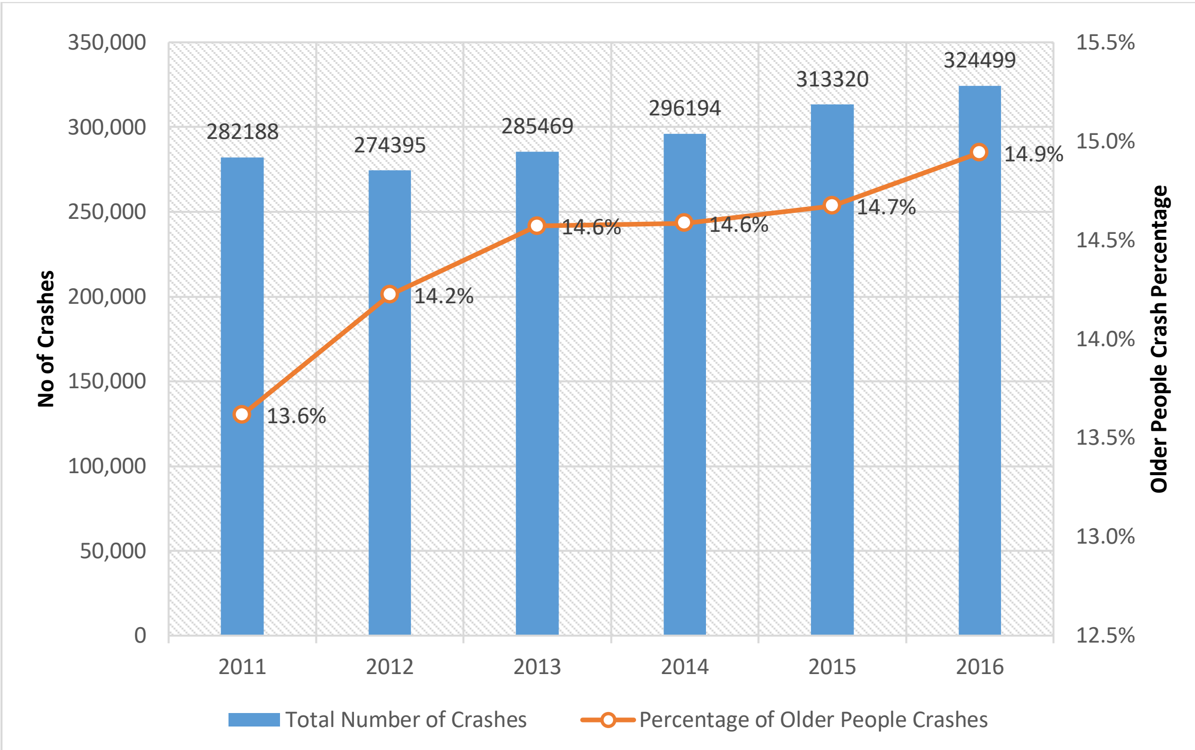

Figure 1. Chart. Total number of crashes and crash percentage of older people over 2011–2016.

Source: IDOT (2012, 2013, 2014, 2015, 2016, 2017)

RESEARCH OBJECTIVES

The objectives of this research are:

- To examine fatality and severe injury risks of crashes among older people compared to other age groups.
- To identify specific areas where crashes among older people may be improved by mitigating vehicle crash risk among older people.
- To recommend strategies for improved safety while promoting mobility and independence among older people.

RESEARCH APPROACH

To achieve the study’s objectives, a literature review was conducted on motor vehicle crashes among older people, including crash characteristics, aging-related impairment, medicine use, and statistical models employed for data analysis. Then, Illinois crash data and county-level sociodemographic data were acquired. The data were screened, combined, compiled, and categorized into different age groups. Using the cleaned data, the percentage of each age group in crash injuries at various roadway, traffic control, weather, and vehicle conditions were developed for comparison. The data were also visualized in GIS (Geographic Information System).

Next, causation analysis was conducted using only crash data involving older people to identify conditions in which older people were prone to crashes or severe crashes, as well as any relation with socioeconomic parameters. Following that, vigorous statistical analyses were performed on crash and socioeconomic data to test the significance of conditions and parameters identified in the causation analysis. Statistical models were run using data from all age groups and older age groups to determine significant variables that affected severe crashes in older people.

An Illinois senior driver survey was conducted as well. Information was gathered on older people's driving exposure, habits, and difficulties; medicine use; crash experiences; perceptions of roadway safety; as well as suggestions on improving roadway geometry and operation. Advanced statistical models were fitted using survey data along with basic statistics to investigate any significant association between survey data and older driver's crash risk. Finally, based on the research findings, strategic recommendations were formulated to improve older people's safety and mitigate motor vehicle crashes.

CHAPTER 2: LITERATURE REVIEW

A literature review was conducted of previous studies related to motor vehicle crashes among the older population. This chapter summarizes the findings in terms of older people's demographics, effects of aging-related physical condition and medicine use on driving performance and crash risk, as well as statistical models employed in analyses of crash data involving older people.

DEMOGRAPHICS ON AGING POPULATION

According to the US Census Bureau, increased longevity and lower fertility have resulted in the rapid growth of the older population across the world as well as in the United States. The current estimate shows that the United States will have the second-highest population of older people (after Europe) by 2050, comprising of 21.4% of the total population. Figure 2 shows the trend in the US population from 2011–2016 along with its older population, revealing the number of older people has been continuously rising from 13% in 2011 to 15% in 2016 (Roberts et al., 2018). In Illinois, the number of older people has also followed the nationwide trend (Figure 3).

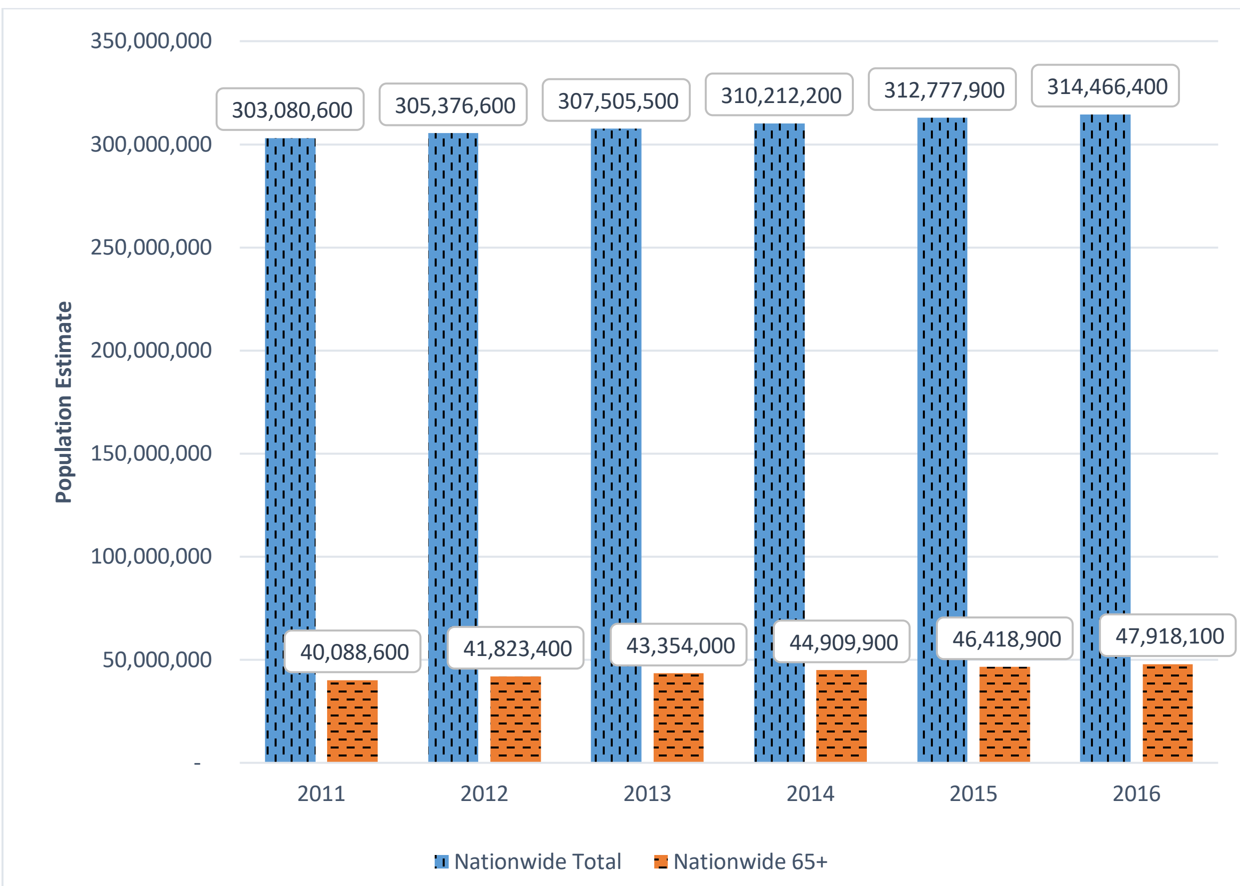

Figure 2. Chart. Population in the United States (2011–2016).

Source: Roberts et al. (2018)

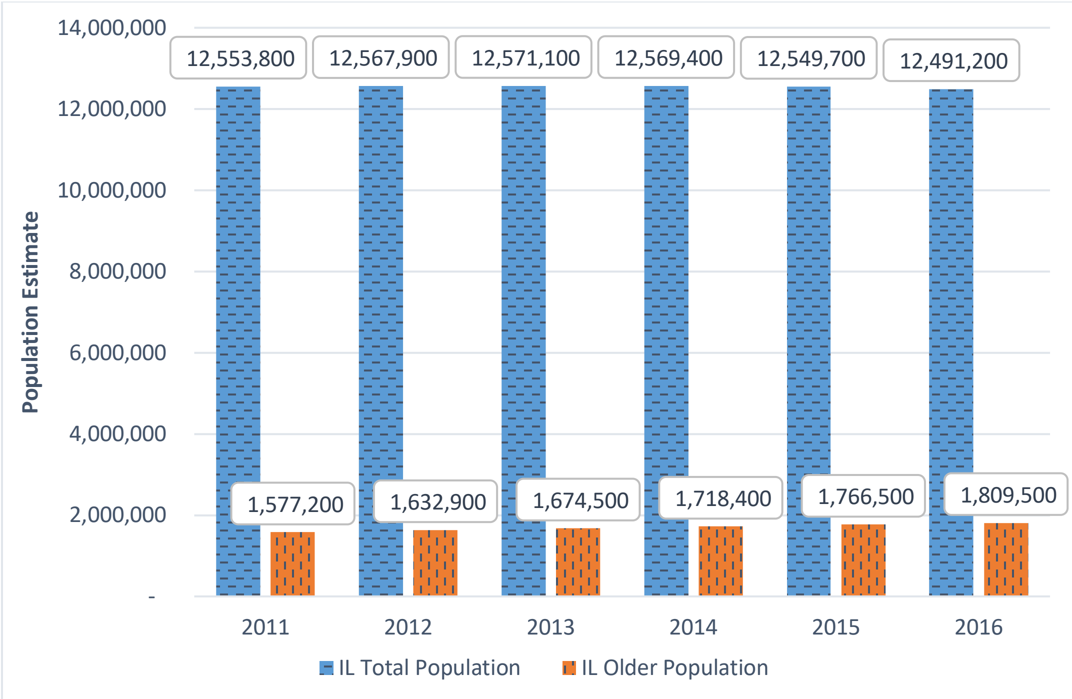

Figure 3. Chart. Population in Illinois (2011–2016).

Source: Roberts et al. (2018)

These trends also resemble the overall increase in older drivers, pedestrians, and pedalcyclists. There will be significant consequences for the older population, as their mobility needs continue to rise. It is important to revise existing mobility regulations involving older people, because motor vehicle crashes and crash-related injuries will continue to rise with the increase of the aging population (Lombardi et al., 2017). To reduce motor-vehicle-related crash injury and severity, it is also important to help older people "age in place" in terms of their accessibility, mobility, safety, and quality of life (Lombardi et al., 2017).

DEFINING OLDER POPULATION GROUPS

Despite having quite a few studies on older people, researchers have not agreed on using chronological age groups as the basis of their investigations. Thus, the existing literature shows different theories in conducting older population safety analysis. Aksan et al.'s (2013) study on older driver visual parameters mentioned that there is no significant age to define a driver as an older driver. Coughlin's (2001) study on policy development for the aging population rejected the theory of using chronological groups for driver safety analysis. Hakamies-Blomqvist (1993) noted that studying the older population is complicated, as aging can be described as a complex function of social, psychological, and biological changes.

Traditionally, people retire by the age of 65, so it makes sense to consider adults aged 65 or above as older people in safety analyses (Elliott et al., 1995). The National Highway Traffic Safety Administration (NHTSA) has considered adults aged 65 or older as the older population, because drivers change their way of driving at this age by limiting driving areas, time, and duration, etc. (NHTSA, 2011). Previous studies have been conducted to identify the older population's involvement in certain crash types and concluded that people aged 65 or older have higher fault rates in traffic crashes (Alam & Spainhour, 2009). Most recent surveys and older population crash-safety articles use people aged 65 or older as a representative group to determine issues related to older driver's crash injuries (Cerrelli, 1989; Chandraratna et al., 2002; Lyman et al., 2002; Pymont et al., 2012). Despite using chronological or functional age groups for labeling "older drivers" in this analysis, note that older people are not comprised of one homogeneous group. Individual differences will likely be found within groups (Cerrelli, 1989).

IMPACTS ON DRIVING DUE TO AGE

Previous studies have found significant declines in older people's performance in terms of their sight, hearing, and balance, which affect their ability to maneuver vehicles or assess road conditions safely (e.g., Lang et al., 2013). According to Lang et al. (2013), while these performance reductions are not necessarily the same for everyone, they can be labeled into three broad categories: motor, sensory, and cognitive declines.

Motor Decline

Motor decline includes older drivers' inability to maneuver vehicles in traffic safely and their decline in overall body movement that may affect their gesticulation ability (Lang et al., 2013).

Sensory Decline

Another significant impairment that affects older drivers' abilities is sensory decline, including vision and hearing.

Vision

Vision is inarguably a major component of driving (Owsley & McGwin, 2010). Visual impairment increases driver discomfort, driving difficulty, and crash risk. Vision bears the utmost significance, as it facilitates drivers' or pedestrians' decision-making abilities in terms of hazard perception and providing attention to road objects (Staplin et al., 2012). Several studies have been conducted on static and dynamic visual acuity as well as contrast sensitivity, which are common visual problems found in older people (Lang et al., 2013). In a review-based study on older people's safety improvement, researchers outlined that visual perception and the visual system change with aging. Most people lose their ability to focus their eyes on nearby objects (presbyopia) due to the thickening of the eye lens in their 40s (Boot et al., 2013). Studies on visual impairment among older drivers have revealed that older drivers with 40% or more impairment with their useful field of view are 2.2 times more likely to be involved in motor vehicle crashes (Huisingh et al., 2014; Owsley et al., 1998; Remington, 2012).

Hearing

Hearing is another important sensory capability that provides road users with information on road environment traffic conditions. Older people also experience common hearing issues that make them susceptible to collisions. Diminished hearing capabilities create challenges for older people in identifying and reacting to traffic signals while driving or using road space (Vachal et al., 2010). Up to 30 million older people in the United States are affected with hearing impairments (Edwards et al., 2017). Edwards et al. (2017) found that after adjusting for covariates (i.e., age, sex, medications, and chronic health conditions), self-reported hearing loss among older people was associated with higher crash involvement.

Cognitive Decline

Cognitive impairment can lead to a decline in working memory, attention, multitasking, hazard perception, and judgement. Older people have previously been reported with making wrong judgments about speed and/or distance and ignoring distractions while using roads. Diminished cognitive abilities result in older people's inability to process complex problems and slower reaction times (Vachal et al., 2010). Previous statistics show that older drivers make critical errors in cross traffic while conducting vehicular maneuvers at or near intersections due to their age-related attention or cognitive deficits (Schlorholtz, 2006). Alzheimer's is a common disease among older people, which is a degenerative brain disease that causes cognitive failure (Gaugler et al., 2016).

EFFECT OF MEDICATIONS ON OLDER DRIVERS

The AAA's long road study (2018) has found heavy usage of medications among older drivers. Almost 97% of older people with a driver's license who actively drive once or more in a week take at least some medications. Among them, around 65% are on more than four medications per day. In addition, the distribution of medication consumption among older people was positively skewed (AAA, 2018). They also revealed that the use of cardiovascular medication among older people was at least 10% greater among males than females, and cardiovascular medication was found more among African American participants (AAA, 2018). The effects of medication on injuries are raising concerns. NHTSA (2015) revealed that 11.1% of drivers or motorcyclists in fatal accidents, 11.4% of fatal pedestrian crashes, and 7.1% of pedalcyclist fatalities were influenced in some form by alcohol, drugs, or medications.

A previous study based on the older population in Orange County, California, has shown that older drivers have a lower injury tolerance than other groups when it comes to motor vehicle crashes (Lotfipour et al., 2013). Fatality rates among older drivers are higher compared to younger drivers due to psychological and pathological changes. Some studies on common prescription and nonprescription medicine have found potential adverse effects on older people's injuries in motor vehicle crashes (American Geriatrics Society and Pomidor, 2016; Elliott et al., 1995; Gaugler et al., 2016; U.S. DOT, 2008). In general, older populations are more prone to biological system failures that introduce limitations to their motor, sensory, and cognitive functions. In addition, previous studies have revealed that older people are more prone to using psychoactive medications for cognitive boosts, which hampers their ability to perform well on the road (Rolison et al., 2018). Common medications for older people have also been found to have anticoagulants, which make them more prone to severe injuries than other drivers or occupants in motor vehicle crashes (Lotfipour et al., 2013). Childs et al. (1994) studied older drivers in California and highlighted the effects of fatigue while driving due to medications. Moreover, some medications that were used to cure common dementia-like syndromes among older people (e.g., certain vitamin deficiencies or thyroid problems) have been known to have potential side effects such as failing cognitive abilities while driving (Gaugler et al., 2016). Another study from Japan has also come into consensus about the effects of medication use on motor vehicle crashes among the older population. Nagata et al. (2012) concluded that excessive use of medications had severe “exaggerating consequences.”

OLDER PEOPLE AND CRASH RISKS

Although older drivers have been found to follow traffic rules safely, they are more prone to fatal injuries in motor vehicle crashes (Mizenko et al., 2015). Due to their chronic medical conditions and medication use, older people may compromise their ability to drive, which may result in greater crash risk (Lang et al., 2013).

According to recent findings, the mobility needs of older people will become more important due to the increasing percentage of the older population. Existing literature has identified that older males are more susceptible to injuries than older females. Dissanayake et al. (2018) found that older drivers (65 or older) have a similar injury risk as younger adults (15–24 years). Older drivers in crashes usually show the following characteristics:

- Multi-vehicle crashes
- Daylight crashes during weekdays
- Crashes occurring at or near intersections or places with complex road geometry
- Crashes due to low speed
- Failure to yield the right-of-way
- Improper turning movements
- Failure to avoid obstructions etc. (Dissanayake et al., 2018).

STATISTICAL MODELING METHODS FOR CRASH DATA ANALYSIS

Some researchers have tried to identify the likelihood of injuries due to different crash-related parameters using statistical modeling. Yoon et al. (2017) conducted crash-severity injury modeling on local bus-related crashes and adopted hierarchical modeling to determine the significance of unobserved socioeconomic characteristics on crash-related injuries. Another study employed logistic regression models to identify contributing characteristics on large-truck fatal crashes using FARS data (Fatality Analysis and Reporting System). The study investigated various road characteristics (road surface condition), crash characteristics (class of injury, crash location, collision type, speed limit, light, and weather conditions), along with driver characteristics on large-truck crashes involved in single- and multi-vehicles (Dissanayake & Kotikalapudi, 2012). In addition, negative binomial models and multinomial logit models have also been used to determine the impact of bus size and operation characteristics on injury severity, which used the frequency of crash frequency and crash severity as outcome variables (Dissanayake & Kotikalapudi, 2012). Some micro-level analyses aiming to determine the effect of certain crash characteristics on injury severity have also used statistical models, including ordered probit, logistic regression, generalized ordered logit, and Poisson regression models (Yoon et al., 2017).

SUMMARY

Older people are more vulnerable to severe crash injuries than younger groups. Various factors influence their behavior and crash risk as drivers, pedestrians, and pedalcyclists. The literature review showed many previous studies have examined motor vehicle crashes among the older population to mitigate their crashes and crash risks.

Most of the studies focused on the association between aging-related physical/medical conditions and crashes involving older people. Past studies generally agree that declines in sensory, perceptual, cognitive, and motor functions; medical conditions; and medicine use are highly associated with motor vehicle crashes involving older people. Inconsistent results were obtained on how to define the older population. Research on the impacts of increased mobility needs, driving behaviors/habits, and socioeconomic characteristics on crash risk among older people is rare. No previous research has been conducted on motor vehicle crashes among the older population in Illinois. Statistical modelling has been largely employed in previous studies to identify contributing factors of motor vehicle crashes. The logistic regression model is one of the most-used models. Recently, hierarchical modelling has been used to analyze crash data with nested characteristics. Despite various methodological approaches, few studies have examined older population crashes using both observed (crash-specific variables) and unobserved parameters (socioeconomic variables). Therefore, this research demonstrated using both hierarchical linear modeling and the logistic regression model to identify any relationship between crash injuries among older people with observed and unobserved parameters in Illinois.

CHAPTER 3: DATA DESCRIPTION

Three sets of data were used in the research, namely crash, demographic, and senior driver survey data. This chapter describes the procedures followed for obtaining the data and summarizes the activities for data preparation, including data screening, combining, compiling, sorting, and categorization.

CRASH DATA

Crash data were acquired for a six-year period (2011–2016) from IDOT's crash database. Then, the crash data were screened, cleaned, combined, and compiled for the subsequent data analysis. As the study targeted the older population (age 65 and older), the crash data were categorized into different age groups for comparison.

The original crash data obtained from IDOT contained information on all motor vehicle crashes that occurred in Illinois between 2011 and 2016. Each year's crash information was stored in three separate datasets: crash, person, and vehicle. The original crash data were converted from a .txt format to a readable. csv (comma-separated values) format in Microsoft Excel. Then, the six annual datasets were merged into a single dataset by joining all annual crash datasets using the unique ID for each crash. The resultant database will be referred to as the "crash database." A similar procedure was followed for the person and vehicle datasets, resulting in the "person database" and "vehicle database," respectively.

The crash data contains information on crash characteristics, as well as roadway, traffic control, and environmental conditions at the time of a crash. The person data contains information of all people involved in each crash, and the vehicle data contains descriptive and dynamic information of all vehicles involved in each crash. Table 1 presents a complete list of data items for crash, person, and vehicle data. The Illinois Crash Number (ICN) and Crash ID are unique for each motor vehicle crash, which are contained in all three sub-datasets.

Table 1. Crash Data Items and Description

Variables	Codes and Description
CountyCode	01-102
CrashMonth	01-12
CrashHour	0-23
CollisionTypeCode	1= Pedestrian, 2= Pedalcyclist, 3= Train, 4= Animal, 5= Overturned, 6= Fixed Object, 7= Other objects, 8= Other non-collision, 9= Parked Motor vehicle, 10= Turning,11= Rear-end, 12= Sideswipe-same direction, 13= Sideswipe-opposite direction,14= Head-on,15= Angle
TrafficControlDeviceCode	1=No controls, 2=Stop sign/flasher, 3=Traffic signal, 4=Yield, 5=Police/flagman, 6=RR crossing gate, 7=Other RR crossing, 8=School zone, 9=No passing, 10=Other regulatory sign, 11=Other warning sign, 12=Lane use marking, 13=Other, 14=Delineators Added 2008, 99=Unknown
RoadSurfaceConditionCode	1= Dry, 2= Wet, 3= Snow or slush, 4= Ice, 5= Sand, mud, dirt, 6= Other, 9= Unknown
RoadDefectsCode	1= No defects, 2= Construction zone Removed 2013, 3= Maintenance zone Removed 2013, 4= Utility work zone Removed 2013, 5= Work zone – unknown Removed 2013, 6= Shoulders, 7= Rut, holes, 8= Worn surface, 9= Debris on roadway, 10= Other, 99= Unknown
LightConditionCode	1= Daylight, 2= Dawn, 3= Dusk, 4= Darkness, 5= Darkness, lighted road, 9= Unknown

Variables	Codes and Description
WeatherCode	1= Clear, 2= Rain, 3= Snow, 4= Fog/smoke/haze, 5= Sleet/hail, 6= Severe cross wind, 7= Other, 8= Cloudy/overcast Added 2013, 9= Unknown
IntersectionRelated	1= Yes, 0= No
AlignmentCode	1= Straight and level, 2= Straight on grade, 3= Straight on hillcrest, 4= Curve, level, 5= Curve on grade, 6= Curve on hillcrest
RoadwayFunctionalClassCode	10= Interstate, 20= Freeway and Expressway, 30= Other Principal Arterial, 40= Minor Arterial (Non-Urban), 50= Major Collector (Non-Urban), 60= Local Road or Street (Non-Urban), 70= Minor Arterial (Urban), 80= Collector (Urban), 90= Local road or Street (Urban)
WorkZoneRelated	1= Yes, 0= No
PersonTypeCode	1= Driver, 2= Pedestrian, 3= Pedalcyclist, 4= Equestrian, 5= Occupant of nonmotorized vehicle, 6= Noncontact vehicle, 7= Passenger
BirthDate	
AgeAtCrash	
Gender	Male= 1, Female= 2
BAC	00-94= Actual reported BAC result, 95= Test refused, 96= Test not offered, 97= Test performed, results unknown
VIS	1= Not obscured, 2= Windshield (water/ice), 3= Trees, plants, 4= Buildings, 5= Embankment, 6= Signboard, 7= Hillcrest, 8= Parked vehicles, 9= Moving vehicle, 10= Blinded – headlights, 11= Blinded – sunlight, 12= Blowing materials, 13= Other, 99= Unknown
PersonInjuryClass	4= Fatality, 3= A-Injury, 2= B-injury, 1= C-injury, 0= No indication of injury.
PEDV	1= No contrasting clothing, 2= Contrasting clothing, 3= Reflective material, 4= Other light source used
VehTypeCode	1= Passenger car, 2= Pickup truck, 3= Van/mini-van, 4= Bus up to 15 passengers, 5= Bus over 15 passengers, 6= Truck – single unit, 7= Tractor w/semi-trailer, 8= Tractor w/o semi-trailer, 9= Farm equipment, 10= Motorcycle (over 150 cc), 11= Motor driven cycle, 12= Snowmobile, 13= All-terrain vehicle (ATV), 14= Other vehicle with trailer, 15= Sport utility vehicle (SUV), 16= Other, 99= Unknown/NA
VehUseCode	1= Not in use, 2= Personal, 3= Driver education, 4= Ambulance, 5= Fire, 6= Police, 7= School bus, 8= CTA (Chicago Transit Authority), 9= Mass transit, 10= Other transit, 11= Military, 12= Agriculture, 13= Tow truck, 14= Construction/maintenance, 15= House trailer, 16= Camper/RV – towed/multi-unit, 17= Camper/RV – single unit, 18= Taxi/for hire, 20= Commercial – multi-unit, 21= Commercial – single unit, 22= State owned, 24= Lawn care/Landscaping Added for 2008, 98= Other, 99= Unknown/NA
VehDefectsCode	1= None, 2= Brakes, 3= Steering, 4= Engine/motor, 5= Suspension, 6= Tires, 7= Exhaust, 8= Lights, 9= Signals, 10= Windows, 11= Restraint system, 12= Wheels, 13= Trailer coupling, 14= Cargo, 15= Fuel system, 16= Other, 99= Unknown
VehManeuverPriorCode	1= Straight ahead, 2= Passing/overtaking, 3= Turning left, 4= Turning right, 5= Turning on red, 6= U-turn, 7= Starting in traffic, 8= Slow/stop – left turn, 9= Slow/stop – right turn, 10= Slow/stop – load/unload, 11= Slow/stop in traffic, 12= Driving wrong way, 13= Changing lanes, 14= Avoiding vehicles/objects, 15= Skidding/control loss, 16= Entering traffic lane from parking, 17= Leaving traffic lane to park, 18= Merging, 19= Diverging, 20= Enter from drive/alley, 21= Parked, 22= Parked in traffic lane, 23= Backing, 24= Driverless, 25= Other, 26= Negotiating a curve, 99= Unknown/NA

Crash data includes information about crash month, day, year, county, time of crash, weekday, crash hour, city code, city class code, collision type code, and other information. To show the severity, crash data includes information such as crash severity code and various injury types: fatal as well as A-, B-, and C-injuries. The road-surface condition code provides information related to favorable (dry) and unfavorable (wet, snow, ice, or sand) road-surface conditions at the time of a crash. In addition, the light condition and weather codes provide information about the light adequacy and surrounding weather at the time of a crash. The roadway alignment code involves the alignment condition at the time of the crash. To determine whether the crashes were related to intersections or work zones, the crash data involved two columns titled “intersection related” and “work zone related.”

Along with ICN and Crash ID information, the person data had detailed data regarding the people involved in roadway crashes, e.g., their age, gender, birthdate, etc. To identify the types of people involved in crashes, the person data provides information about types of people involved in crashes such as drivers, passengers, or pedestrian/pedalcyclists. DRAC (driver action) provides information about people’s physical condition at the time of a crash, while BAC (blood alcohol content) provides information about alcohol impairment. VIS provides information about obscured vision at the time of a crash. In addition, the person data provide information about pedestrian and pedalcyclist visibility during crashes, along with the injury classes of people involved in a crash.

Using Crash ID, the three sub-datasets were linked together, resulting in a comprehensive crash dataset containing crash, people, and vehicle data for all motor vehicle crashes from 2011 to 2016. The final crash dataset was stored in Microsoft Access. Note that for one specific crash, there might be more than one entry on people or vehicles if more than one person or vehicle were involved in the crash.

DEMOGRAPHIC DATA

In addition to the crash data from IDOT’s crash database, the research team also collected a large set of Illinois demographic data from the US Census Bureau. The data were important to understand what demographic factors were highly associated with motor vehicle crashes among older people, especially severe crashes, in Illinois and helped develop appropriate strategies to improve the safety of older people.

The US Census Bureau’s tool “American Fact Finder” was employed to download demographic information obtained from the American Community Survey during 2011–2016. Figure 4, Figure 5, and Figure 6 show the interfaces of the US Census Bureau’s “Download Center” used to complete the task.

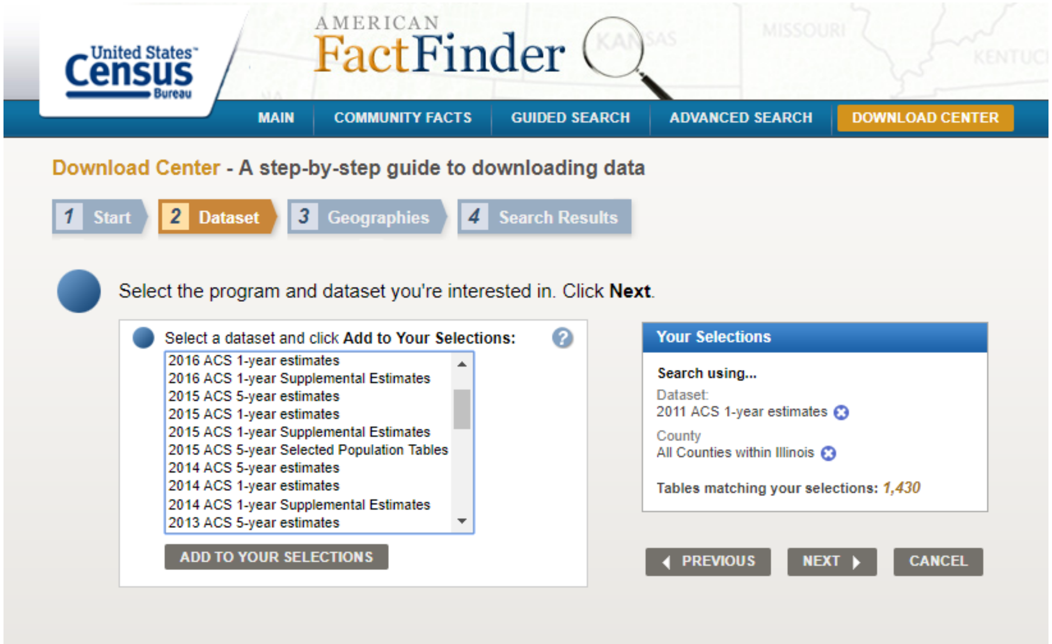

Figure 4. Photo. Interface for selecting datasets.

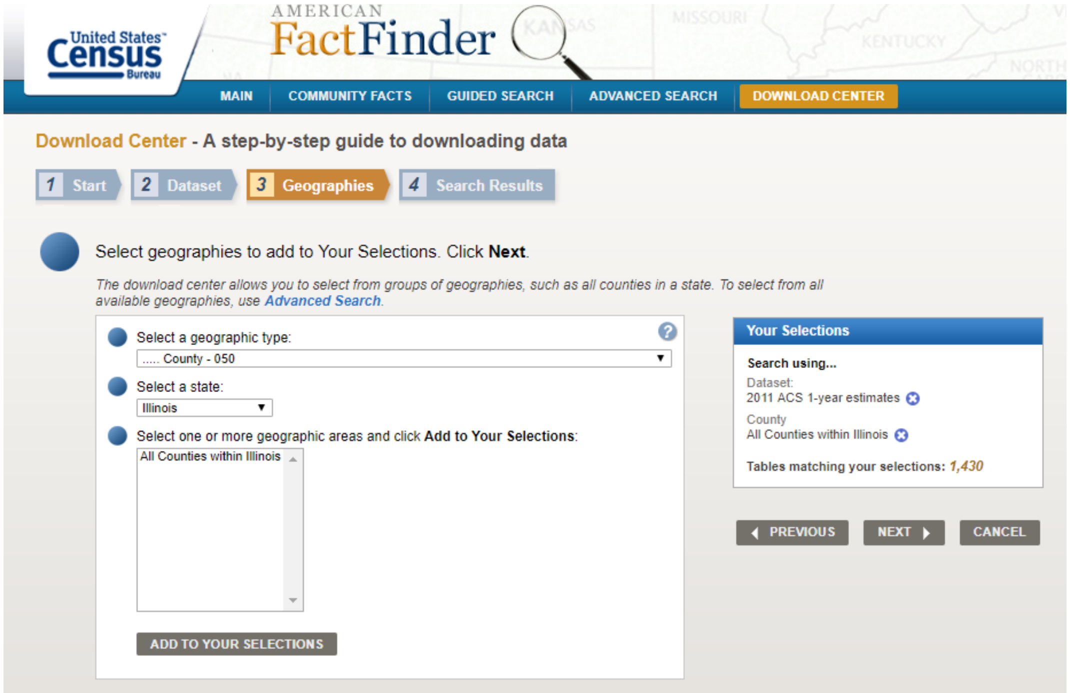

Figure 5. Photo. Interface for selecting geographic area.

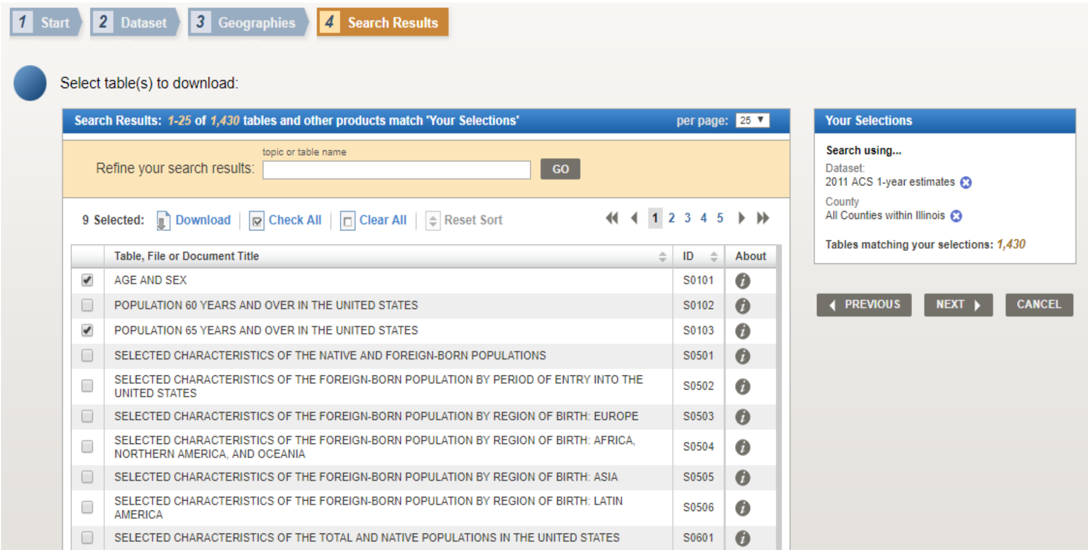

Figure 6. Photo. Interface for selecting datasets within the selected area.

Demographic information used for this research were retrieved from the American Community Survey data, including all related socioeconomic characteristics such as age, sex, population estimates, household characteristics, education attainment, median income, occupancy characteristics, race, employment status, household income, etc. The socioeconomic data retrieved were aggregated data at the county level. They were later used to construct statistical models to identify significant socioeconomic factors that affect older people's safety.

OLDER DRIVER SURVEY DATA

To complement the crash data and demographic data, a survey of licensed older drivers was conducted in Illinois to better understand older people's driving exposure and habits, physical conditions, medicine use, opinions on crash risk, and suggestions to improve their safety. A questionnaire was developed for the survey, which includes five sections: demographic characteristics, driving exposure, driving behavior and habit, physical conditions and medications, and driving safety. For easy completion and data compilation, the questionnaire was designed to be short, easy to understand, provide more multiple-choice questions, and avoid open-end questions. Appendix D shows the survey instrument.

To obtain a representative sample of older drivers across Illinois and remove possible bias from unbalanced data, a proportional sampling method was employed in the survey. This is a sampling method in which a finite population is divided into subpopulations and then random sampling techniques are applied to get samples in each subpopulation proportional to their size. First, a sample size of 1,200 was determined. With the help of the Technical Review Panel (TRP), the population for licensed older drivers was obtained and then further divided into three age groups (65–74, 75–84, and 85 and older) within each county and categorized as male and female. Following that, the 1,200 samples were distributed among the subcategories in proportion to their population. Last, a random sampling technique was used to select samples of older drivers within each subcategory based on the sample size assigned to it. Appendix E shows the final sample size table for each subcategory used in the study.

The survey was conducted using hard copies, as a large percentage of older people may not have access to computers or the internet. With the help of the TRP and IDOT, hard copies of survey questionnaires were mailed to the sampled older drivers with a prepaid return envelope. The survey was conducted from September through October 2019, and a total of 417 returned responses were gathered. The answers to the survey questions were voluntary and anonymous.

After receiving hard copies of the survey responses, the research team digitized them into an Excel file. Then, responses for each question were coded in a binary format for the subsequent analyses, where 1 meant success or the occurrence of a parameter while 0 meant the failure or absence of a parameter in the study.

SUMMARY

Illinois crash data from 2011–2016 were acquired from IDOT's crash database. Each year's crash information was stored in three separate datasets: crash, person, and vehicle. The crash dataset contains information on crash characteristics, as well as roadway, traffic control, and environmental conditions at the time of a crash. The person dataset contains information of all people involved in each crash, and the vehicle dataset contains descriptive and dynamic information of all vehicles involved in each crash. The crash data were screened, combined, and compiled, as well as categorized into different age groups for comparison.

In addition, county-level socioeconomic data during the same period were retrieved from the US Census Bureau. The information gathered included age, gender, population estimates, household characteristics, education attainment, median income, occupancy characteristics, race, employment status, household income, etc.

To gather information to complement crash and socioeconomic census data, a survey of licensed older drivers in Illinois was conducted. Hard copies of the questionnaire were mailed to the 1,200 older drivers sampled, using the proportional random sampling technique. A response rate (417/1200) was achieved. In addition to the basic demographic information of respondents, data collected from the survey also included older people's driving exposure, behaviors, and habits; physical condition; medicine use; crash experience; and perception of roadway safety.

CHAPTER 4: METHODOLOGY

This chapter presents the methods used to analyze the crash, demographic, and survey data gathered in the study. Both basic descriptive analysis methods and advanced statistical models were employed, including descriptive analysis of crash and survey data, crash causation analysis using crash and demographic data, odds ratios of survey variables, multiple logistic regression and hierarchical linear modelling of crash and demographic data, and multiple logistic regression of survey data. The selection of statistical models was based on the literature review on analysis methods of crash data and the characteristics of the data collected in the study.

DESCRIPTIVE ANALYSIS

To reveal crash trends and patterns, crash frequency and severe crashes related to older people were identified and compared with total crashes from 2011 to 2016. Further, crashes related to older people were presented in comparison to crashes of other age groups at various roadway geometry, traffic operational, and environmental conditions. The analysis was conducted for each year from 2011 to 2016. Data with an extremely low number of entries were combined over the six-year period to increase the sample size and analysis reliability.

Similarly, frequency and ranking of survey responses were developed to show the distributions of responses to survey questions, including basic demographic characteristics, physical condition, driving exposure/habit, medicine use, etc.

CRASH CAUSATION ANALYSIS

A crash causation analysis was conducted to identify conditions/situations where older people are more prone to motor vehicle crashes, particularly fatalities and severe injuries. Using the crash and demographic data for older people obtained from IDOT and the US Census Bureau, analyses on the factors/variables related to a high number of motor vehicle crashes or severe crashes involving older people were performed for the following categories:

- People characteristics (e.g., type of person, BAC, VIS, injury class, PEDV, and collision type, etc.).
- Roadway characteristics (surface conditions, light conditions, alignment conditions, intersection and work-zone related, etc.).
- Environmental characteristics (weather conditions).
- Demographic/socioeconomic characteristics (race, poverty level, education level, employment condition, etc.).

The number of injuries were calculated for three older people age groups (age 65–74, 75–84, and 85 or older) with respect to the above variables and compared from year to year from 2011–2016. Because K- and A-injuries are more critical and expensive compared to other injury classes, this analysis focused on K-and A-injuries involving people aged 65 or older. The number of injuries and severe injuries (K+A) involving older people were ranked from high to low across individual factors and different years. The top-ranked factors were identified as crash- or severe crash-prone conditions involving older people.

In addition, the crash data were filtered and sorted by county to determine the county's portion in the total number of injuries and severe crash injuries. County-level crash data were then combined and grouped together with the socioeconomic data obtained from the US Census Bureau. Scatterplots and trending lines were developed to identify any relation between socioeconomic parameters and injuries involving older people.

ODDS RATIO

An odds ratio is a statistic that quantifies the strength of the association between two events. It is defined as the ratio of the odds of event A in the presence of event B and the odds of event A in the absence of event B (Figure 7). Two events are independent only if the odds ratio equals 1. If the odds ratio is greater than 1, then A and B are positively associated. In contrast, if the odds ratio is less than 1, then A and B are negatively correlated.

$$Odds\ Ratios = \frac{Odds\ of\ event\ A\ in\ Presence\ of\ B}{Odds\ of\ event\ A\ in\ Absence\ of\ B}$$

Figure 7. Equation. Odds ratio for event A and B.

Source: Szumilas (2010)

In the study, odds ratios were calculated to quantify the association of various variables with four survey parameters: driving difficulty, annual miles travelled, number of days driven per week, and crash/near-crash experience. For simplicity, multiple-level variables were collapsed into binary variables. Specifically, respondents were considered to have a high level of difficulty if they tried to avoid three or more types of unfavorable driving conditions. Respondents were considered to have a low level of difficulty if they tried to avoid two or fewer types of unfavorable driving conditions. Similarly, driving less than 5,000 miles per year was considered as low annual miles traveled, while driving more than 5,000 miles per year was categorized as high annual miles traveled. The number of days driven per week was categorized into 1–2 days and more than two days a week.

MULTIPLE LOGISTIC REGRESSION ANALYSIS

Categorical data analysis methods were used to analyze crash data obtained from IDOT along with demographic data, as well as crash/near-crash data gathered from the older driver survey, because crash data are typical categorical (in person-injury type). This study focused on determining the association of injuries among the older population with other variables; therefore, logistic regression models were employed. The logistic regression model belongs to the generalized linear model family, which has been used in previous studies on crash data analysis (e.g., Dissanayake & Kotikalapudi, 2012).

Overview of Multiple Logistic Regression

Logistic regression is generally used when there is a binary outcome (Y = 1 or Y = 0), where 1 refers to success. If a single dependent variable is predicted from a single predictor, it is called simple logistic regression. When a single dependent variable is predicted from two or more predictors, it is called multiple logistic regression. In a multiple logistic regression model, more than one covariate (X1, X2, ………, Xn) is connected to the binary response variable Y in the following model format:

$$\text{logit}(P_i) = \log\left(\frac{Pi}{1-Pi}\right) = \beta_0 + \beta_1 X_1 + \text{----------------} + \beta_j X_j + \text{---------------} + \beta_n X_n;$$

Figure 8. Equation. Multiple logistic regression model.

Source: Kononen et al. (2011)

Where, P_i = response probability, β = model coefficient, and X_i = predictor variables.

The predictors can be continuous or categorical variables. A positive model coefficient means an increase in the risk of a successful event and a negative means a decrease in the risk (Kononen et al., 2011). The method of maximum likelihood was used to estimate multiple logistic model coefficients. The χ^2 test p-value of each coefficient was used to test the significance of the variable associated with that coefficient. A significance level of 0.05 was used in the study.

Collinearity Analysis of Predictors

The crash dataset contains many data items that may be correlated to each other. If using those data directly as predictors in the modelling, the dependence of predictive variables may distort the analysis results. Therefore, collinearity analysis was first conducted before logistic modelling to determine independent predictive variables for use in the model.

Statistical software SPSS was employed to conduct the collinearity analysis and variance inflation factor (VIF), and tolerance values for each variable were determined. The VIF value showed the impact of collinearity among the variables in any kind of regression model, which is close to the reciprocal of tolerance value. Usually, the VIF value lies between 1–10, and a VIF value less than 3 gives higher confidence about the independence of the variable associated with it. The objective of this study was to determine the factors relating to the occurrence of crashes of various severity levels. So, “person injury class” was considered as the outcome variable, which was analyzed with the other dependent parameters in the collinearity analysis.

Logistic Regression Modelling

In the analysis of crash and demographic data, person-injury level was the dependent variable, while crash (crash, person, and vehicle) and socioeconomic data were the explanatory variables. Because the study focused on severe crashes, the dependent variable only considered two injury levels: severe injuries (K and A) coded as “1” and non-severe injuries (B and C) coded as “0.” Among the explanatory variables, crash data variables were individual person-level variables (one data record for each person involved in crashes), while demographic or socioeconomic data variables were county-level aggregated variables (one data record for each county). To combine the individual crash data and aggregated socioeconomic data into one input dataset, the county where each crash occurred was identified and socioeconomic data from that county was used in the socioeconomic inputs for the individual crash data input. Crashes that occurred in the same county in the same year had the same socioeconomic data in the input dataset. In the analysis of survey data, crash/near crash was the dependent variable, while other survey variables were the explanatory variables.

Dummy variables were used to code categorical input variables with more than two categories. The number of dummy variables used is equal to the number of categories minus one. One category was selected as the base or reference category (coded as "0" for all dummy variables), to which all other categories were compared. For instance, "traffic control device" is a categorical variable with four categories; therefore, three dummy variables were used to code them (Table 2). Herein, columns represented dummy variables, rows represented the categories, and no control was chosen as the reference category. Generally, when selecting the reference category, for variables involving any treatment (e.g., traffic control device), the non-treatment category is usually considered as the base level. For variables not involving any treatment (e.g., age group), the category that has the largest data size is selected as the reference category.

Table 2. Dummy Variables for Traffic Control Device

Traffic Control Device	D1	D2	D3
No control	0	0	0
Signal control	1	0	0
Stop control	0	1	0
Other (yield, RR etc.)	0	0	1

The statistical software SAS was employed to run the multiple logistic regression. Screened independent crash data from 2011 to 2016 as well as socioeconomic and demographic data of 102 counties in Illinois during the same period were merged and entered in SAS. The SAS PROC LOGISTIC procedure was used to fit the logistic model and run the analysis. The gradient convergence criterion was used to assess the convergence of the maximum likelihood algorithm. To compare the crash risk between older population groups and other age groups, the analyses were run using crash data of all age groups and then crash data of older age groups only.

HIERARCHICAL LINEAR MODELING

As mentioned in the multiple logistic regression analysis section, the model inputs included individual person-level crash data and aggregated county-level socioeconomic data. Both data were treated the same in the logistic model, with individual injuries occurring in the same county in the same year having the same socioeconomic values in the model input. But the individual crash data and aggregated socioeconomic data were not at the same level. Individual crashes and person(s) involved in each crash were nested within the areas to which they belong (Figure 9). Yoon et al. (2017) demonstrated the nested characteristics. As the commonly used generalized linear models were usually unable to consider the ordered nature of the crash and regional data, the use of a hierarchical model to analyze the unobserved effects at each level was appropriate. Therefore, the hierarchical linear models were employed in the study to further analyze the data and identify significant factors that impact severe crash injuries.

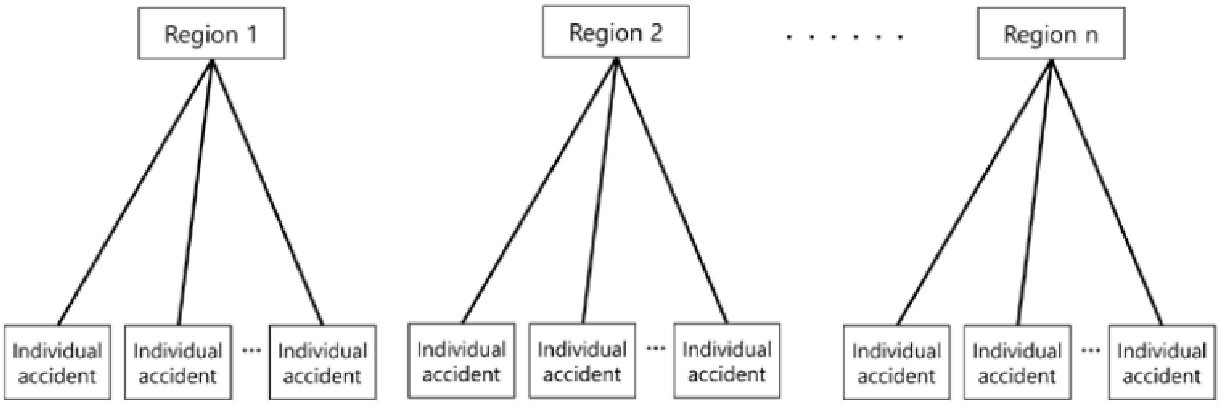

Figure 9. Diagram. Hierarchical nature of crash and neighborhood data.

Source: Yoon et al. (2017)

Overview of Hierarchical Linear Model

In the basic hierarchical linear model (HLM) structure, there are usually two-level variables: lower level variables (Level 1 variables) and higher level variables (Level 2 variables). Here, lower level variables were nested within the upper level variables. The following is the model equation for Level 1 variables (Ravand, 2015).

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + \varepsilon_{ij} \text{ , where } \varepsilon_{ij} \sim N(0, \sigma^2)$$

Figure 10. Equation. Equation for showing the relationship between Level 1 variables.

Source: Ravand (2015)

where,

Y_{ij} = dependent variable measured for i^{th} Level 1 unit nested within the j^{th} Level 2 unit
X_{ij} = value on the Level 1 predictor
β_{0j} = intercept for the j^{th} Level 2 unit
β_{ij} = regression coefficient associated with X_{ij} for the j^{th} Level 2 unit
ε_{ij} = random error associated with the i^{th} Level 1 unit nested within the j^{th} Level 2 unit.

Here, Y_{ij} was the dependent variable where X_{ij} was the independent variable. Linear combinations of the mean were represented by β where “I” stood for the individual Level 1 variables and “j” represented aggregated Level 2 variables. ε represented the random error associated with Level 1 and Level 2 variables. In the process of hierarchical linear modeling, the standard error was assumed to be normally distributed with a mean of 0 and carrying a variance, which is represented by σ2. Level

1 variables were used as outcome variables in Level 2, and they were connected to upper level predictors using the following equation (Boedeker, 2017):

$$\beta_{0j} = \gamma_{00} + \gamma_{01} W_j + \mu_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} W_j + \mu_{1j}$$

Figure 11. Equation. Level two equation.

Source: Boedeker (2017)

where,

β_{0j} = intercept for the j[th] Level 2 unit
β_{1j} = slope for the j[th] Level 2 unit
W_j = value on the Level 2 predictor
γ_{00} = overall mean intercept adjusted for W
γ_{10}= overall mean intercept adjusted for W
γ_{01} = regression coefficient associated with W relative to Level 1 intercept
γ_{11} = regression coefficient associated with W relative to Level 1 slope
μ_{0j} = random effects of the j[th] Level 2 unit adjusted for W on the intercept
μ_{1j} = random effects of the j[th] Level 2 unit adjusted for W on the slope.

In Level 2 models, β_{0j} and β_{1j} were the regression coefficients that were used as outcome variables and were related to all Level 2 predictors, which makes the Level 2 models between-unit models (Woltman et al., 2012). This is important that μ_{0j} and μ_{1j} are two new terms in Level 2 introduced in hierarchical models that make it different from the common generalized linear regression equations. These terms represented the effects of Level 2 variables and W_j functions as the upper level predictor. The random effects in Level 2 followed the assumption below (Yoon et al., 2017):

$$\binom{\mu_{0j}}{\mu_{1j}} \sim N \begin{bmatrix} 0 & \sigma^2{}_{u_0} & \sigma^2{}_{u_0 u_1} \\ 0 & \sigma^2{}_{u_1 u_2} & \sigma^2{}_{u_1} \end{bmatrix}$$

Figure 12. Equation. Assumption for the random effects in level 2.

Source: Yoon et al. (2017)

Considering the Level 1 and Level 2 models and their connection, the combined model becomes:

$$Y_{ij} = \gamma_{00} + \gamma_{10} W_j + \gamma_{11} W_j X_{ij} + \mu_{1j} X_{ij} + \mu_{0j} + \varepsilon_{ij}$$

Figure 13. Equation. Combined equation of level 1 and level 2.

Source: Yoon et al. (2017)

where,

Y_{ij} = dependent variable measured for i[th] Level 1 unit nested within the j[th] Level 2 unit
W_j = value on the Level 2 predictor

γ_{00} = overall mean intercept adjusted for W
γ_{10}= overall mean intercept adjusted for W
γ_{1j} = regression coefficient associated with W relative to level-1 slope
μ_{0j} = random effects of the j[th] Level 2 unit adjusted for W on the intercept
μ_{1j} = random effects of the j[th] Level 2 unit adjusted for W on the slope
ε_{ij} = random error associated with the i[th] Level 1 unit nested within the j[th] Level 2 unit.

Hierarchical Linear Modeling

In the study, the individual crash-injury data were considered as Level 1 variables, while aggregated county-level socioeconomic data were treated as Level 2 variables. A random intercept HLM model was employed because it considers both intragroup and intergroup effects simultaneously with the nested data. Similar to logistic regression modelling, the dependent variable in HLM is person-injury severity with two categories: severe injuries (K- and A-injuries) coded as "1" and non-severe injuries (B- and C-injuries) coded as "0."

Due to the tedious iterative nature of the analysis, the statistical software developed specifically for hierarchical linear modelling, HLM7 (Garson, 2014), was used to run the analysis. The restricted maximum likelihood method in HLM was used to estimate the variances among fixed variables (Boedeker, 2017; Garson, 2014). This was a complex procedure that used ordinary least-square regression to fit the model for fixed variables. Then, by maximizing the likelihood of residuals, it found the model variance and covariances, which determined the model's reliability (Boedeker, 2017).

Before the crash data and socioeconomic data were inputted in the software, the collinearity analysis was conducted and only noncollinear variables were entered into the model. The multiple-level categorical variables were collapsed into binary variables in the analysis. All the data were sorted in SPSS before importing into HLM7 (Figure 14 and Figure 15).

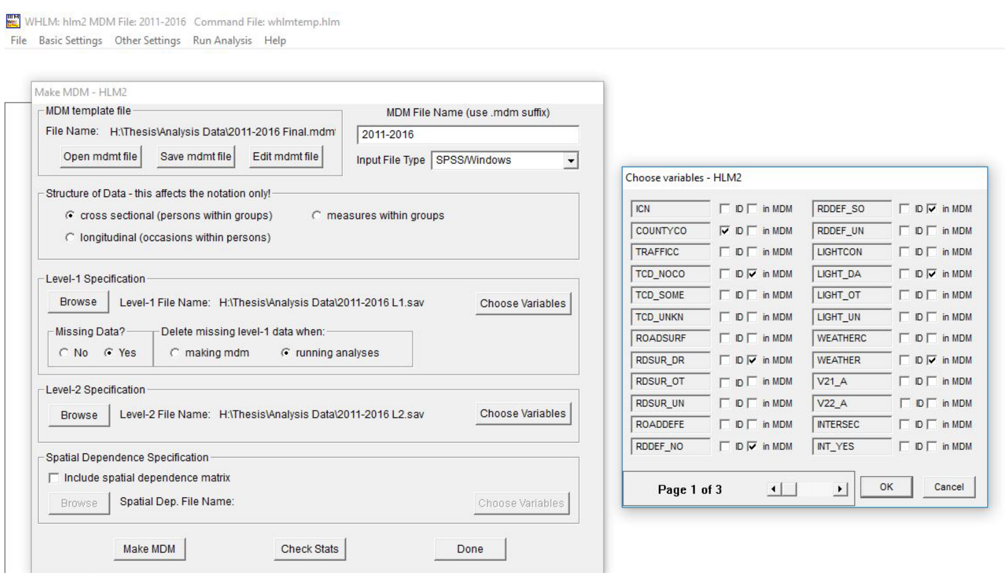

Figure 14. Photo. Importing level 1 variables in HLM7.

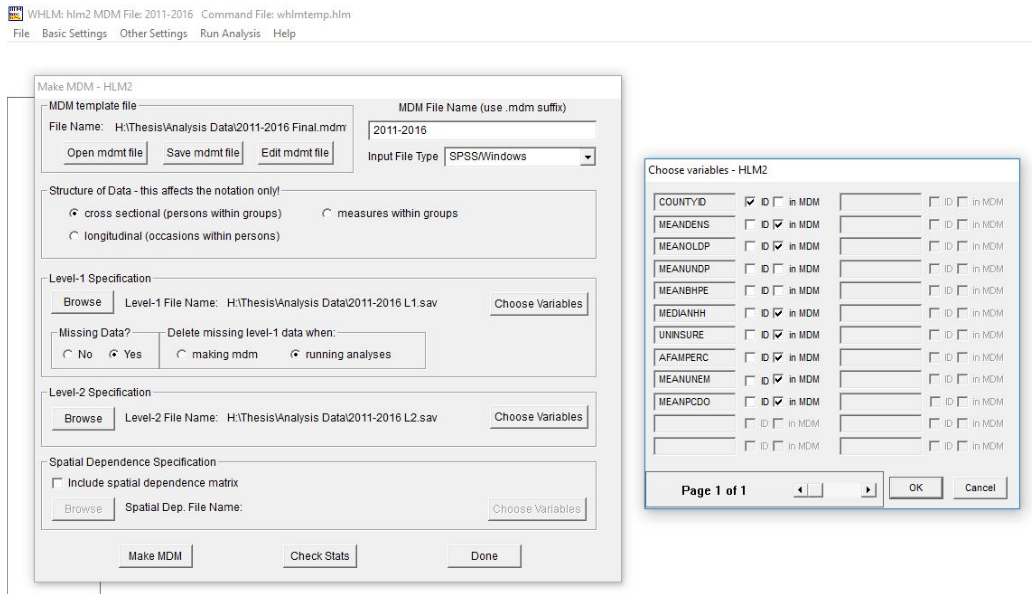

Figure 15. Photo. Importing level 2 parameters in HLM7.

SUMMARY

Both basic descriptive analysis and advanced statistic modelling were used to analyze the data gathered in the study. For the crash and demographic data, descriptive analysis was conducted first to identify crash frequency of older people at various roadway geometry, traffic control, and environmental conditions and compare them with those of younger age groups. Then, a crash causation analysis was conducted to identify conditions/situations where older people are more prone to motor vehicle crashes, particularly severe injuries. Last, logistic regression models and hierarchical linear models were employed to examine the association between severe crashes and different roadway geometry, operation, environmental, and socioeconomic variables. Logistic regression models are popular categorical data-analysis models that have been largely used for crash data analysis. Hierarchical linear modelling has been recently employed in crash data analysis to handle data with nested characteristics. Models were fitted using data from all age groups and older people.

For the survey data, first, frequency and ranking of survey responses were developed to show the distributions of responses to survey questions, including basic demographic characteristics, physical condition, driving exposure/habit, medicine use, etc. Then, odds ratios were calculated to quantify the association of various variables with four survey parameters: driving difficulty, annual miles travelled, number of days driven per week, and crash/near-crash experience. Last, multiple logistic regression analysis was performed to test the effects of survey variables on crash risk among older drivers.

CHAPTER 5: CRASH AND DEMOGRAPHIC DATA ANALYSIS RESULTS

This chapter presents the results of crash and demographic data analyses following the methods described in Chapter 4. The chapter consists of four sections: descriptive analysis, crash causation analysis, logistic regression analysis, and hierarchical linear modelling. The descriptive analysis results showed the pattern and trends of older population motor vehicle crashes. The causation analysis results revealed conditions/situations where older people are more prone to motor vehicle crashes, particularly fatalities and severe injuries. The logistic regression analysis and hierarchical linear modelling results identified factors that significantly affect severe crashes involving older people.

DESCRIPTIVE ANALYSIS

Descriptive analysis was conducted on crash data to identify the crash frequency of older people at various roadway geometry, traffic control, and environmental conditions and compare them with those of younger age groups.

Injury Frequency over the Study Period

Figure 16 and Figure 17 show the total injuries and injuries involving older people as well as total severe injuries and severe injuries involving older people over 2011–2016, respectively. A similar upward trend was observed for both total severe crashes and severe crashes involving older people. In addition, compared to the percentage of older people in overall crashes, severe crash percentages involving older people were consistently higher over 2011–2016, indicating older people were more likely to get severely injured or killed in motor vehicle crashes. In addition, the increased trend curve slope of severe crash percentages involving older people was steeper than that of overall crashes, implying the safety of older people has worsened recently.

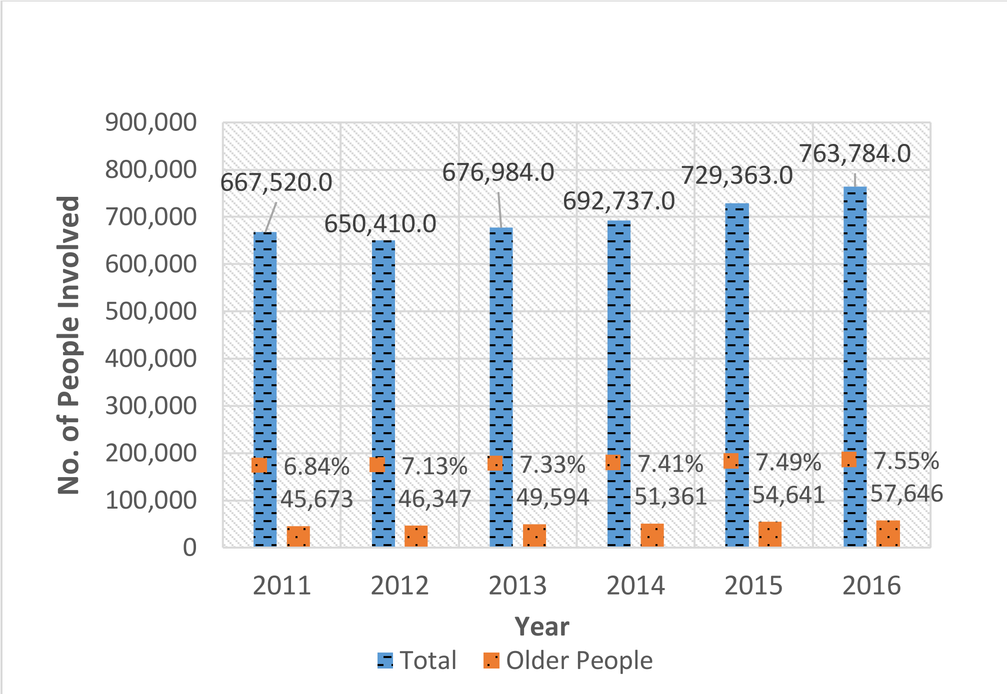

Figure 16. Chart. Number of people involved in crashes over 2011–2016.

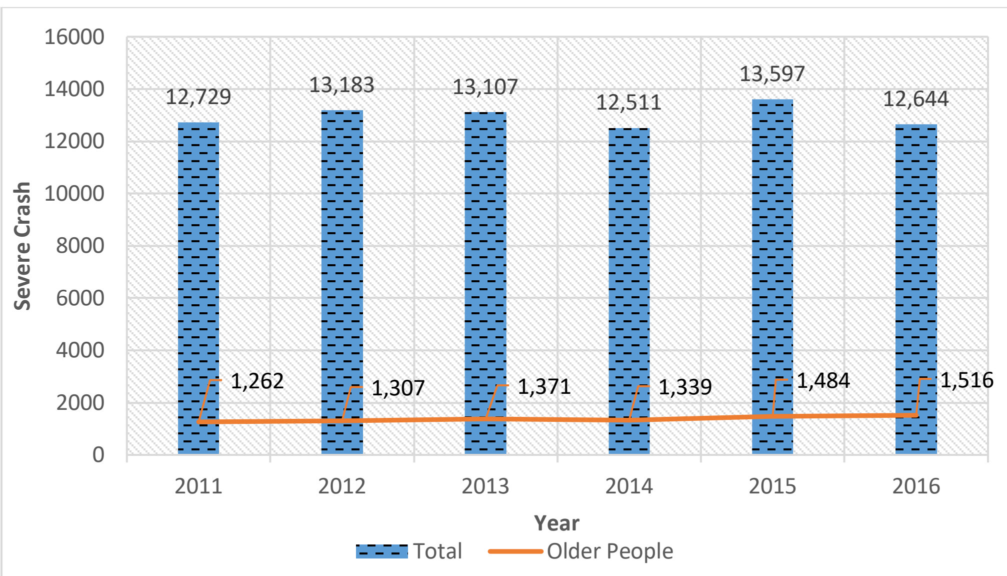

Figure 17. Chart. Number of people involved in severe crashes over 2011–2016.

Injury Data of Different Age Groups

This section briefly describes the descriptive analysis of age group percentages in motor vehicle injuries in terms of crash-related parameters to better understand crash trends among groups. For the analysis, older people were categorized into three age groups: 65–74, 75–84, and 85 and older. Older people were compared with the remaining three age groups: 0–20, 21–34, and 35–64.

The descriptive analysis results are presented by each crash-related parameter in the following sections. Similar patterns were obtained for all six years. The results from 2011 are presented as an example. Appendix A presents the analysis results of the remaining five years.

Crash Injury Class

Figure 18 shows the crash frequency and percentage of each age group in different injury classes. The number of K- and A-injuries were much lower than B- or C-injuries. The relative percentage values revealed a different pattern for fatalities in comparison with other injury classes. Fatalities involving older people (19%) accounted for more than twice the percentages of A-, B-, or C-injuries (9%, 9%, and 8%, respectively) in 2011. This indicated that older people were more vulnerable than other age groups in motor vehicle crashes. For example, the older population only accounted for 14% of the total US population in 2011. Of the total fatalities in 2011, 19% were older people, which implies a high fatality risk of older people in Illinois that needs immediate attention.

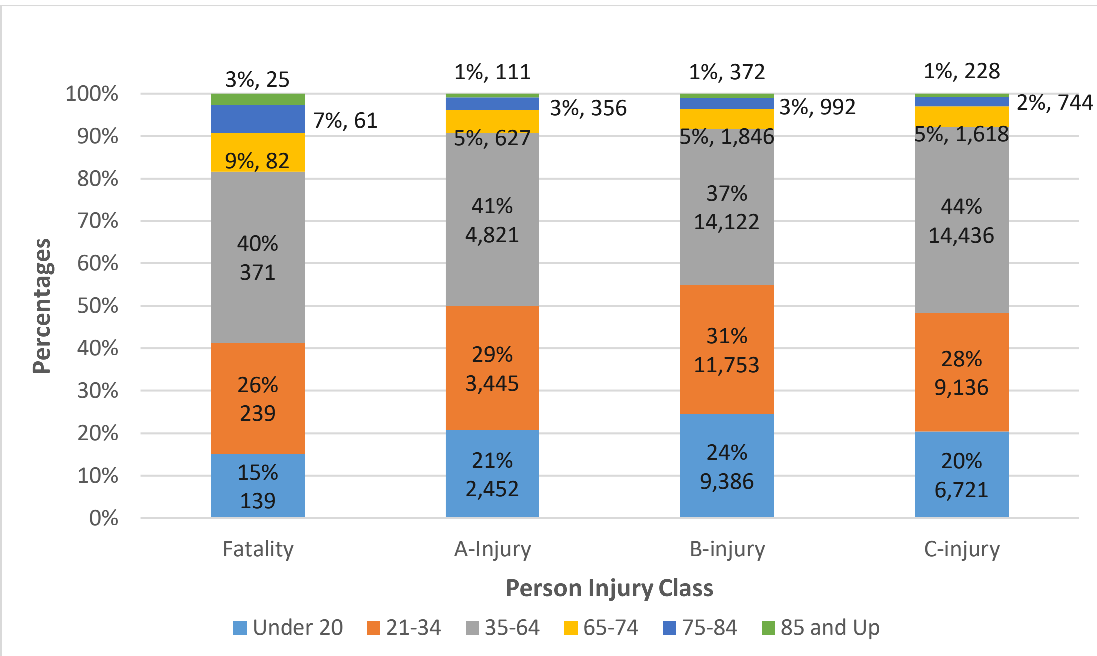

Figure 18. Chart. Injury class vs. age group.

The crash frequency and percentage of K- and A-injuries were further analyzed among male and female groups. Among all fatalities, the total number of older males (97) was more than older females (81). Among all fatalities in 2011, however, the total percentage of older males (16%) was much lower than older females (23%) (Figure 19). This is due to the higher older female population than male. This trend was only for fatalities, however. For A-injuries, both older male and female involvement was 9%.

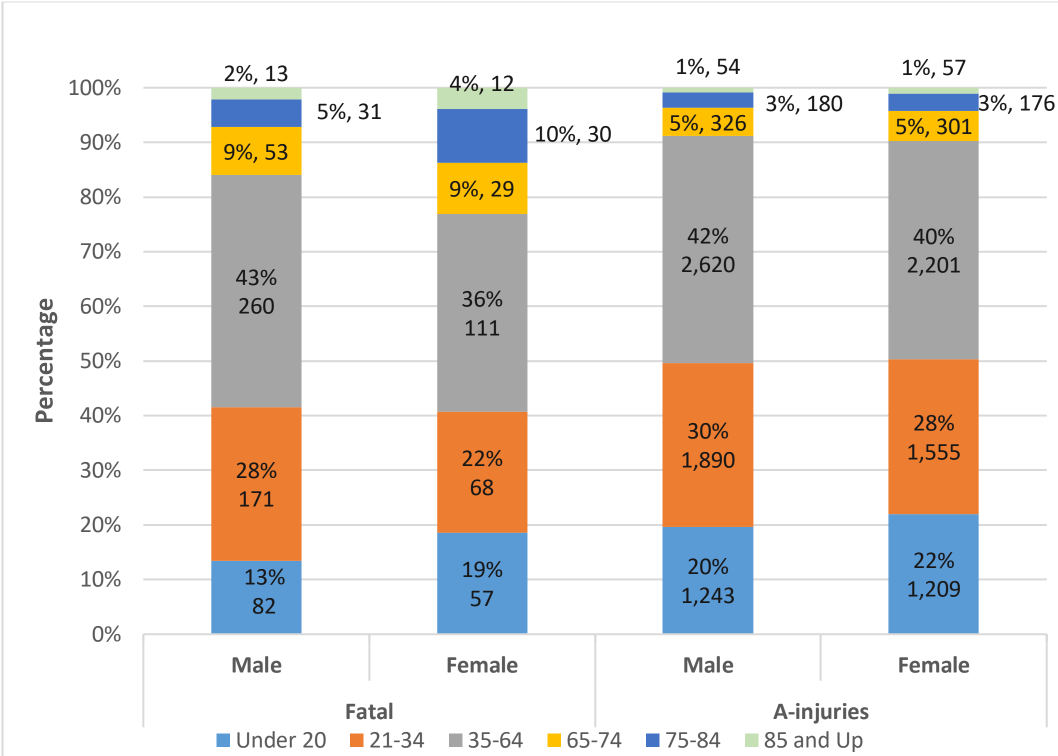

Figure 19. Chart. Injury class (by gender) vs. age groups (2011).

Types of People Involved

An investigation related to the types of people involved in all crashes from 2011 identified that most people involved were drivers, while passengers were second. The number of pedestrians/ pedalcyclists and nonmotorized vehicle occupants was significantly lower (Table 3). Figure 20 presents the percentages of the types of people involved among all age groups. Older people contributed to 8% of total drivers involved in crashes, while 6% of the passengers involved in crashes were aged 65 or higher.

Table 3. Types of People Involved in Roadway Crashes

Person Type	Passenger	Driver	Pedestrian	Pedalcyclist	Noncontact vehicle	Occupant of NMV	Equestrian
Under 20	74,576	54,592	1,561	1,122	75	19	0
21–34	30,618	139,990	1,273	914	136	7	0
35–64	30,586	203,671	1,773	882	212	15	2
65–74	4,503	23,002	235	78	22	3	0
75–84	2,788	10,719	114	21	13	5	0
85 and older	1,009	3,112	39	4	6	0	0
Total	**173,000**	**485,142**	**5,159**	**3,139**	**1,025**	**53**	**2**

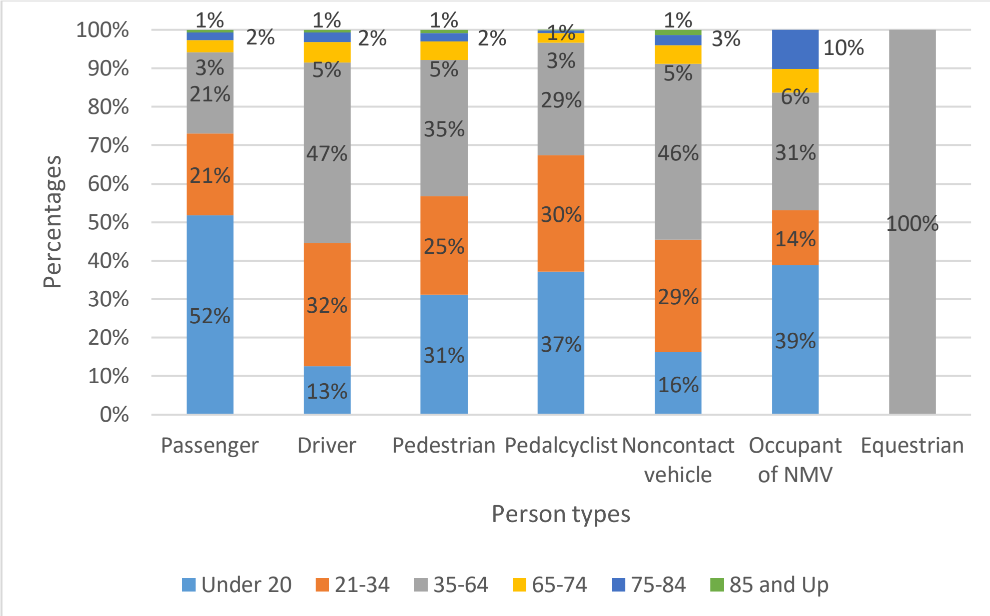

Figure 20. Chart. Types of people vs. age groups (2011).

Blood Alcohol Content

An analysis was made to determine the involvement of different age groups regarding driving under the influence (DUI). In crash data, the blood alcohol content (BAC) is listed in five different classes (Figure 21). A BAC of "0–0.079%" corresponds to an acceptable amount of alcohol in a driver's blood. A reported BAC higher than the 0.08% legal limit is not acceptable. From the data, only 3% of all drivers reported with an unacceptable amount of BAC while driving were older people, which is much lower than other age groups. Note that the number of crashes with BAC tested is much lower than those not tested.

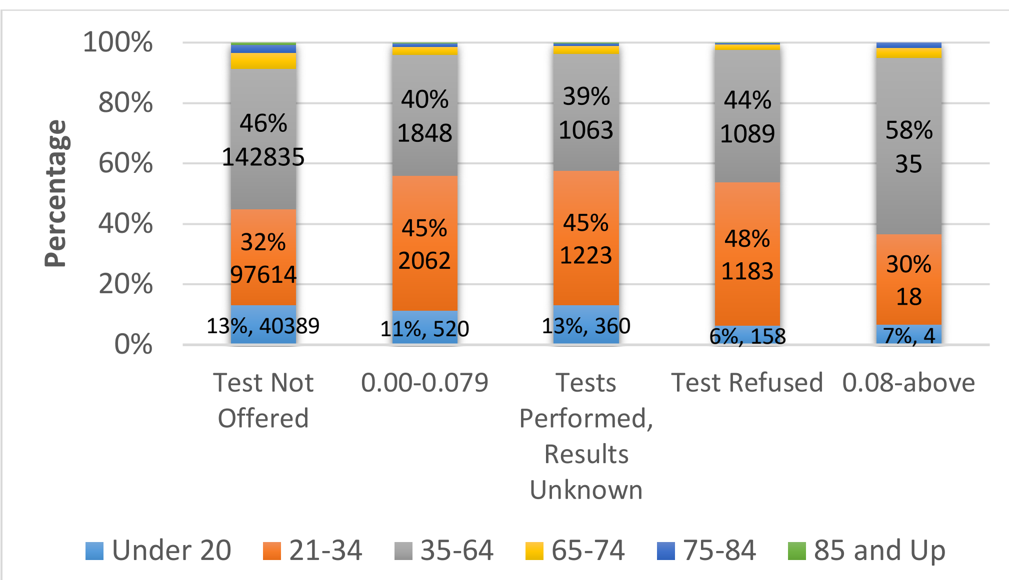

Figure 21. Chart. Blood alcohol content vs. age groups (2011).

Obscured Vision

An analysis was also made regarding obscured vision parameters. In crash data, this information was sorted under the “VIS” (vision) column, where the visual obstruction parameters were listed for twelve cases. From the reported crash information, moving vehicles and windshield water/ice were two major phenomena that obscured drivers’ vision (Table 4). Figure 22 shows that the percentage of older drivers who had obscured vision at the time of a crash due to parked vehicles, sunlight, and trees/plants was higher than that of moving vehicles and windshield water/ice. The percentages of signboard and blinded headlight conditions for older people were also high. However, because the number of occurrences was small, those percentages were not meaningful indicators for obscured vision characteristics.

Table 4. VIS vs. Age Groups

VIS	*Under 20*	*21–34*	*35–64*	*65–74*	*75–84*	*85 and Up*	Total
Not obscured	39,546	98,005	143,360	16,359	7,605	2,198	**307,073**
Moving vehicle	729	1,719	2,209	260	141	36	**5,094**
Windshield (water/ice)	512	1,107	1,312	152	60	17	**3,160**
Parked vehicles	265	621	762	125	63	20	**1,856**
Blinded by sunlight	200	397	596	95	87	30	**1,405**
Trees, plants	122	138	258	38	23	4	**583**
Hillcrest	100	121	151	15	21	7	**415**
Embankment	33	57	63	15	7	3	**178**
Buildings	26	68	118	9	6	0	**227**
Blinded headlights	15	31	35	5	7	3	**96**
Signboard	3	12	17	4	3	1	**40**
Blowing materials	29	52	91	11	3	2	**188**

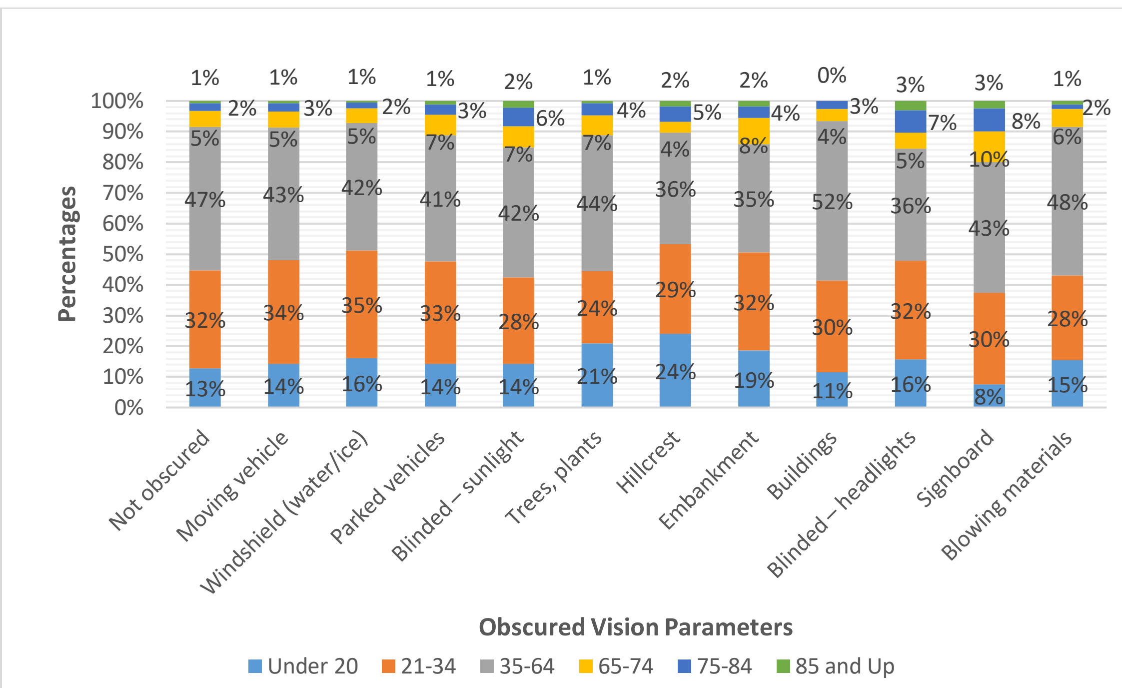

Figure 22. Chart. VIS vs. age groups (2011).

Pedestrian/Pedalcyclist Visibility

There is a high number of road users who are pedestrians/pedalcyclists or occupants from nonmotorized vehicles (NMVs). An analysis was conducted to determine the percentage of older people among non-motorists involved in motor vehicle crash injuries. Surprisingly, despite wearing contrasting clothing while walking or bicycling, the percentage of older people involved in crashes (8%) is higher than those without contrasting clothing (6%). The crash involvement percentages for reflective material and other light sources are 6% and 4%, respectively, making them more effective at increasing older non-motorists' visibility than contrasting clothing (8%) (Figure 23).

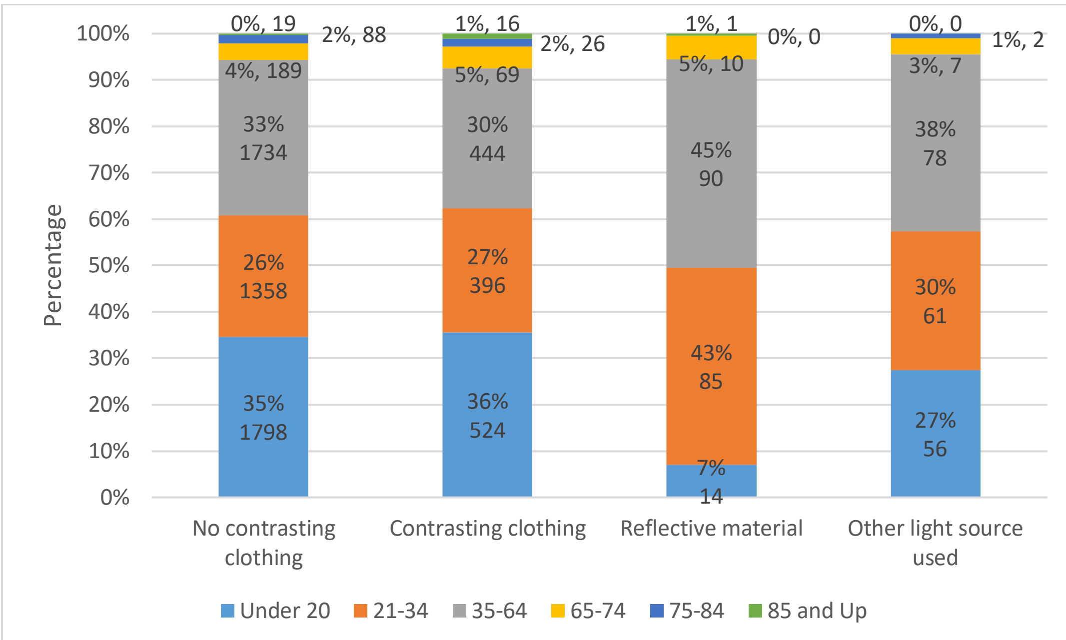

Figure 23. Chart. Pedestrian/pedalcyclist visibility at the time of the crash (2011).

Collision Type

The Illinois crash data also provided information on the type of collision. The crash data lists 15 types of collisions. Table 5 shows that most collisions that occurred were rear-end, turning, or same-direction sideswipe. Figure 24 shows that 6%, 8%, and 7% of older people were involved in rear-end, turning, and same-direction sideswipe collisions, respectively. Notably, older people accounted for 10% and 9% of angle and parked motor vehicle collisions, respectively, indicating roadway geometry and sight-distance issues were highly associated with crashes involving older drivers. Older people's involvement (12%) in train collisions was also high. However, given the small number of occurrences, the percentage may not capture the true distribution of the data.

Table 5. Total Number of Collisions in 2011

Age		Under 20	21–34	35–64	65–74	75–84	85 and Up	Total
Collision Types	*Rear-end*	47,107	63,268	91,824	9,291	3,699	979	**216,168**
	Turning	27,073	32,112	43,008	6,034	3,528	1,179	**112,934**
	Angle	18,790	21,540	29,249	4,292	2,636	880	**77,387**
	Same-direction sideswipe	9,587	16,644	24,283	2,763	1,275	402	**54,954**
	Fixed object	11,079	14,467	12,488	1,206	626	208	**40,074**
	Animal	4,133	6,317	12,469	1,480	498	65	**24,962**
	Parked motor vehicle	4,356	6,447	7,573	942	541	225	**20,084**
	Pedestrian	2,236	2,515	3,596	499	249	77	**9,172**
	Opposite-direction sideswipe	1,529	2,157	3,267	345	183	51	**7,532**
	Pedalcyclist	1,654	1,747	2,293	288	112	35	**6,129**
	Head on	1,349	1,781	2,264	276	138	35	**5,843**
	Overturned	1,753	1,749	1,764	156	41	7	**5,470**
	Other non-collision	715	1,198	1,668	130	54	15	**3,780**
	Other object	562	983	1,363	139	74	11	**3,132**
	Train	22	13	32	2	6	1	**76**

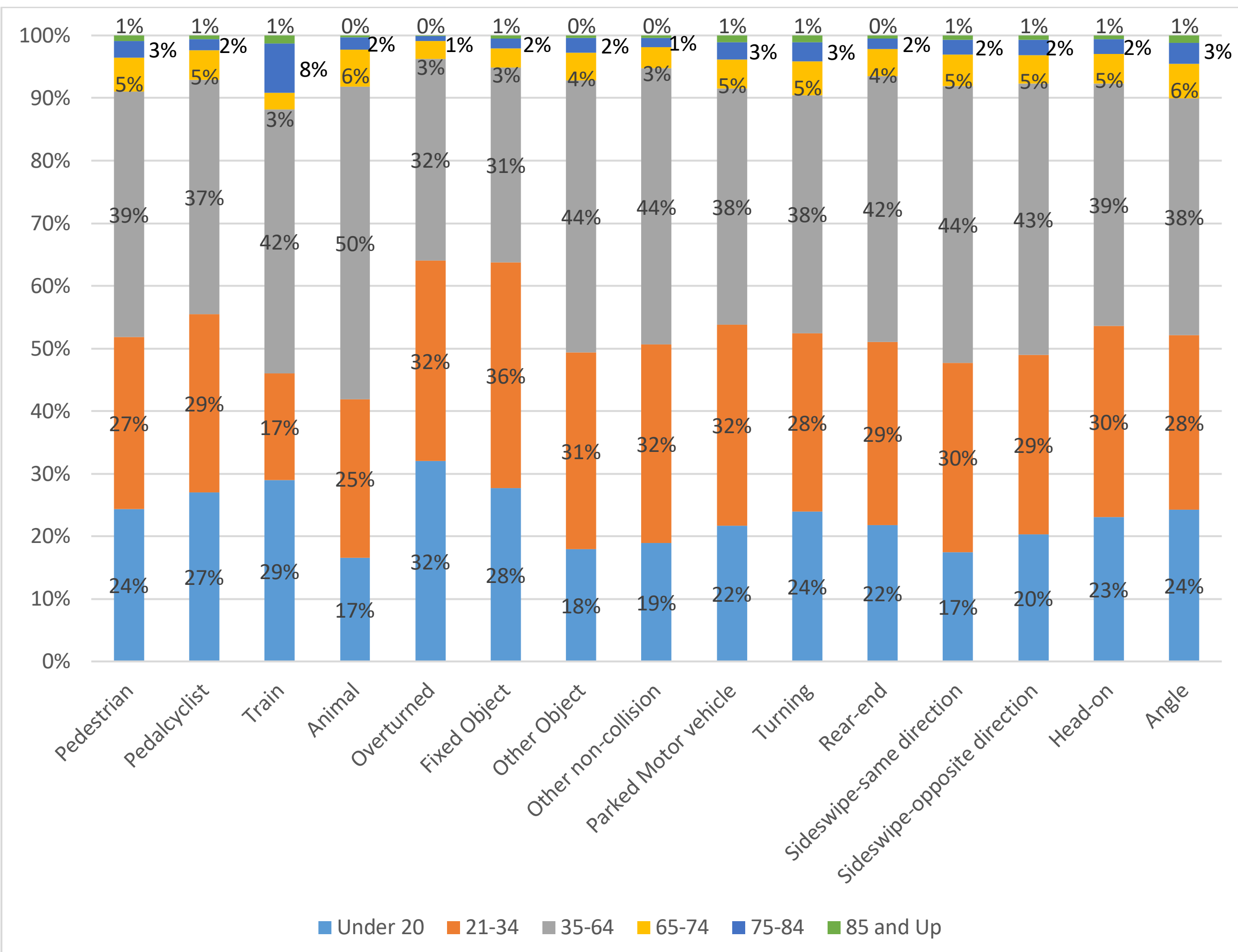

Figure 24. Chart. Collision types vs. age groups (2011).

Surface Condition

For the analysis, wet, snow/slush, ice, sand, etc. (codes 2–6) were considered unfavorable surface conditions for driving, while dry road surfaces were considered favorable (code 1). From the crash data, 427,937 crashes involved favorable driving conditions, while 146,866 crashes occurred in unfavorable conditions. Most crashes may have occurred on dry surface conditions because the weather was clear on most days and most travel activities occur under clear weather conditions. This driving/travel habit is particularly exercised by older people. Figure 25 shows that under unfavorable surface conditions, the involvement of older people in crashes is 6%, which is 2% lower than under favorable surface conditions.

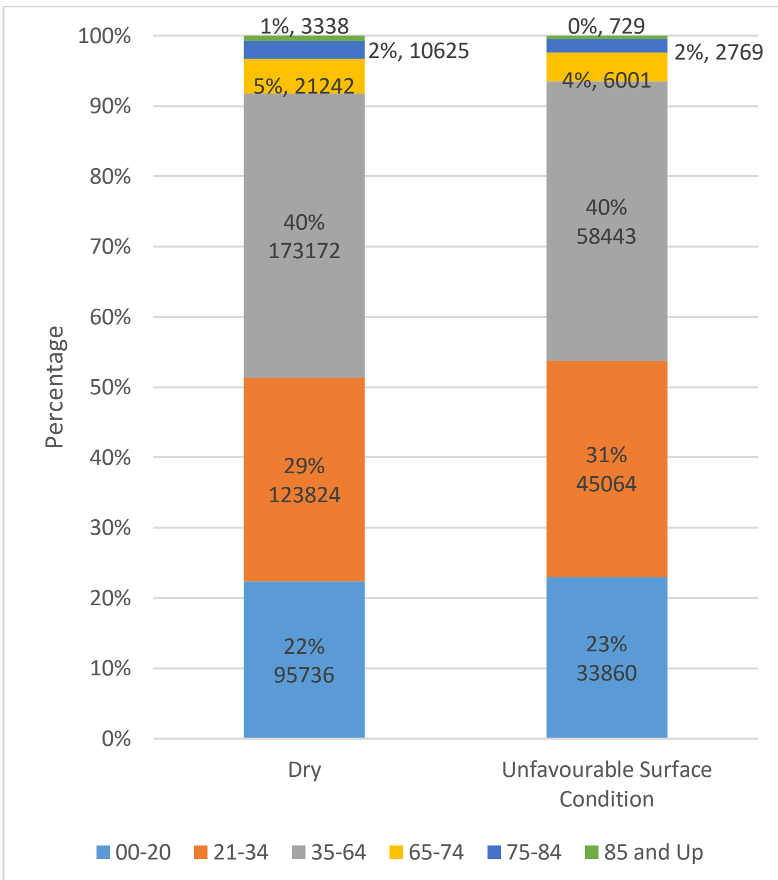

Figure 25. Chart. Surface conditions vs. age groups.

Weather Condition

The analysis of crashes in different weather conditions revealed a similar pattern as surface conditions. Crashes that occurred in clear weather were four times more than those that occurred in unfavorable weather. Rain, snow, smoke, hail, severe cross wind, clouds, and other weather conditions were considered as unfavorable weather for the analysis. Figure 26 shows that injuries involving older people were 8% in clear weather cases and 6% for unfavorable conditions.

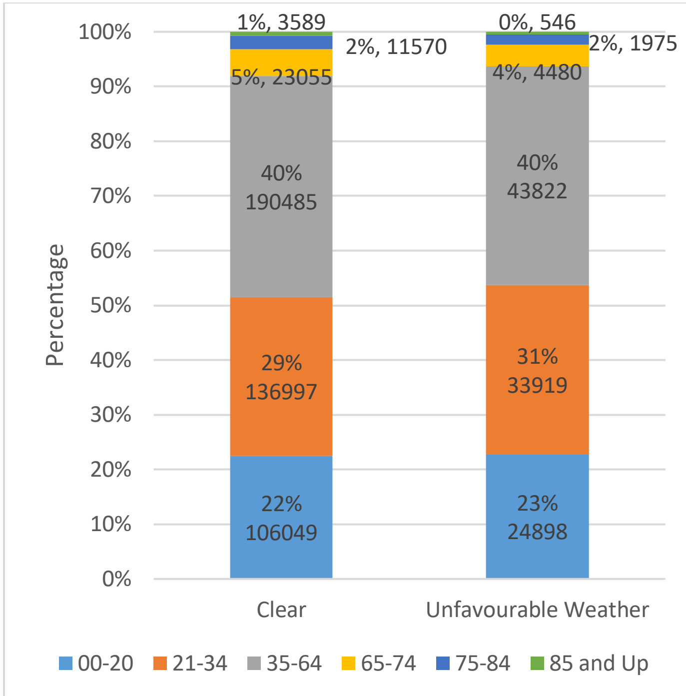

Figure 26. Chart. Weather condition vs. age groups (2011).

Light Condition

In addition, 9% of reported crashes in broad daylight involved older people, while only 4% of reported crashes in unfavorable light conditions involved older people (Figure 27). This may be because older people tend to travel or drive during daylight and avoid driving at night or in dark locations.

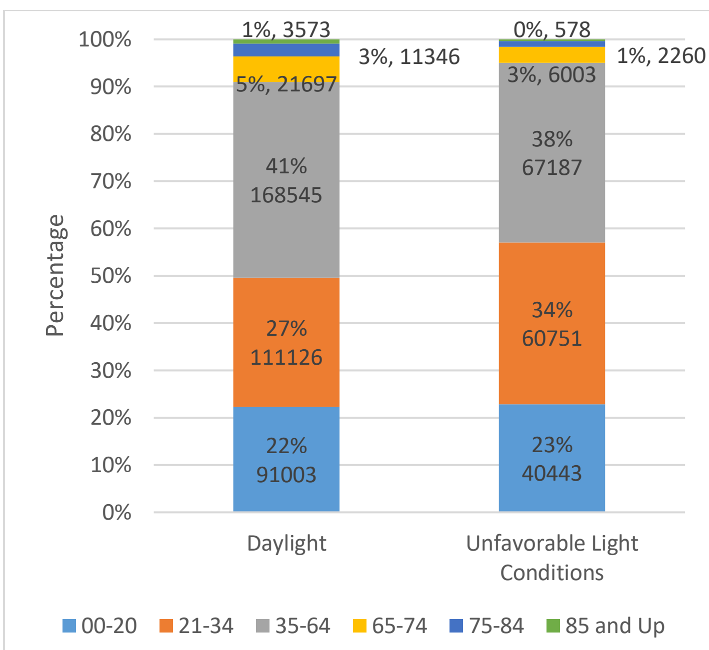

Figure 27. Chart. Light condition vs. age groups (2011).

Roadway Alignment

Crashes that occurred because of different roadway alignment conditions also followed the same pattern. Most crashes occurred on straight and level roads and the second most occurred on straight and grade roads. Older people comprised of 8% of the reported injuries along straight and level, straight and grade, and straight on hillcrest roads. The percentage of older people, however, is slightly lower (6%) on curved roads, including level, grade, and hillcrest alignment (Figure 28).

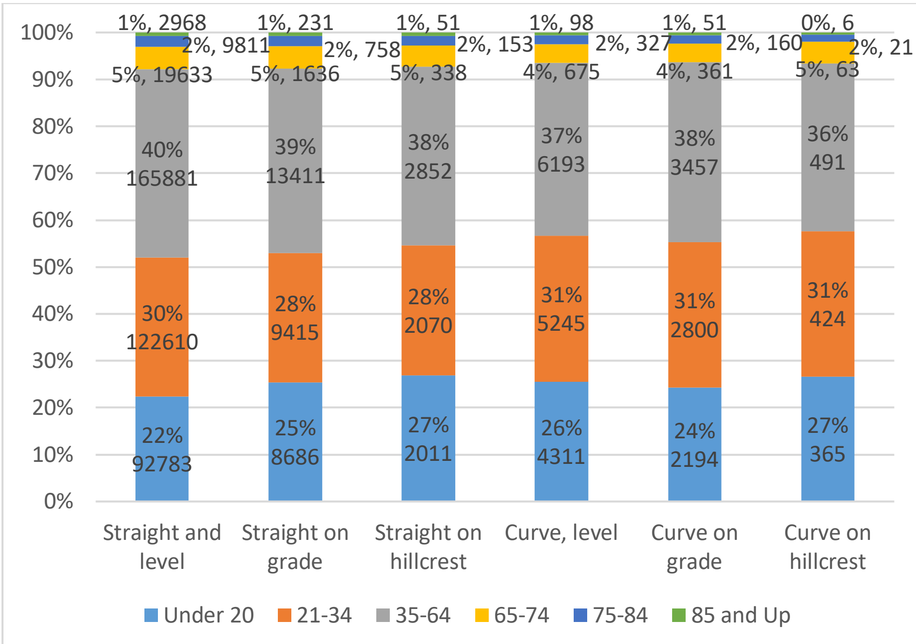

Figure 28. Chart. Alignment types vs. age groups.

Intersection and Work-zone Related

Among all intersection-related crash injuries from the 2011 crash data, 9% involved older people (Figure 29). For work-zone-related crashes, 7% of the injuries involved older people (Figure 30).

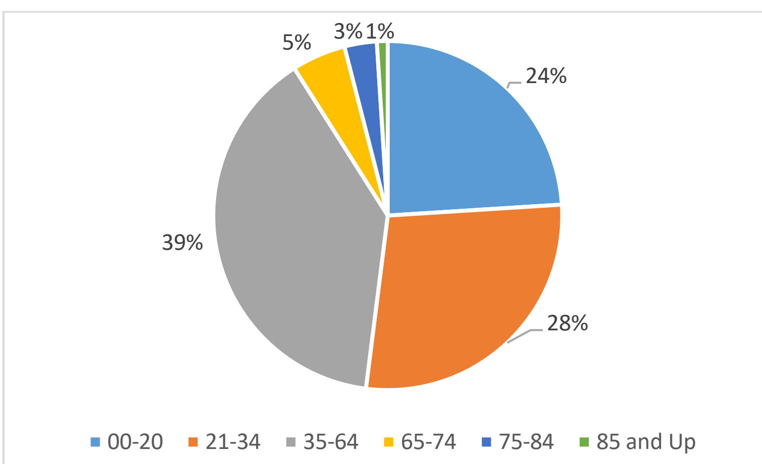

Figure 29. Graph. Intersection-related crashes vs. age groups.

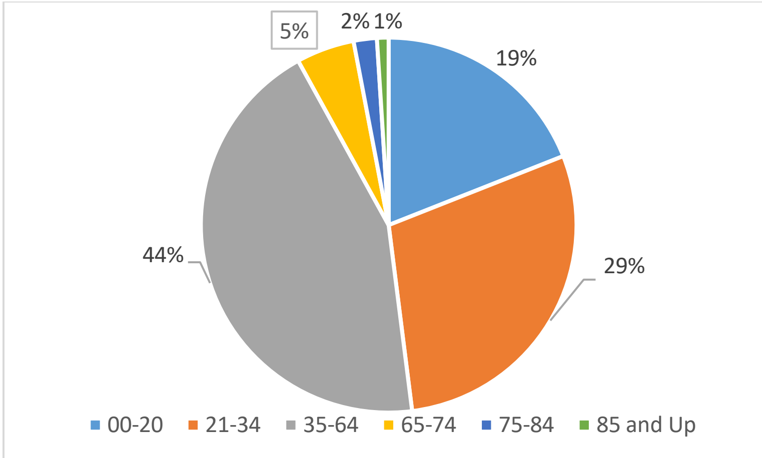

Figure 30. Graph. Work-zone-related crashes vs. age groups.

CRASH CAUSATION ANALYSIS RESULTS

This section presents the analysis results for people, roadway, environmental, and demographic characteristic variables. People, roadway, and environmental characteristic data were retrieved from IDOT crash data.

People Characteristics

The people characteristics considered in the study included type of person, BAC, VIS, injury class, PEDV, and collision type, etc. The analysis results are detailed in the following subsections. A color scheme was used to illustrate the data ranking, with green indicating the highest and red indicating the lowest.

Type of Person

Seven types of people were coded in the crash database. First, the research team accumulated the number of crashes per type of person for total crashes, fatalities, and A-injuries involving older people. Then, the data were sorted and ranked from high to low, as shown in Table 6.

This ranking followed the same pattern for all six years and for overall crashes involving older people as well as fatalities and A-injuries. Drivers contributed to the largest share during 2011–2016, with more than 80% (between 81–82%) of total crashes, 57–67% of crash fatalities, and 68–72% of A-injuries involving older people. Passengers were the second-largest group for crashes involving older people, comprising 17–18% for total, 15–19% for fatalities, and 20–22% for A-injuries.

Although the ranking for overall total crashes, fatalities, and A-injuries were the same, the numbers for non-motor-vehicle-related types of people revealed a different pattern. For total crashes, pedestrians comprised only 1% of older people involved in crashes. However, surprisingly, 14%–19% of crash fatalities involved pedestrians, which is very alarming. Also, pedestrians' share in A-injuries (6%–10%) was much higher than that of the total. Pedalcyclists were the fourth-largest group. Though their shares were not significant in total injuries involving the older population, they involved 7% of the total fatalities in 2011 (reduced to 1% in 2016) and 1–2% of A-injuries within the study period, which makes them another vulnerable group. The results indicated that older pedestrians and bicyclists were more vulnerable than older motor-vehicle road users. Measures need to be taken to improve sidewalk, crosswalk, and bike-lane design as well as their traffic control, particularly facilities within or close to older communities.

Noncontact vehicle occupants, occupants of nonmotorized vehicles, and equestrians were bottom ranked. The crash share for these parameters was minimal, and they mostly followed a similar trend. Their results were nonconclusive due to the low number of crashes involving them.

Blood Alcohol Content

The second variable analyzed regarding driver characteristics was blood alcohol content (BAC). BAC tests were not offered for an average of 99% of total crashes and 96%–98% for A-injuries. For fatalities, however, it was the second-largest group (23–34%) (Table 7). Among the remaining crashes that posted BAC results, neither fatalities nor A-injuries occurred due to alcohol abuse (with BAC 0.08% and above). About 66%–75% of the fatalities were reported with BAC below the legal limit (< 0.08%). Only 1–2% of A-injuries were reported with a BAC content below 0.08%. The results indicated that DUIs were not a frequent occurrence for older people. However, this conclusion needs to be confirmed with other data sources, especially those with fatality information (e.g., FARS).

Obscured Vision

The ranking was also established for obscured vision (VIS) parameters (Table 8). For total crashes, almost 95–96% were reported having no obscured vision. Among the remaining 4–5% of reported crashes, moving vehicles were found to be the largest vision-obstructing parameter among older people. Water or ice in windshield, being blinded by sunlight, and parked vehicles comprised the second-largest group. A substantial number of crashes occurred because trees/plants and hillcrest obscured vision. The final quarter of the ranking involved obstructed vision due to embankment, blowing materials, buildings, being blinded by headlights, and signboards, which comprised a smaller number of crashes.

Almost 96% (2011) to 100% (2012) of fatal injuries involved people with no visual obstructions. Within 2011–2016, only 16 fatalities occurred due to obstructed vision. The visual obstruction conditions involved were moving vehicles, windshields, being blinded by sunlight, trees, hillcrest, embankments, blowing materials, and being blinded by headlights. The number of reported A-injuries due to obstructed vision was found to be 3%–4% of the total A-injuries. The ranking of the involved parameters was similar to the total crashes for all six years.

Table 6. Type of Person Ranking for Total Crashes, Fatalities, and A-injuries (2011–2016)

Person Type	2011			2012			2013			20014			2015			2016		
	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A
Driver	36,833	96	785	37,612	96	804	40,289	114	831	41,877	118	829	44,576	128	886.00	46,985	134	804
Passenger	8,300	29	225	8,147	27	234	8,710	31	247	8,894	31	232	9,402	29	265.00	9,981	41	254
Pedestrian	388	30	68	408	29	89	421	25	101	425	28	77	500	30	130.00	495	42	90
Pedal cyclist	103	11	14	107	7	18	108	3	19	97	1	18	112	3	15.00	131	3	16
Noncontact vehicle	41	0	0	61	0	0	53	0	0	56	0	0	42	0	-	34	0	0
Occupant of nonnotarized vehicle	8	2	2	12	1	2	10	1	0	12	2	4	9	0	-	20	0	1
Equestrian	0	0	0	0	0	0	0	4	0	0	0	0	0	0	-	0	0	0

Table 7. Reported BAC Ranking for Total Crashes, Fatalities, and A-injuries (2011–2016)

BAC Parameters	2011			2012			2013			2014			2015			2016		
	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A
Test not offered	26,583	32	711	27,433	24	724	34,069	26	764	37,305	30	767	41,655	27	828	43,886	39	726
0.01–0.079	182	63	9	134	68	10	234	88	10	227	88	5	266	88	12	250	95	13
Tests performed, results unknown	99	0	5	101	4	10	116	0	13	150	0	13	135	0	15	135	0	15
Test refused	58	0	1	34	0	1	84	0	3	105	0	5	151	0	7	194	0	4
0.08 and above	3	0	0	0	0	0	10	0	0	16	0	0	7	0	0	6	0	0

Table 8. VIS Ranking for Total Crashes, Fatalities, and A-injuries (2011–2016)

Vision Obscured By	2011			2012			2013			2014			2015			2016		
	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A
Not obscured	26,162	75	677	26,909	76	679	29,467	83	707	31,976	78	699	36,119	92	748	38,739	97	686
Moving vehicle	437	0	9	481	0	5	489	1	8	482	0	8	587	1	7	614	1	8
Windshield (water/ice)	229	0	3	204	0	8	293	2	5	283	1	9	291	1	5	305	0	4
Blinded—sunlight	212	1	4	293	0	7	263	0	6	225	2	5	295	0	2	329	0	9
Parked vehicles	208	0	2	223	0	4	207	0	4	205	0	1	223	0	2	230	0	1
Trees, plants	65	0	3	83	0	1	80	1	1	54	0	2	77	0	3	74	0	2
Hillcrest	43	0	2	29	0	1	48	1	1	41	0	1	53	0	5	86	1	5
Embankment	25	1	1	9	0	0	12	0	0	16	0	0	16	0	2	11	0	0
Blowing materials	16	1	0	24	0	1	17	0	0	34	0	2	19	0	1	12	0	0
Buildings	15	0	0	16	0	0	24	0	1	19	0	0	30	0	0	24	0	0
Blinded—headlights	15	0	0	17	0	1	15	0	0	28	0	2	33	1	3	32	0	0
Signboard	8	0	0	7	0	0	9	0	0	9	0	0	4	0	0	4	0	0

Gender and Injury Class

An analysis of gender and injury classes revealed about 56–65% of fatalities involved males and 35–44% involved females (Table 9). For A-injuries, 46–49% were male and 51–54% were female. Male and female A-injury numbers were comparative over the study period, while fatality numbers for older males were consistently higher than older females. Because there was a higher older male population in fatal injuries than female, the results indicated that older males were more aggressive and likely to get killed in motor vehicle crashes.

Table 9. Gender Ranking for Fatalities and A-injuries (2011–2016)

Rank	Person Type + Injury Class	2011		2012		2013		2014		2015		2016	
		F	A	F	A	F	A	F	A	F	A	F	A
1	K-Male	97	559	94	528	113	585	100	561	123	622	130	547
2	K-Female	71	534	66	619	61	612	80	598	67	672	90	613

Pedestrian/Pedalcyclist Visibility

Reported pedestrian/pedalcyclist visibility (PEDV) parameters for total injuries, fatalities, and A-injuries followed a similar trend. Most of the total pedestrian/pedalcyclist crashes (69–76%) involved no contrasting clothing. Only 18–26% of total crashes involved pedestrians/pedalcyclists with contrasting clothing. The remaining 5–6% reported reflective materials and other light sources were used (Table 10). The results showed that contrasting clothing and reflective material improved older people's safety and reduced their chance of getting killed or severely injured in motor vehicle crashes.

Collision Types

Among the total crashes involving older people, rear-end, turning, angle, and sideswipe ranked first, second, third, and fourth highest, respectively. Collisions due to animals, fixed objects, parked motor vehicles, and pedestrians were the next highest parameters. Ranking lowest were sideswipes from the opposite direction, head-on collisions, pedalcyclists, overturned, other non-collisions, and trains (Table 11).

For fatal injuries—unlike the trend found for total crashes—fixed object, pedestrian, turning, angle, and head-on collisions were involved in the most casualties. Fatalities due to pedalcyclists, rear-ends, and other objects comprised the second-most important parameters.

For A-injuries, rear-end, turning, angle, fixed-object, and pedestrian crashes were found to be the most important collision-type parameters. The next important parameters involved head-on and overturned collisions as well as those due to parked vehicles.

Because of the high percentage of older people for different collision types, the researchers investigated the percentage of older drivers responsible for injuries. They performed an analysis of two types of people in a collision: drivers and non-drivers. To understand the percentage of older people involved in these types of collisions, the data were compared with data for younger age groups (0–20, 21–34, and 35–64).

Table 10. PEDV Ranking for Total Crashes, Fatalities, and A-injuries (2011–2016)

Rank	PEDV Parameters	2011			2012			2013			2014			2015			2016		
		T	F	A	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A
1	No contrasting clothing	296	30	52	345	29	70	339	24	80	361	23	60	405	19	101	398	31	78
2	Contrasting clothing	111	8	20	103	4	18	94	3	18	94	2	20	97	8	18	106	5	16
3	Reflective material	11	1	1	15	1	4	15	0	4	11	0	3	13	0	4	12	0	0
4	Other light source used	9	0	1	9	0	3	19	0	3	8	0	4	15	1	4	15	0	1

Table 11. Collision-type Ranking for Total Crashes, Fatalities, and A-injuries (2011–2016)

Collision Types	2011			2012			2013			2014			2015			2016		
	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A
Rear-end	13,969	8	196	14,459	12	197	15,726	8	224	16,064	9	185	17,360	14	237	18,514	22	218
Turning	10,741	26	260	9,903	20	226	10,594	31	227	11,499	30	259	12,754	30	296	13,350	36	250
Angle	7,808	21	215	8,784	21	269	9,078	33	254	8,480	25	256	8,529	20	241	9,197	29	219
Sideswipe—same direction	4,440	1	18	4,544	3	24	5,056	3	33	5,439	3	22	5,858	5	42	6,399	3	25
Animal	2,043	1	4	1,860	1	13	1,873	0	8	1,886	0	4	2,077	0	9	1,949	2	8
Fixed object	2,040	39	142	2,091	37	181	2,230	39	164	2,462	44	161	2,389	46	147	2,346	41	160
Parked motor vehicle	1,708	1	32	1,746	2	17	1,762	1	31	2,039	0	23	2,046	0	28	2,153	1	37
Pedestrian	825	30	70	837	29	86	904	24	99	837	27	74	965	28	129	1006	40	89
Sideswipe—opposite direction	579	2	18	620	4	20	701	3	21	787	5	20	716	4	22	736	3	21
Head-on	449	17	63	417	18	46	483	22	61	547	29	73	595	26	68	586	30	60
Pedal cyclist	435	11	15	485	7	19	518	3	18	466	1	19	507	2	15	522	0	16
Other object	224	5	9	224	4	5	261	1	3	325	2	12	387	0	5	427	4	9
Overturned	204	3	36	172	2	34	193	5	42	228	4	36	221	11	45	199	5	42
Other non-collision	199	0	15	201	0	9	198	1	9	287	1	13	230	2	6	251	3	9
Train	9	3	1	4	0	1	17	0	4	15	0	3	7	2	2	11	1	2

Considering the total injuries for drivers and non-drivers, the percentage of older people in different collision types were identified. Among 12,758 severe crashes (K- and A-injuries) involving drivers, older drivers contributed to 910 severe crashes, or 14% of the total share in 2011. Among the six age groups, the 35–64 age group had the highest share for severe crashes (about 46%) and people aged 85 or older had the lowest share (less than 1%). This is not unusual, as people aged 85 or older are not usually physically fit enough to drive and have less mobility than those aged 65–84.

Table 12 shows the trend for driver involvement in collisions resulting in severe injuries for the six age groups. Not all age groups followed similar trends for collision-type involvement. For younger age groups, fixed-object, rear-end, and turning crashes were most prominent, while for drivers aged 65 or older, turning, angle, and rear-end collisions caused the most severe injuries.

Table 12. Driver Involvement in Collisions Resulting in Severe Injuries (2011)

Collision Types	0–20		21–34		35–64		65–74		75–84		85 or Older	
	K	A	K	A	K	A	K	A	K	A	K	A
Pedestrian	0	5	0	3	0	12	0	2	0	1	0	3
Pedalcyclist	0	0	0	4	0	3	0	0	0	0	0	0
Train	0	0	0	1	3	3	0	0	2	1	0	0
Animal	0	7	0	15	5	64	1	3	0	0	0	0
Overturned	8	92	10	187	29	263	2	23	0	6	0	2
Fixed object	30	265	71	609	89	647	16	69	11	47	8	12
Other object	0	3	2	15	1	29	2	1	1	4	0	0
Other non-collision	0	11	0	36	2	73	0	11	0	1	0	0
Parked motor vehicle	0	20	4	73	3	60	1	14	0	7	0	8
Turning	4	168	18	423	29	655	10	100	7	75	2	22
Rear-end	1	104	10	431	21	787	1	91	3	40	0	21
Sideswipe—same direction	1	24	2	75	4	123	0	10	0	3	0	4
Sideswipe—opposite direction	2	18	2	30	6	68	0	10	0	5	1	2
Head-on	10	47	20	136	37	200	6	29	3	16	1	1
Angle	4	130	19	344	25	578	10	95	6	54	2	21

An analysis was made for non-driver injuries that involved all other types of people, except drivers, revealing surprising results. For 2011, pedestrian-related severe injuries were the highest for all age groups (Table 13). Other major collision types responsible for non-driver severe injuries were fixed objects, turning, and rear-end crashes (for ages 0–64). For older people, the most prominent non-driver severe injuries were turning, rear-end, and angle crashes, which followed a similar trend as driver collisions.

Among 4,535 severe injuries involving non-drivers, crashes involving older people resulted in 381 severe injuries (8% of total), of which 72 were fatal. In driver-related severe crashes, 96 fatalities involved older people. For people between the ages of 0–64, 472 and 277 fatalities involved drivers and non-drivers, respectively. This indicates that older people who were non-drivers were involved in more fatalities than younger people of the same type. For every 4.9 younger drivers with severe injuries, there was one crash involving older drivers. For every 3.85 non-drivers with severe injuries, there was one older person who was a non-driver. This number is alarmingly high, requiring further in-depth research to mitigate measures. The results followed a similar trend for the remaining years and can be found in Appendix B.

Table 13. Non-driver Involvement in Collision Resulting in Severe Injuries (2011)

Collision Types	0–20		21–34		35–64		65–74		75–84		85 or Older	
	K	A	K	A	K	A	K	A	K	A	K	A
Pedestrian	13	282	22	212	62	332	15	40	13	17	2	9
Pedalcyclist	6	137	4	85	5	126	6	11	4	3	1	1
Train	0	0	1	1	0	0	0	0	1	0	0	0
Animal	0	9	0	8	1	11	0	1	0	0	0	0
Overturned	4	74	6	51	6	38	1	4	0	2	0	0
Fixed object	30	258	17	210	13	146	2	6	2	6	0	6
Other object	0	3	3	0	2	5	0	2	2	2	0	0
Other non-collision	1	27	2	16	0	18	0	1	0	1	0	1
Parked motor vehicle	0	25	5	34	4	19	0	2	0	3	0	0
Turning	4	226	5	126	4	166	1	37	2	18	4	13
Rear-end	2	193	4	133	2	173	2	31	1	18	1	2
Sideswipe—same direction	0	29	1	26	0	25	1	1	0	2	0	0
Sideswipe—opposite direction	5	17	1	11	1	12	1	1	0	1	0	0
Head-on	11	71	5	41	7	52	4	8	1	8	2	1
Angle	3	207	5	109	10	133	0	24	2	15	1	11

Roadway Characteristics

This section discusses roadway characteristics related to severe injury crashes. The roadway characteristics considered in the analysis are surface condition, light condition, and roadway alignment.

Surface Conditions

About 79–84% of the total crashes involving older people occurred in dry surface conditions; the remaining 16–23% occurred in unfavorable surface conditions (i.e., wet, snow or slush, ice, sand, mud, dirt). This trend was similar for fatalities (81–86% and 13–19%) and A-injuries (78–86% and 12–22%) for all six years (Table 14).

Light Conditions

More than 80% of the reported total crashes occurred in daylight, while the remaining occurred in unfavorable light conditions, including dawn, dusk, and darkness on lighted roads. The trend for K- and A-injuries was also similar (Table 15).

Alignment Conditions

On average, 87% of total crashes involving older people occurred on straight and level roads, 7% on straight on grade, 3% on curve and level, 2% on curve on grade, 1% on straight on hillcrest, and the remaining on curve on hillcrest road alignments. This pattern was similar for fatal and A-injuries (Table 16).

Table 14. Surface Conditions Ranking for Total Crashes, Fatalities, and A-injuries (2011–2016)

Surface Conditions	2011			2012			2013			2014			2015			2016		
	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A
Dry	35205	144	882	38187	128	992	38114	142	955	38844	144	900	43087	165	1054	46661	189	975
Unfavorable	9499	24	197	7064	31	138	10435	32	228	11683	34	251	10598	25	232	10841	30	183

Table 15. Light Condition Ranking for Total Crashes, Fatalities, and A-injuries (2011–2016)

Light Conditions	2011			2012			2013			2014			2015			2016		
	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A
Daylight	36616	123	884	37428	108	949	39944	133	967	41224	122	920	43742	152	1055	46327	162	905
Unfavorable	8841	45	206	8666	52	193	9354	41	222	9807	57	235	10599	38	235	10936	57	257

Table 16. Alignment Condition Ranking for Total Crashes, Fatalities, and A-injuries (2011–2016)

Alignment Conditions	2011			2012			2013			2014			2015			2016		
	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A
Straight and level	32,412	128	887	33,481	121	950	36,356	125	974	39,362	129	941	44,109	138	1020	47,331	167	921
Straight on grade	2,625	12	77	2,632	14	81	2,910	23	84	3,132	17	81	3,377	13	109	3,615	14	107
Curve, level	1,100	16	59	1,161	12	47	1,191	12	63	1,312	16	55	1,541	18	74	1,632	22	59
Curve on grade	572	10	32	585	1	24	682	9	32	719	11	35	760	13	35	800	8	41
Straight on hillcrest	542	2	20	483	2	24	588	4	18	620	4	23	771	5	30	811	6	28
Curve on hillcrest	90	0	2	79	3	3	81	1	5	113	1	2	128	2	11	140	1	3

Table 17. Weather Condition Ranking for Total Crashes, Fatalities, and A-injuries (2011–2016)

Weather Conditions	2011			2012			2013			2014			2015			2016		
	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A	T	F	A
Clear	38,214	149	935	40,270	133	1026	40,526	147	1006	41,815	149	950	44,869	158	1088	47,669	187	978
Unfavorable	7,001	19	155	5,650	27	118	8,600	27	186	8,982	30	205	9,211	32	200	9,363	32	179

Environmental Characteristics

The environmental characteristic considered in the analysis is the weather condition at the time of the crash. The data show that 82–85% of total crashes, 83–89% of fatalities, and 82–90% of A-injuries were reported to occur in clear weather conditions. The rest occurred in unfavorable weather conditions (rain, snow, fog/smoke/haze, sleet/hail, severe cross wind, cloudy/overcast) or other weather conditions (Table 17).

Demographics

The research team also conducted a causation analysis using demographic data from 102 counties in Illinois. Data for demographic parameters were obtained from 2011–2016. The following parameters were selected for the analysis: population, poverty level, race, educational attainment, and employment.

The focus of this analysis was to determine whether the crash statistics (both total crashes and severe injuries) conformed to the demographic characteristics for a certain area. The purpose was to reveal any trends between crash occurrences involving older people and demographic features. To match the demographic data, the number of total crashes and severe injuries involving older people and their percentages among total crashes of all age groups were determined for each county in Illinois. Because most socioeconomic data are continuous, scatterplots were used to show any patterns and trends between the data with crashes involving older people.

Crash Frequency

First, the research team identified the number of total crashes and severe crashes (including K- and A-injuries) in 102 Illinois counties for the study period (2011–2016). The research team also determined the number of older people involved in crashes per county. Based on the data, the relative percentages of severe crashes among total crashes for the overall and older populations were calculated. Then, the percentages of severe crashes among total crashes involving older people were plotted against the percentage of the total number of severe crashes among the total motor vehicle crashes for all counties in Illinois.

Figure 31 presents the scatterplot obtained from these two variables for 2011. It shows a considerably positive correlation with an upward trendline. Some outliers were observed in the figure, and the names of the outlier counties were labeled. To remove the effects of the outliers, the graph was redeveloped without outliers (Figure 32). Figure 32 shows a positive relation between the severe crash percentage in total crashes involving older people and severe crash percentage in total crashes. Similar patterns were obtained for the remaining years (2012–2016), as shown in Appendix C. Each year, with the increase of total severe crashes (K- and A-injuries), the number of severe crashes among the older population also increased.

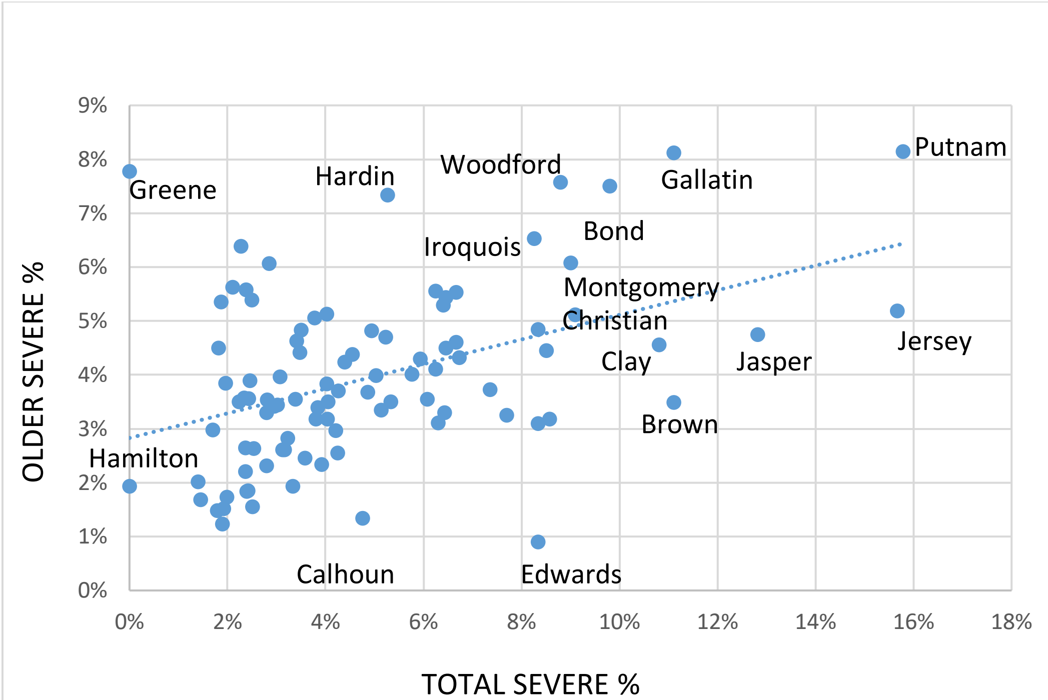

Figure 31. Graph. Severe crashes involving older people vs. percentage of total severe crashes (2011).

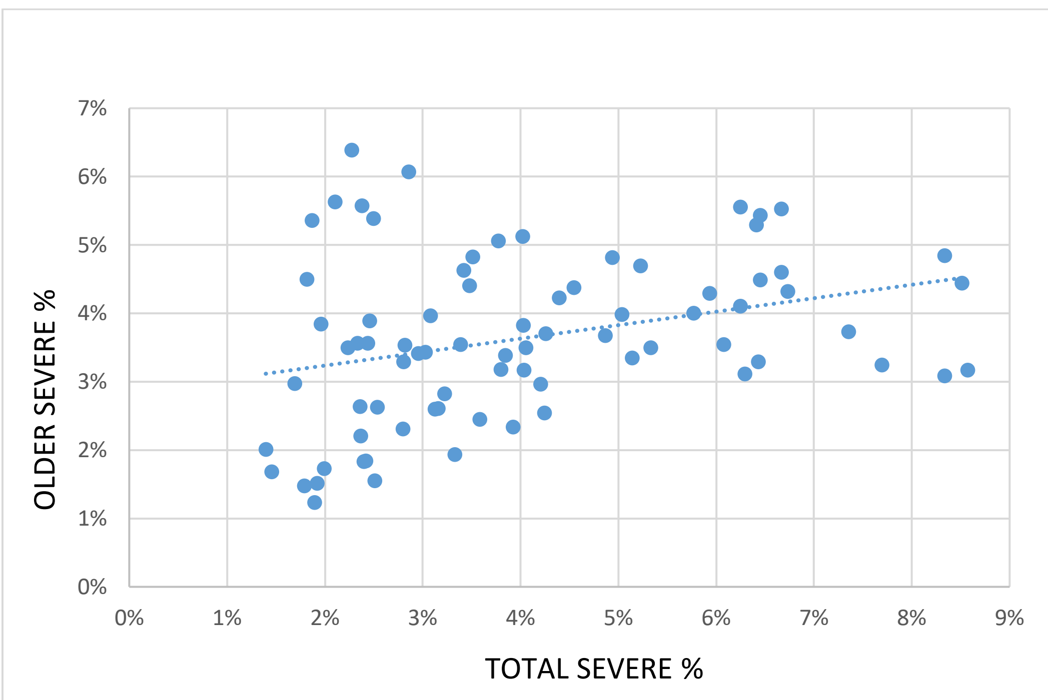

Figure 32. Graph. Severe crashes involving older people vs. percentage of total severe crashes without outliers (2011).

Race

The association between the percentage of African American and Hispanic populations and the number of crashes involving older populations was also examined (Figure 33 and Figure 34). During the six-year study period, Pulaski, Cook, Alexander, and St. Clair counties comprised of the top 15% of the older black/African American and Hispanic populations. Most Illinois counties were dominantly white and had less than 2% of Hispanic and African American populations.

Scatterplots were developed for all study years. The correlation between older African American and Hispanic populations with crashes involving older people showed negative trends for all five years, except 2014. This indicated that Caucasians were the dominant race contributing to motor vehicle crashes involving older people. Figure 33 shows the scatterplot for 2011, and Appendix C shows the plots for 2012–2016.

Educational Attainment

The association between the number of crashes involving older people and their educational attainment was also analyzed. Two education levels were considered: up to high school education and higher education (college education, graduate studies, or professional degrees).

Pope, Gallatin, Carrol, Hardin, White, Calhoun, Hamilton, Henderson, and Stark counties had the highest percentage of older people with an education up to high school. Over the study period, crashes involving older people and older people without higher education showed a high positive tendency. This indicates that counties with a higher older population without higher education experienced more crashes involving older people. Figure 35 and Figure 36 are representative scatterplots for 2011, and Appendix C shows the remaining plots.

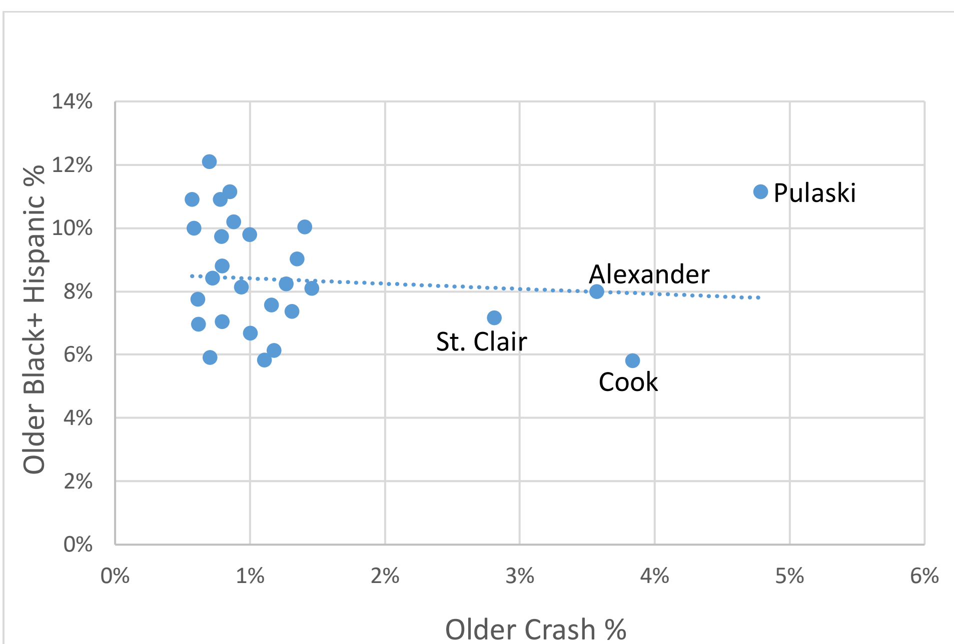

Figure 33. Graph. Older African American and Hispanic populations vs. percentage of total crashes involving older people (2011).

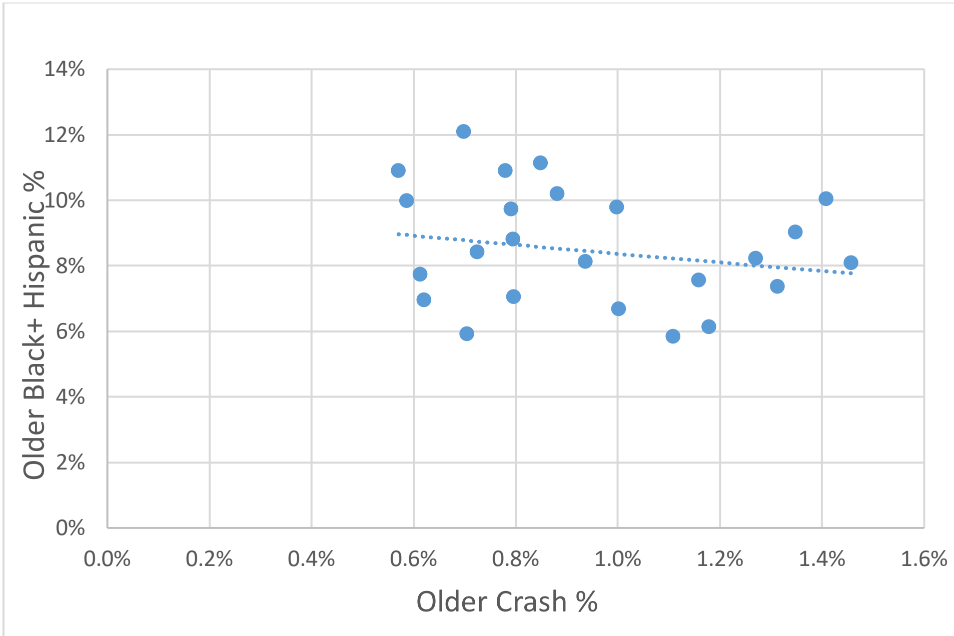

Figure 34. Graph. Older African American and Hispanic population vs. percentage of total crashes involving older people without outliers (2011).

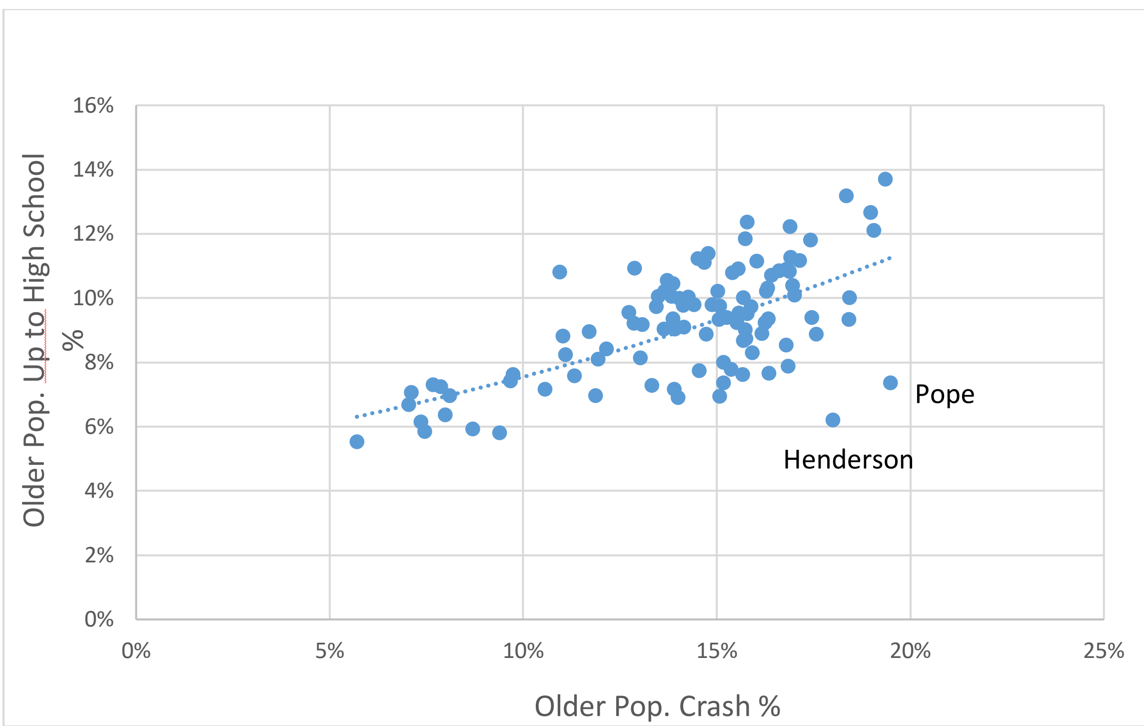

Figure 35. Graph. Older people with high school education vs. percentage of total crashes involving older people (2011).

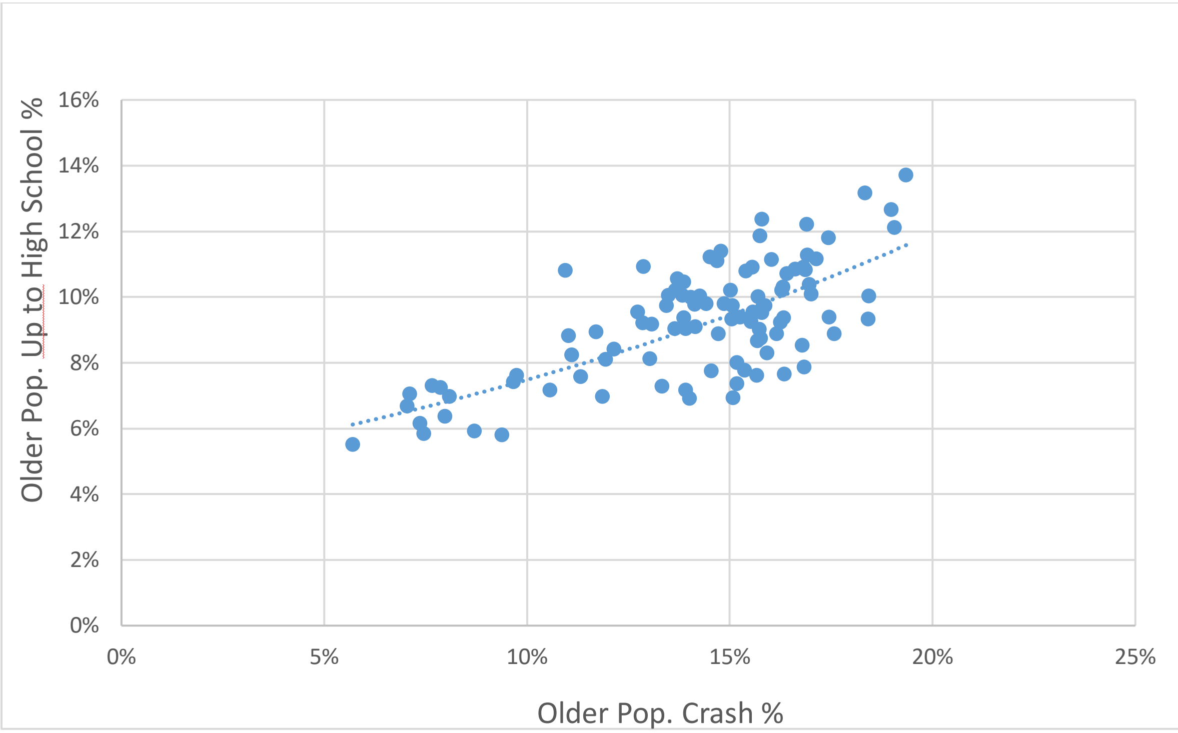

Figure 36. Graph. Older people with high school education vs. percentage of total crashes involving older people without outliers (2011).

Employment

Though the percentage of the older population in the labor force is considerably low, the percentage of older people in the workforce showed a high correlation with crashes involving older people for all study years. As the number of employed older people increased, so did the number of total crashes involving older people. This implies that employed older people can be considered as high-risk population groups. Figure 37 and Figure 38 show the representative trend for 2011, and Appendix C shows the remaining charts.

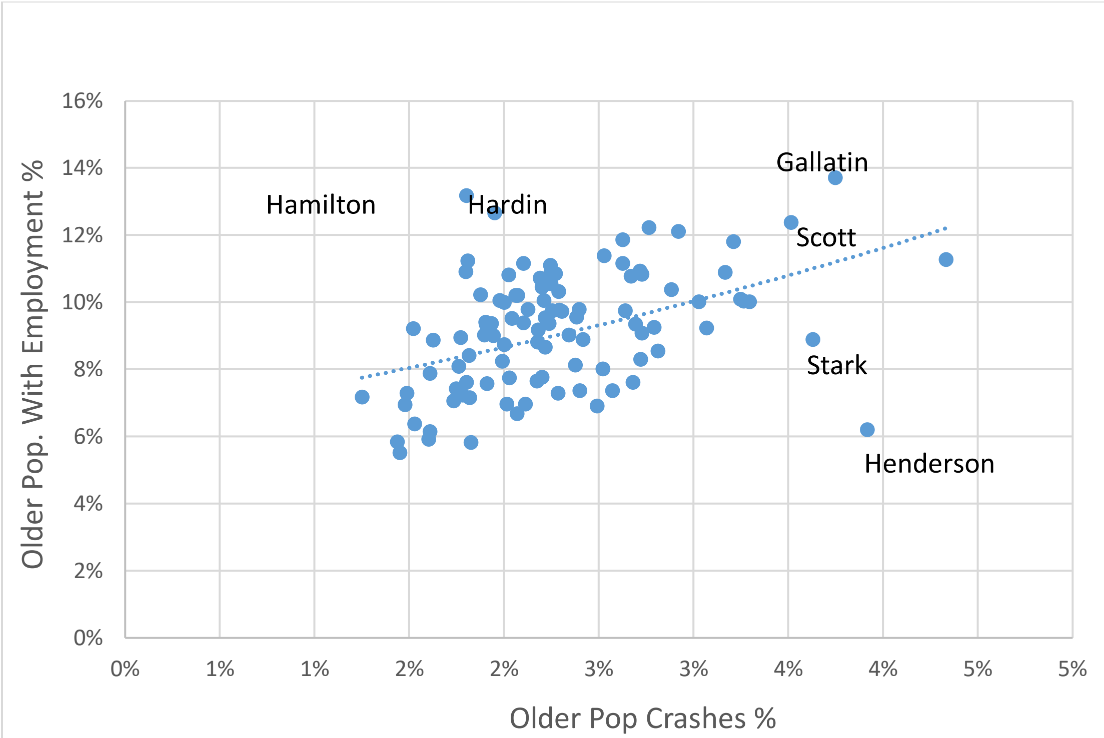

Figure 37. Graph. Employed older people vs. percentage of total crashes involving older people (2011).

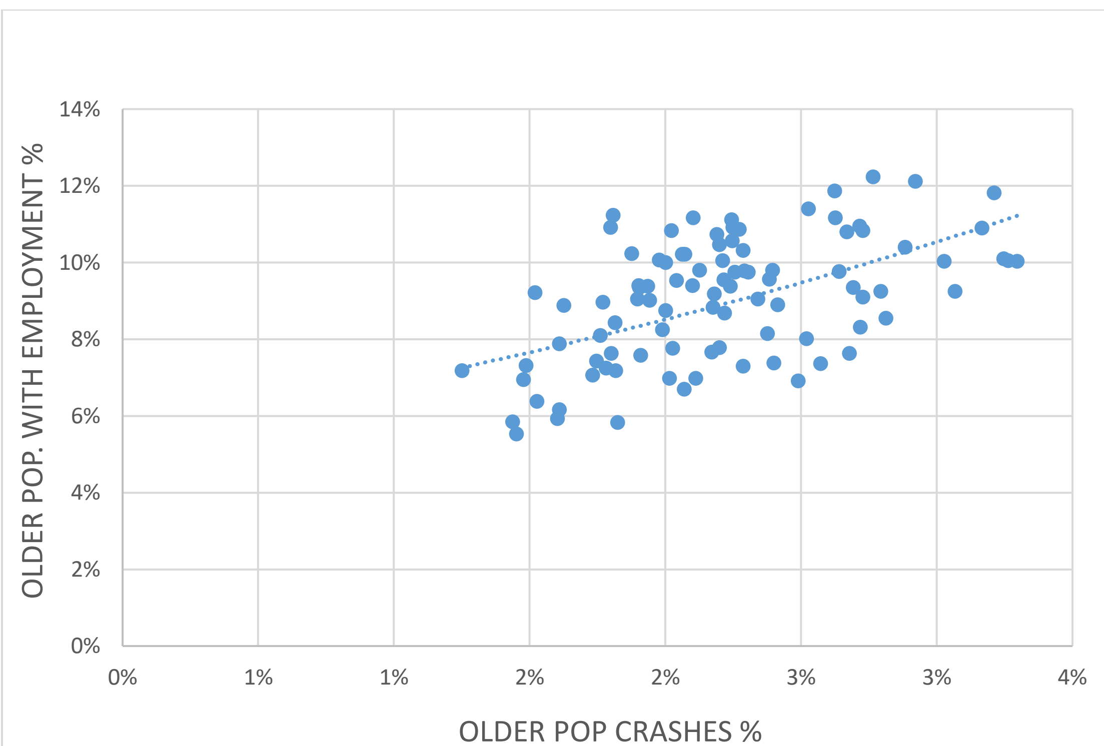

Figure 38. Graph. Employed older people vs. percentage of total crashes involving older people without outliers (2011).

MULTIPLE LOGISTIC REGRESSION ANALYSIS RESULTS

The results of the causation analysis indicate that crashes involving older people, particularly severe crashes, are related to some roadway geometric, traffic operational, and environmental properties, as well as aggregated socioeconomic and demographic characteristics. The analysis, however, could not determine if the correlation was statistically significant. Therefore, the crash and socioeconomic data were further analyzed using logistic regression models to identify significant factors that impact severe crashes. The model was fitted using data of all age groups and data of the older population only. For the analysis of all age groups, the total number of data points is 761,104, among which 107,137 were coded as severe injuries. For the analysis of only older age groups, there were 68,082 data points, among which 10,885 were severe injuries. Both models converged and satisfied the default precision value, which is $1E^{-8}$. This section first presents the screened independent predictive variables from the collinearity analysis, then the results and discussion of multiple logistic regression analyses.

Independent Predictive Variables

Collinearity analysis was first conducted before logistic modelling to determine independent predictive variables for use in the model. Table 18 shows the screened independent parameters with VIF values less than 3.0, which were considered the crash data input variables in the subsequent multiple logistic regression analysis.

Table 18. Collinearity Statistics

Independent Variables	Collinearity Statistics	
	Tolerance	VIF
TCD_Yield/Railroad Cross etc.	0.778	1.285
RdSur_Wet/Snow	0.496	2.016
RdDef_SomeDefects	0.593	1.687
Light_Dark/Dawn	0.964	1.037
Weather_Rain/Snow	0.503	1.986
Int_Yes	0.778	1.285
Lane_4 or more	0.943	1.061
Gender_Male	0.993	1.007
VehTyp_Car/SUV/Minivan/Pickup	0.995	1.005
VehDefects_SomeDefect	0.918	1.09
Time_OffPeakHour	0.993	1.007
Age_65_Over	0.996	1.004
Dependent Variable: PersonInjuryClass		

Analysis Results

The χ^2 test p-values of model coefficients were used to determine the significance of the explanatory variables associated with them. A significance level of 0.05 was employed in the study. A p-value less than 0.05 means a significant impact of the corresponding variable on crash severity. Further, the sign of model coefficients was used to interpret how the corresponding variables were related to the dependent crash severity level variable. A positive coefficient indicated a positive relationship and vice versa.

All Age Group

Table 19 presents the maximum likelihood estimates of socioeconomic variable coefficients of the logistic model fitted using all age group data, along with their standard errors, χ^2 statistic, and p-values. P-values lower than 0.05 were highlighted. Mean density, median household income, percentage of uninsured adults, percentage of African Americans, and average number of people served by one primary care physician had statistically significant impacts on crash injury severity. Specifically, as the mean population density and average number of people served by one primary care physician increased, the likelihood to have severe injuries in motor vehicle crashes also increased. In contrast, as median household income, percentage of uninsured adults, and percentage of African Americans increased, the risk to have severe injuries decreased. The results imply that Caucasians contributed more to severe injury crashes than African Americans. Uninsured drivers drive more carefully than insured drivers, so the risk for them to be involved in severe crashes is also lower. Severe injuries were highly associated with low-income households and a lack of physician care, indicating motor vehicle crashes are not merely an engineering or a safety problem. Joint efforts from multiple agencies are needed to tackle this issue.

Table 19. Socioeconomic Predictor Outputs (All Age Groups)

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	0.2678	0.1170	5.2441	0.0220
Mean density	1	0.000016	5.479E-6	9.0101	0.0027
Older people percentage	1	-0.4179	0.3054	1.8722	0.1712
Median HH income	1	-0.00002	8.52E-7	628.2686	<.0001
Uninsured adult percentage	1	-4.4073	0.3596	150.2445	<.0001
African American percentage	1	-1.8732	0.0933	402.9139	<.0001
Unemployment percentage	1	-0.6405	0.3730	2.9494	0.0859
Average number of people served by one primary care physician	1	0.000101	4.532E-6	494.4286	<.0001

Similarly, Table 20 presents the results of crash-level explanatory variables for the logistic model fitted using data from all age groups. All crash-level explanatory variables tested in the study were statistically significant, except road defect. The effects of some variables were obvious. For instance, vehicles with defects increased the chance to be involved in severe crashes. Similarly, in dark or dawn conditions or driving along curves or slopes, the risk to have severe injuries was higher than in daylight conditions or driving along straight and flat roads. Also, people who drove big trucks were more aggressive than those who drove family vehicles; therefore, big trucks were more related to severe crash injuries. The effects of other variables were not as obvious. The results showed that on wet/snowy roads or in unfavorable weather (rain/snow), the likelihood of having severe injuries was lower compared to favorable roadway surfaces and weather conditions. Drivers tend to slow down under unfavorable conditions, focus on driving, and drive more carefully on slippery surfaces or raining/snowy days. This was similar for the intersection-related and number of lanes variables. The results indicated that at intersections or segments with less than four lanes, crash injuries were less severe than those that occurred at non-intersection-related locations or segments with more than four lanes. This implies that drivers, pedestrians, or pedal cyclists were more careful when they crossed intersections or wide roadways, because those locations had most of the conflict points in a roadway network.

Table 20. Crash-level Predictor Outputs (All Age Groups)

	Analysis of Maximum Likelihood Estimates					
Parameter	Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Traffic Control Devices	Signal	1	-0.0795	0.0105	57.5611	<.0001
	STOP	1	0.0869	0.0124	49.2848	<.0001
	Others (Yield/Railroad crossing etc.)	1	0.3427	0.00933	1348.5626	<.0001
	No Control	0	0	.	.	.
Road Surface Condition	Wet/Snow	1	-0.1132	0.0121	87.1393	<.0001
Road Defect	Some	1	-0.00746	0.0212	0.1233	0.7255
Light Condition	Dark/Dawn	1	0.1832	0.00747	600.9158	<.0001
Weather Condition	Rain/Snow	1	-0.0396	0.0133	8.9277	0.0028
Intersection Related	Yes	1	-0.0823	0.00929	78.4596	<.0001
Number of Lanes	4 or more	1	-0.0604	0.00703	73.6569	<.0001
Roadway Alignment	Curve/Grade	1	0.1686	0.00843	400.1484	<.0001
Age Group	00 to 20	1	-0.1674	0.00921	330.4691	<.0001
	21 to 34	1	-0.0364	0.00810	20.1766	<.0001
	65 to 74	1	0.0719	0.0147	23.8078	<.0001
	75 to 84	1	0.1799	0.0201	80.3228	<.0001
	85 and more	1	0.2823	0.0330	73.3231	<.0001
	35 to 64	0	0	.	.	.
Gender	Male	1	0.1842	0.00673	750.0599	<.0001
Vehicle Types	Car/SUV/Van/Pickup	1	-0.2075	0.00680	932.2443	<.0001
Vehicle Defects	Some	1	0.2792	0.00924	913.3256	<.0001
Time	Peak Hour	1	-0.0344	0.00674	25.9856	<.0001

It is interesting to investigate the estimated coefficients of different age groups. People aged 35–64 were the reference group. Compared to the reference group, all older groups had positive coefficients, while all younger groups had negative coefficients. The absolute values of those coefficients also increased as the age difference with the reference group increased. The results indicated that as people age, their risk of getting severely injured in motor vehicle crashes increases. The older population is more vulnerable in motor vehicle crashes compared to younger groups. Males were found to be involved in more severe injuries than females. This holds true, given that males are more aggressive than females. The last significant variable was traffic control device. Compared to no control, stop or yield sign control experienced severe crashes. As the highest level of traffic control, signal control was effective in reducing severe injuries. This finding indicates that traffic control in some locations was not adequate, which needs to be upgraded to signal control to mitigate severe motor vehicle crashes.

Older People Groups

Table 21 presents the estimated coefficients of demographic variables and their χ^2 test statistics for the logistic model fitted using only older groups. Similar results were obtained as the model was fitted using all age group data. Median household income, percentage of uninsured adults, percentage of African Americans, and average number of people served by one primary care physician were statistically significant. The sign of those variables' coefficients was also the same as those from the model using all age group data, indicating similar positive/negative effects of those variables on crash injury severity. In addition, the absolute values of the coefficient for percentage African Americans was higher than those from the overall model. This implies that Caucasians contributed to most of the severe injuries among the older population, and this effect is more significant for older groups. In contrast, the effect of percentage of uninsured adults among the older population is less compared to that in the all age group. This indicates that older people were more careful when they were not covered by insurance, as their physical conditions may make them prone to severe injuries compared to similar younger groups.

Table 21. Socioeconomic Predictor Outputs (Older Age Group)

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	0.5538	0.3561	2.4186	0.1199
Mean Density	1	0.000022	0.000017	1.6792	0.1950
Older People Percentage	1	-1.4699	0.9242	2.5298	0.1117
Median Household Income	1	-0.00002	2.61E-6	72.5161	<.0001
Uninsured Adult Percentage	1	-3.8329	1.1043	12.0478	0.0005
African American Percentage	1	-2.1462	0.2934	53.5121	<.0001
Unemployment Percentage	1	-1.5882	1.1509	1.9045	0.1676
Average Number of People Served by One Primary Care Physician	1	0.000121	0.000014	75.4573	<.0001

Table 22 shows the results of crash-level variables for the logistic model fitted using older group data. The effects of light condition, gender, roadway alignment, road surface, vehicle type, and vehicle defect among older people were similar to those from the overall model. Different results were obtained for other variables, however. Number of lanes, intersection related, and weather condition were not statistically significant among the older population. In addition, the sign of the coefficients for weather condition and intersection related were reversed compared to the results from the overall model. This means that although older people were vulnerable in motor vehicle crashes regardless of weather conditions and locations, they experienced more severe crashes in unfavorable weather and at intersection-related locations.

The results of the traffic control variable also confirmed the challenges older people face when crossing locations with traffic-conflict points. For older people, signal- and stop-sign control only had marginal effects on crash severity. They acted similarly to no control. Further, the existence of stop-sign control even increased the chance of having severe injuries for older people. This adverse impact was even worse for yield-sign control, as its coefficient was much higher than that of stop-sign control and its effect was statistically significant (p-value less than 0.05).

Table 22. Crash-level Predictor Outputs (Older Age Groups)

Analysis of Maximum Likelihood Estimates						
Parameter Descriptions	Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Traffic Control Devices	Signal	1	-0.0587	0.0333	3.1091	0.0779
	STOP	1	0.0654	0.0379	2.9722	0.0847
	Others (Yield, RR etc.)	1	0.4814	0.0304	250.4691	<.0001
	No	0	0	.	.	.
Road Surface Condition	Wet/Snow	1	-0.1046	0.0395	7.0193	0.0081
Road Defect	Some	1	0.0519	0.0691	0.5640	0.4526
Light Condition	Dark/Dawn	1	0.1466	0.0269	29.7599	<.0001
Weather Condition	Rain/Snow	1	0.0302	0.0427	0.4993	0.4798
Intersection Related	Yes	1	0.00500	0.0295	0.0287	0.8656
Number of Lanes	4 or more	1	-0.0350	0.0221	2.5007	0.1138
Roadway Alignment	Curve/Grade	1	0.0842	0.0277	9.2136	0.0024
Gender	Male	1	0.0861	0.0213	16.3224	<.0001
Vehicle Types	Car/SUV/Van/Pickup	1	-0.2166	0.0216	100.6461	<.0001
Vehicle Defects	Some	1	0.3538	0.0308	132.3370	<.0001
Time	Peak Hour	1	-0.0482	0.0217	4.9632	0.0259

HIERARCHICAL LINEAR MODELING RESULTS

Given that individual crashes and person(s) involved in each crash were nested within the counties to which they belong, hierarchical linear modelling was used to further analyze the crash and demographic data to account for their ordered nature. The χ^2 test statistics and p-values were used to determine the significant influencing variable on severe crashes involving old people. The results were compared with those from the logistic regression analysis.

Table 23 and Table 24 present county-level socioeconomic variable coefficients estimated for all age groups and older age groups, respectively, along with χ^2 test statistics and p-values. P-values less than 0.05 were highlighted. The results for all age groups (Table 23) show that the mean percentage of older population in a county was statistically significant even at the 0.01 confidence level. For example, as the percentage of the older population increased in a certain county, the risk of severe older people motor vehicle injury also increased, indicating older people were the main fatal and A-injury crash victims. Another significant variable was the average number of people served by one doctor, which was significant for both the overall and older people models at the 0.01 significance level. This result highlighted the importance of medical care in mitigating severe motor vehicle crash injuries. Other tested variables were not statistically significant, but the results showed a negative relationship between household income and percentage of African American population with severe injuries for both the overall and older people models. The older people model, however, showed a positive relationship between percentage of uninsured adults with severe injuries and a negative relationship between percentage of unemployed adults with severe injuries, which is opposite of the results from the overall model. This may be because most uninsured and/or unemployed adults belong to non-older age groups.

Table 23. HLM Result Output for Socioeconomic Variables (All Age Groups)

Fixed Effects	Coefficient	Standard Error	t-Ratio	p-Value
For INTRCPT1, β0, INTRCPT2, γ_{00}	1.628472	0.245049	6.645	<0.001
Mean Density, γ_{01}	-0.000034	0.000023	-1.466	0.146
Mean Old Population Percentage, γ_{02}	1.846973	0.454825	4.061	<0.001
Median Household Income, γ_{03}	-0.000001	0.000002	-0.718	0.475
Uninsured Adult Percentage, γ_{04}	-0.351817	0.762366	-0.461	0.646
Percentage of African American, γ_{05}	-0.46082	0.183282	-2.514	0.014
Mean Unemployment Percentage, γ_{06}	0.635446	0.957165	0.664	0.508
Avg People Served by One Doctor, γ_{07}	0.000024	0.000008	3.043	0.003

Table 24. HLM Result Output for Socioeconomic Variables (Older Age Groups)

Fixed Effects	Coefficient	Standard Error	t-Ratio	p-Value
For INTRCPT1, β0, INTRCPT2, γ_{00}	1.812919	0.338703	5.353	<0.001
Mean Density, γ_{01}	-0.000044	0.000027	-1.64	0.104
Mean Old Population Percentage, γ_{02}	1.174458	0.713696	1.646	0.103
Median Household Income, γ_{03}	-0.000002	0.000003	-0.709	0.48
Uninsured Adult Percentage, γ_{04}	0.251998	1.142538	0.221	0.826
Percentage of African American, γ_{05}	-0.490299	0.231438	-2.118	0.037
Mean Unemployment Percentage, γ_{06}	-0.43938	1.078357	-0.407	0.685
Avg People Served by One Doctor, γ_{07}	0.000041	0.000015	2.67	0.009

Table 25 and Table 26 show the injury-level variable results for the all age and older age groups, respectively. The analysis of all age groups (Table 25) found that other than the road defect, number of lanes, and time of the crash variables, all other tested variables had a significant effect on severe injuries. Specifically, dark conditions, on grade/curve, and driving big trucks or vehicles with defects increased severe injury risk. In unfavorable weather, on slippery road surface conditions, and at intersections, the chance of severe injuries was lower than in bad weather, on dry surfaces, and on non-intersection segments. This may be because people usually drove more carefully during unfavorable weather and road-surface conditions, and traffic signals and stop signs at intersections worked effectively to control traffic. It was alarming to see that yield signs, railway crossings, and school-zone traffic control devices worked against the purposes for which they were designed and implemented. The results showed that compared to traffic signals, stop signs, and even no control, these three traffic control devices increased the chance of severe injuries. Further investigation was needed to examine the appropriateness of those traffic control devices. Based on the investigation results, warranties or the implementation guide for those control devices may need to be revised or updated. The last tested variable, age group, also showed high-level significance; older people were more prone to severe injuries in motor vehicle crashes compared to younger groups.

Table 25. HLM Result Output for Level 1 Variables (All Age Groups)

Fixed Effects	Category	Coefficient	Standard Error	t-Ratio	p-Value
Traffic Control Devices	Yield/RR/School etc.	0.170197	0.021354	7.97	<0.001
Road Surface Conditions	Wet/ Snow/Slush/Ice/Sand etc.	-0.043353	0.009969	-4.349	<0.001
Road Defects	Some Defects	-0.001442	0.012782	-0.113	0.91
Light Conditions	Dawn/Dusk/Darkness/Darkness with Light etc.	0.086801	0.00495	17.537	<0.001
Weather Conditions	Rain/Snow/Fog/Hail etc.	-0.008385	0.004169	-2.011	0.044
Intersection Related	Yes	-0.033279	0.010683	-3.115	0.002
Number of Lanes					
	More than 4 Lanes	-0.006918	0.007048	-0.981	0.326
Roadway Alignment	Straight and Level				
	Grade/Curve etc.	0.039268	0.007084	5.543	<0.001
Gender	Male	0.074982	0.003835	19.551	<0.001
	Female				
Vehicle Types	Passenger Car/SUV/Minivan/Pickup	-0.049054	0.007994	-6.137	<0.001
	Truck/Bus				
Vehicle Defects	No Defects				
	Some Defects	0.079556	0.012708	6.26	<0.001
Time of Crash	Peak Hour	-0.007825	0.006792	-1.152	0.249
	Off-peak Hour				
Age Groups	0–64				
	Over 65 years old	0.050994	0.007006	7.279	<0.001

Similar results as the overall model were obtained for the older people model as for individual person-level variables. All significant variables in the older people model were also significant in the overall model. The variable coefficient signs were also consistent; just the size of each variable's impact changed, which was reflected in the absolute value of their coefficients. For instance, there was a larger adverse effect of yield signs, railway crossings, and school-zone traffic control devices for older people. The only difference lay in two variables: weather conditions and intersection related. The two variables were significant in the overall model, but not in the older people model. This indicated that driving carefully in bad weather and at intersections did not reduce older people's severe injury risk like it did for younger groups. Moreover, the weather condition coefficient reversed in the older people model. This implies that the chance for older people to get severely injured in a motor vehicle crash increases (although not significantly), despite the fact that older people try to avoid travel in bad weather and drive more carefully in bad weather conditions.

Table 26. HLM Result Output for Level 1 Variables (Older Age Groups)

Fixed Effects	Category	Coefficient	Standard Error	t-Ratio	p-Value
Traffic Control Devices	Yield/RR/School etc.	0.225981	0.031623	7.146	<0.001
	-				
Road Surface Conditions	Wet/ Snow/ Slush/Ice/Sand etc.	-0.061462	0.016231	-3.787	<0.001
Road Defects	Some Defects	0.012925	0.022888	0.565	0.572
Light Conditions	Dawn/ Dusk/ Darkness/ Darkness with Light etc.	0.060404	0.010068	6	<0.001
Weather Conditions	Rain/Snow/Fog/ Hail etc.	0.02578	0.016501	1.562	0.118
Intersection Related	Yes	-0.000447	0.017192	-0.026	0.979
Number of Lanes	0-4				
	More than 4 Lanes	-0.00532	0.008129	-0.654	0.513
Roadway Alignment	Straight and Level	-	-	-	
	Straight on Grade/ Curve etc.	0.022461	0.01041	2.158	0.031
Gender	Male	0.047256	0.006168	7.661	<0.001
	Female				
Vehicle Types	Passenger Car/SUV/Minivan/Pickup	-0.059514	0.007672	-7.757	<0.001
	Truck/ Bus				
Vehicle Defects	No Defects				
	Some Defects	0.115069	0.021463	5.361	<0.001
Time of Crash	Peak Hour	-0.003579	0.005241	-0.683	0.495
	Off Peak Hour				

SUMMARY

The descriptive data analysis found that the percentage of crashes involving older people in total crashes has been increasing over the study period in Illinois. Although the total number of fatalities and A-injuries was stable, fatalities and A-injuries involving older people showed a steady increasing trend. This indicates that older people are more vulnerable than other age groups in motor vehicle crashes, particularly fatal crashes. Moreover, older non-motor-vehicle users are more likely to get injured than older motor vehicle drivers and passengers. Using a reflective light source is more effective in increasing the visibility of older non-motorists. Compared to younger groups, obscured vision adversely impacts older people more when there are parked vehicles and trees/plants on the roadside and when they are blinded by sunlight. Older people’s relative involvement is higher for rear-end, turning, or same-direction sideswipe collisions compared to other collision types. The percentage of older male fatalities among total male fatalities was lower than the percentage of females. This may be because the percentage of older males in the total male population is much lower than females. Most crashes involving older people occurred during daylight in good weather. Driving under the influence is not as big of an issue for older drivers as it is for younger drivers.

The causation analysis found that moving vehicles were the largest vision-obstructing parameter in severe injuries involving older people. Older males were involved in more fatalities than older females, although the older male population is lower than females. The top collision types involving older people were rear-end, turning, and angle for both total crashes and severe crashes. Similar results as the descriptive analysis were obtained. Most total injuries and severe injuries involving older people occurred during daylight in good weather and along straight and level roadways. This may be because older people drive mostly in the daytime and clear weather and most roadways are straight and level in Illinois. Collison types associated with a high number of A-injuries and fatalities included rear-end, turning, angle, and fixed-object collisions. The results of alcohol use were not conclusive, because BAC tests were not performed for most injury crashes; only fatal crashes frequently reported BAC values. Socioeconomic data showed that crashes involving older people had a positive relation with their employment rate and poor population, and a negative relation with their education level and African American and Hispanic populations.

Logistic regression models and hierarchical linear models were employed to analyze crash and socioeconomic data. Overall, the results from the two models were similar and consistent with findings from the causation analysis. The regression analysis showed that median household income, percentage of African Americans, and unemployment rate were negatively associated with severe crash risk involving older people. Both models also found that the higher the average number of people served by one physician, the higher the risk for severe motor vehicle crash injury. Not surprisingly, in dark conditions, along curves, and when driving big trucks or vehicles with defects, severe injury risk increased for older people. During wet or snowy roadway surface conditions, the chance for older people to be involved in severe injuries was lower than when road surfaces were dry. This implies that older people avoided driving during unfavorable roadway surface conditions and when they did, they were more careful and focused on the primary driving task. Severe injury crashes for older people were more likely at locations with traffic control devices such as yield signs, railroad crossing signs, etc.

CHAPTER 6: SENIOR DRIVER SURVEY DATA ANALYSIS RESULTS

Various statistical analyses were performed to examine the survey data distribution as well as their association with crash risk. First, the frequency distributions of survey variables were developed to rank the responses. Then, odds ratios were determined to quantify the association between the occurrence of two responded events, and logistic regression analysis was conducted to model the impacts of survey variables on crashes involving older people. Incomplete responses were removed from the statistical analyses.

FREQUENCY DISTRIBUTION

Table 27 presents the distribution of responses to survey questions on demographic characteristics, physical condition, medication, driving exposure, and driving habit. Most respondents were Caucasian older females aged 65 to 74 with a college education. Most still drove frequently every day, but rarely on high-speed freeways. It was common for older people to experience some mobility difficulty and impairment in their physical condition that needed prescription medications. This may have affected their driving ability adversely, but older drivers were more conservative and DUIs were not a frequent occurrence for them.

Table 27. Response Frequencies

Description		Total
Age	65 to 74	244
	75 to 84	130
	85 or older	38
Gender	Male	188
	Female	226
Difficulty	Using stairs	61
	Walking more than ¼ mile	67
	Carrying heavy objects	117
Roads	Local roads	174
	Highway	155
	Freeway	24
Alcohol	Use alcohol	32
	Not use alcohol	373
Days	Every day	209
	3–5 days	151
	1–2 days	43
Ethnicity	Caucasian	353
	African American	26
	Asian	11
Education	Some college	137
	Up to high school	114
	College degree and above	155
Medication	On medication	130
	Not on medication	168
Impairment	Stiff joints	33
	Trouble seeing	29
	Slower reaction time	44

RANKING

Rankings of different parameters such as driving condition, mobility difficulty, driving ability impairment, near crash, and risk circumstances were performed based on frequency of occurrence from the obtained responses (Table 28 to Table 31). The ranking tables showed that the top driving condition older people try to avoid is bad weather, followed by rush hour and heavy traffic. It makes sense that older people found those driving conditions challenging, because they demand more attention on the driving task compared to clear weather and free-flow conditions. Slow reaction time, stiff joints/muscles, and vision impairments were the most reported driving ability impairments, which are all related to the aging physical conditions of older people. Rear-end and sideswipe were the most-reported collision types older people encountered. This may be due to the slow reaction time and vision impairment associated with older people. Headlight glare at night and speed of drivers were the top-reported risk circumstances, which matched the results from the driving conditions that older people tried to avoid.

Table 28. Ranking Based on Driving Condition That Older People Try to Avoid

Rank	Driving Condition	Total
1	Bad weather	269
2	Rush hour	191
3	Heavy traffic	171
4	Nighttime	165
5	Unfamiliar roads	109
6	Long trips	95
7	High-speed roads	68
8	Left turn across traffic	32
9	Driving alone	21

Table 29. Ranking Based on Driving Ability Impairment

Rank	Driving Ability Impairment	Total
1	Slower reaction time	44
2	Stiff joints and muscles	33
3	Trouble seeing	29
4	Trouble hearing	11
5	Medication	3

Table 30. Ranking Based on Crash or Near-crash Experience

Rank	Crash or Near crash	Total
1	Rear-end	11
2	Sideswipe	11
3	Parked vehicle	7
4	Fixed objects	6
5	Turning	6
6	Angle	6
7	Pedestrian/bicyclist	6
8	Head on	1
9	Overturned	0

Table 31. Ranking Based on Risk Circumstances

Rank	Risk Circumstances	Total
1	Headlight glare at night	172
2	Speed of drivers	125
3	Blind spots	77
4	Short merging/diverging segment	48
5	Blowing materials	25
6	Reading signs	21
7	Left turn at intersections	18
8	Insufficient sight distance	10
9	Small turn radius	3

ODDS RATIOS

Odds ratios were calculated to quantify the association of various variables with four survey parameters: driving difficulty, annual miles travelled, number of days driven per week, and crash/near-crash experience. For simplicity, multiple-level variables were collapsed into binary variables. Table 32 to Table 35 present the odds ratio values.

The results showed that older drivers (age 75 and older) experienced higher driving difficulty compared to younger groups (age 65–74). Older female people faced more difficulty than males when driving. Caucasian older people usually had less difficulty in driving than those of other races. Moreover, older people with higher education reported less diving difficulty.

Table 32. Odds Ratios for Diving Difficulty

Description	High Difficulty	Low Difficulty	Odds Ratios
65 to 74	106	138	0.81
75 or older	82	86	
Male	72	116	0.59
Female	116	110	
Caucasian	156	197	0.84
Other ethnicity	18	19	
Up to high school	9	105	2.00
College	12	280	
Local roads	89	85	1.63
Highway/freeway	70	109	

The odds ratio results for miles travelled annually and the number of days travelled per week matched in most cases, because both variables measured older people's driving exposure. Overall, older Caucasian males with higher education had a higher exposure to motor vehicle traffic. Older people (75 and older) tended to drive fewer miles than younger older people (65–74). Older people who usually drove on freeway/highways were prone to driving more miles but less frequently than those who often used local roads.

Table 33. Odds Ratios for Miles Travelled Annually

Description	Less than 5,000	More than 5,000	Odds Ratios
65 to 74	65	179	0.46
75 or older	74	94	
Male	47	141	0.48
Female	93	133	
Caucasian	114	239	0.50
Other ethnicity	18	19	
Up to high school	55	59	2.47
College	80	212	
Local roads	78	96	2.82
Highway/freeway	40	139	

Table 34. Odds Ratios for Days Driven in a Week

Description	1–2 days	More than 2 days	Odds Ratios
65 to 74	26	218	1.06
75 or older	17	151	
Male	15	173	0.61
Female	28	198	
Caucasian	31	322	0.35
Other ethnicity	8	29	
Up to high school	43	71	6.20
College	26	266	
Local roads	11	163	0.48
Highway/freeway	22	157	

Table 35. Odds Ratios for Near-crash or Crash Experience

Description	Near crash	No-crash experience	Odds ratio
Male	32	95	1.563
Female	25	116	
Warning	11	50	1.418
No warning	45	290	
On medication	27	103	2.328
Not medication	17	151	
Alcohol	10	22	3.153
No alcohol	47	326	
65–74	34	210	1.074
75 or older	22	146	
Caucasian	47	306	0.507
Other ethnicity	10	33	
Up to high school	16	98	0.972
College	42	250	
Local roads	29	145	1.177
Highway/freeway	26	153	

As expected, older males and older people on prescription drugs or with alcohol use experienced more crash or near-crash events. Surprisingly, the results showed that warnings from physicians on the side effects of prescription medicines were associated with more crash or near-crash events among older drivers. The odds ratio results quantified the relationship between selected variables and crash/near-crash experiences but did not provide enough information to determine if any relation with crash/near-crash experiences was statistically significant. Therefore, logistic regression analysis was conducted in the study to further analyze the survey data.

LOGISTIC REGRESSION

Logistic regression models were used to identify significant survey variables on older driver crash/near crash. As mentioned in the Sampling section, a sample size of 1,200 was determined using a proportional sampling technique based on the older male and female populations in each Illinois county. A total of 417 responses were received. Responses with missing data were eliminated from the statistical analysis. Therefore, only 365 responses were usable for the logistic model. The 365 responses were not proportional to the older people population in each subpopulation, as originally designed. The unbalanced data may have caused biased analysis results. To address this issue, sample weights were calculated for each gender and older age group factorial cell (Table 36 and Table 37). The weight of each factorial cell was determined as the product of ratio of the number of received responses over the original sample size and ratio of the original assigned sample size in that factorial cell over the actual received responses in that factorial cell (Figure 39).

$$Weight = \frac{Number\ of\ received\ responses}{Original\ sample\ size} * \frac{Original\ assigned\ sample\ size}{Actual\ received\ responses}$$

Figure 39. Equation. Weight calculation based on received responses.

Source: Johnson (2008)

Table 36. Designed and Received Sample Size

	Sample (1,200)			Received Response (365)		
Description	**Age 65–74**	**Age 75–84**	**85 and older**	**Age 65–74**	**Age 75–84**	**85 and older**
Males	312	167	98	97	56	9
Females	320	181	121	126	56	20

Table 37. Weights Based on Gender and Age Group

	Weight		
Description	**Age 65–74**	**Age 75–84**	**85 and older**
Males	0.978	0.907	3.312
Females	0.772	0.983	1.840

Besides gender and older age groups, other explanatory variables considered in the logistic analysis included ethnicity, education, driving days, miles driven, roadway types, alcohol consumption, medication, and medication warning. The statistical software SAS was employed to run the logistic regression analysis. A new variable W_var was added in the input data and code “weight = W_var” was used in SAS to incorporate the weights in the analysis.

Table 38 presents the logistic regression analysis results. The results revealed that higher exposure led to a high-crash/near-crash risk. People aged 75 or older had less chance of being involved in crashes/near crashes, as they had lower mobility compared to people aged 65 to 74. Older people who drove more days a week, more miles per year, and on local roads had a higher chance of being involved in crashes/near crashes. Those variables, however, were not all statistically significant. The only two significant variables were alcohol consumption and medication use. The results confirmed that alcohol and prescription drug use increased crash/near-crash risk among the older population significantly. Also, the result for medication warning was consistent with that from the odds ratios analysis. A warning of the side effects of prescription drugs increased older people's chances of being involved in crashes/near crashes. However, this effect was only marginal.

Table 38. Survey Data Logistic Regression Analysis Results

Effects	Category	Coefficient	Standard Error	Wald Chi-Square	P value
Gender	Male	0.3051	0.3406	0.8024	0.3704
	Female				
Age Group	65–74				
	75–84	-0.03	0.4046	0.0055	0.9408
	85 and older	0.582	0.4919	1.3998	0.2368
Ethnicity	Caucasian				
	Asian	0.7895	0.9917	0.6338	0.426
	Hispanic	1.9995	1.0911	3.3582	0.0669
	African American	0.8706	0.6739	1.669	0.1964
Education	College degree and above				
	Some college	0.2281	0.3958	0.3322	0.5644
	Up to high school	0.0975	0.4596	0.045	0.8321
Driving Days	Every day	1.4285	0.9209	2.4061	0.1209
	3–5 days	1.3816	0.8976	2.3691	0.1238
	1–2 days				
Miles Driven	Less than 5,000				
	5,000–10,000	0.7576	0.4345	3.0402	0.0812
	10,001–15,000	0.6425	0.5941	1.1694	0.2795
	More than 15,000	0.5859	0.7568	0.5994	0.4388
Roadway Types	Local roads	0.9702	0.6116	2.5165	0.1127
	Highway	0.9492	0.5989	2.5121	0.113
	Freeway				
Alcohol Consumption	Yes	1.2106	0.5234	5.3498	0.0207
	No				
Medication	Yes	0.8081	0.3646	4.9119	0.0267
	No				
Medication Warning	Yes	0.6145	0.473	1.688	0.1939
	No				

Table 39 shows the ranking of prescription medicine reported by survey respondents. Antidepressants and hypertensives were the top prescription drugs used by older drivers, followed by antihistamines and hypoglycemics. Drug-use frequency was not high compared to the total responses. However, considering the significant impact of even a small percentage of use, the adverse impact of medicine cannot be overemphasized. Note that an older driver could be on multiple prescription drugs at the same time. Further investigation is needed to examine the effect of specific medicines or groups of medicine on motor vehicle crash risk involving older people.

Table 39. Ranking of Medication Used by Older People

Description	Frequency	Rank
Antidepressants	38	1
Hypertensive	36	2
Antihistamines	15	3
Hypoglycemic	12	4
Skeletal muscle relaxants	6	5
Opioid and non-steroidal analgesic	5	6
Anticonvulsants	4	7
Benzodiazepines	3	8
Antiparkinsonian agents	3	8
Anti-inflammatory	1	9

SUMMARY

The survey data distribution and ranking were developed, odds ratios of selected pairs of variables were calculated, and logistic regression analysis was performed to test the effects of variables on crash risk among older drivers. The survey found that it was common for older people to experience driving difficulty due to their aging physical conditions, and a large portion of older drivers used prescription drugs on a regular basis. Older people were more comfortable driving on local roads with low traffic volume and speed and tried to avoid driving at night and in bad weather conditions. Collisions involving older drivers were mostly related to low response time and physical impairment. Not surprisingly, crash risk increased as driving exposure increased. Older drivers who drove more days a week and had a higher annual mileage faced a higher chance of being involved in crashes/near crashes. However, the statistical analysis showed this effect was not significant. The only two significant variables found were alcohol and medicine use, which increased crash risk among older drivers. Surprisingly, a physician warning of the side effects of prescription drugs marginally increased older drivers' crash risk. The study also found that Caucasian older drivers were less likely to be involved in motor vehicle crashes compared to other races, but the association between and older people crashes is not significant. In addition, older female drivers and older drivers with a college education faced a lower crash risk, which is consistent with the crash data analysis results.

CHAPTER 7: SUMMARY AND RECOMMENDATIONS

Adults aged 65 or older form a vulnerable population that is susceptible to roadway traffic injuries. Motor vehicle crashes are among the leading causes of unintentional injury deaths for the older population. The fatality rate among older pedestrians, pedalcyclists, and drivers has risen continuously in the United States. Compared to younger people, older people face additional crash risks resulting from aging-related physical/medical conditions and prescription medications. As the older population keeps increasing, agencies are facing more challenges in improving older people's safety. It is critical to understand how demographic characteristics, physical/medical conditions, and driving habits of older people affect their crash risks under different roadway and environmental conditions. Previous research in this regard has been limited. To address this need, IDOT initiated this research study to examine the fatality and severe injury risks of crashes among older people and identify specific areas where crashes may be reduced. To achieve these objectives, the research team conducted a literature review of related studies, descriptive analyses, causation analyses, and statistical analyses using Illinois crash data and county-level socioeconomic data from 2011 to 2016 and a survey of licensed older drivers in Illinois.

Crash data over 2011–2016 were acquired from IDOT and Illinois county-level demographic data, and socioeconomic data over the same study period were retrieved from the US Census Bureau. In addition to screening, joining, and compiling, the data were categorized into different age groups for comparison. Descriptive analyses of the crash data and socioeconomic data were conducted to reveal the relation between crash frequency, type, and severity with roadway geometry, traffic operation, environment, and socioeconomic characteristics. The causation analyses were used to identify conditions where older people were prone to motor vehicle crashes. Further, multiple logistic regression analyses and hierarchical linear model analyses were performed to test if the impacts of crash data variables and socioeconomic variables on severe older people crashes are significant.

To complement the crash data and socioeconomic data, a mail-in survey was conducted to gather information on driving exposure, habits, physical/medical conditions, prescription medicine usage of older drivers in Illinois, along with their perceptions of roadway safety and suggestions to improve safety. The proportional sampling method was employed in identifying mail recipients. Responses were converted into a digital Excel file format and coded before data analyses. Besides frequency analyses of survey response, odds ratio and multiple logistic analyses were conducted to model the association between older driver crash/near crash and different survey variables.

FINDINGS

The findings from each task of the study are listed below:

Literature Review:

1. Motor vehicle crashes among the older population have been extensively researched. Most studies focused on the association between aging-related physical and medical conditions and crashes involving older people.

2. Past studies generally agree that declines in sensory, perceptual, cognitive, motor function, as well as medical conditions and medicine use are highly associated with motor vehicle crashes involving older people.

3. Previous studies were inconsistent on how to define the older population, and research on the impacts of increased mobility needs, driving behaviors/habits, and socioeconomic characteristics on crash risk among older people was rare.

4. No previous research had been done on motor vehicle crashes among the older population in Illinois.

5. Statistical modelling has been largely employed in previous studies to identify contributing factors of motor vehicle crashes. The logistic regression model is one of the most used models. Hierarchical modelling has been used recently to analyze crash data with nested characteristics.

Descriptive Analyses:

6. The percentage of older people in the total number of people involved in crashes has been increasing over the study period in Illinois. Older people are more vulnerable than other age groups in motor vehicle crashes, particularly fatal crashes.

7. Using reflective material or a light source is effective in increasing older non-motorists' visibility. Compared to younger groups, obscured vision adversely impacts older people more when there are parked vehicles and trees/plants on the roadside and when they are blinded by sunlight.

8. Older people's relative involvement is higher for rear-end, turning, or same-direction sideswipe collisions compared to other collision types. Most crashes involving older people occurred during daylight in good weather. DUIs were not a frequent occurrence for older people.

Causation Analyses:

9. Moving vehicles were found to be the largest vision-obstructing parameter in severe injuries involving older people.

10. Older males were involved in more fatalities than females, although the older male population is lower than the female.

11. Top collision types involving older people were read-end, turning, and angle collisions for both total crashes and severe crashes. Most total injuries and severe injuries among the older population also occurred during daylight in good weather and along straight and level roadways. This may be because older people drive mostly in the daytime and clear weather and most roadways are straight and level in Illinois.

12. Crashes involving older people had a negative relationship with African American and Hispanic populations and older people education level, and a positive relationship with older population under poverty level and older people employment rate.

Multiple Logistic Regression Analyses:

13. Median household income, percentage of African Americans, and unemployment rate were negatively associated with severe crash risk involving older people.

14. The higher the average number of people served by one physician, the higher the risk for severe motor vehicle crash injury. Severe injury risk increases for older people in dark conditions, along curves, and when driving vehicles with defects.

15. At wet or snowy roadway surface conditions, the chance for older people to get severe injuries is lower than at dry surfaces. This outcome is likely a result of older people avoiding driving during unfavorable roadway surface conditions.

16. Significantly higher number of severe older people crashes occurred at locations with yield signs and railroad crossing sings compared to locations with no traffic control devices.

Older Driver Survey:

17. It is common for older drivers to experience driving difficulty and take prescription drugs.

18. The reported risk circumstances include headlight glare, high speed, insufficient sight distance, short merging/diverging segment, blowing material, reading signs, left turn at intersections, and small turn radius.

19. Medicine use significantly increases older drivers' crash/near-crash risk, but a physician warning of the side effects of prescription drugs marginally increases older drivers' crash risk.

20. Crash risk increases as driving exposure increases. To reduce crash risk, older drivers tend to drive on local roads with low traffic volume and speed and try to avoid driving at night and in bad weather conditions.

21. Consistent results were obtained regarding the impacts of gender and education on crash risk. As for race, the survey study found that Caucasian older drivers are less likely to be involved in motor vehicle crashes compared to other races.

In conclusion:

- Motor vehicle crashes among the older population are affected by several factors related to the roadway, traffic, environment, vehicles, socioeconomic characteristics, and older people themselves. To address these issues, collaborative efforts are needed by multiple stakeholders, including health care providers, the general public, and older people.

- Per findings 9, 12, and 19, the roadway and traffic sign design guides appear to not fully consider the older population's special needs due to the declines in their sensory, perceptual, cognitive, and motor function.

- Per findings 7, 17, and 21, reduced severe motor vehicle crashes among the older population are achievable through enhancing the traffic control at high-risk locations and reducing the exposure of older drivers.

RECOMMENDATIONS

Considering the crash data statistical analysis and older driver survey results, several observations and suggestions related to design guides, traffic control devices, and safety culture were offered.

Design Guides

- Longer perception and reaction times, longer gaps, as well as longer diverging/merging segments can be considered in roadway geometric design guides. This will help reduce the number of older people who are involved in rear-end, turning, and angle crashes.

- Provisions on street parking and roadside clear zones can be revisited and revised to restrict on-street parking further away from intersections as well as provide longer non-street parking zones and wider clear zones. This will help reduce collisions with fixed objects and parked motor vehicles.

- Larger font can be considered for traffic signs to increase their visibility to older people.

Traffic Control Devices

To improve the effectiveness of traffic control devices, the findings of this research suggest the following procedure could identify target locations and countermeasures.

1. Identify locations with traffic control devices (particularly yield sign and rail crossing sign locations) for severe crashes involving older motorists, pedestrians, and pedalcyclists within the past five years.

2. Gather all related information, including device type, design, location, crash type, severity, frequency, as well as roadway and weather condition at the time of the crash, etc.

3. Follow the HSM Chapter 4 Network Screening procedure to conduct field reviews, develop collision diagrams and site condition diagrams, and check the warrants of the traffic control devices.

4. Conduct a diagnosis analysis to identify issues with traffic control devices that contributed to severe crashes involving older motorists, pedestrians, and bicyclists.

5. Suggest corresponding countermeasures. Possible improvements include using signal control instead of stop or yield signs or protected left turns instead of permitted left turns,

using older people's walking speed to design traffic signals, as well as adding a bicycle face head or phase in the signal device and phasing design.

Safety Culture

- Initiate campaigns, outreach programs, public service announcements, or education programs to help form a safety culture that respects older motorists, pedestrians, and pedalcyclists.

- Campaigns should be focused towards the demographics overrepresented in the crash data, such as older males, older people with only up to high school education, low-income communities, and older people who are still employed.

- Campaign/program materials could include some basic statistics on crashes involving older people, as well as patterns, trends, high-risk situations, and tips to reduce crash risks. These could include:

    - Taking routes with minimized left turns
    - Avoiding driving alone
    - Avoiding peak traffic hours
    - Avoiding routes with heavy traffic
    - Avoiding routes with high-speed traffic
    - Avoid traveling during inclement weather, dusk/dawn, and nighttime
    - Choose familiar local roads when possible.

LIMITATIONS

- A list of drugs was developed based on older drivers' survey responses. However, the effect of specific medicines or groups of medicine on older people's crash risk was not investigated because no medical data linked to crash data were available.

- Public transportation reduces the exposure of older people (motorists, passengers, pedestrians, pedalcyclists, etc.) to live traffic. However, this study did not examine the impact of public transportation use on older people safety due to lack of transit ridership data.

- Data were not available to calculate safety performance functions. As a result, specific countermeasures, including the related crash modification factors, could not be evaluated.

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APPENDIX A: DESCRIPTIVE CRASH DATA ANALYSIS (BY YEAR)

A-01: Year 2012

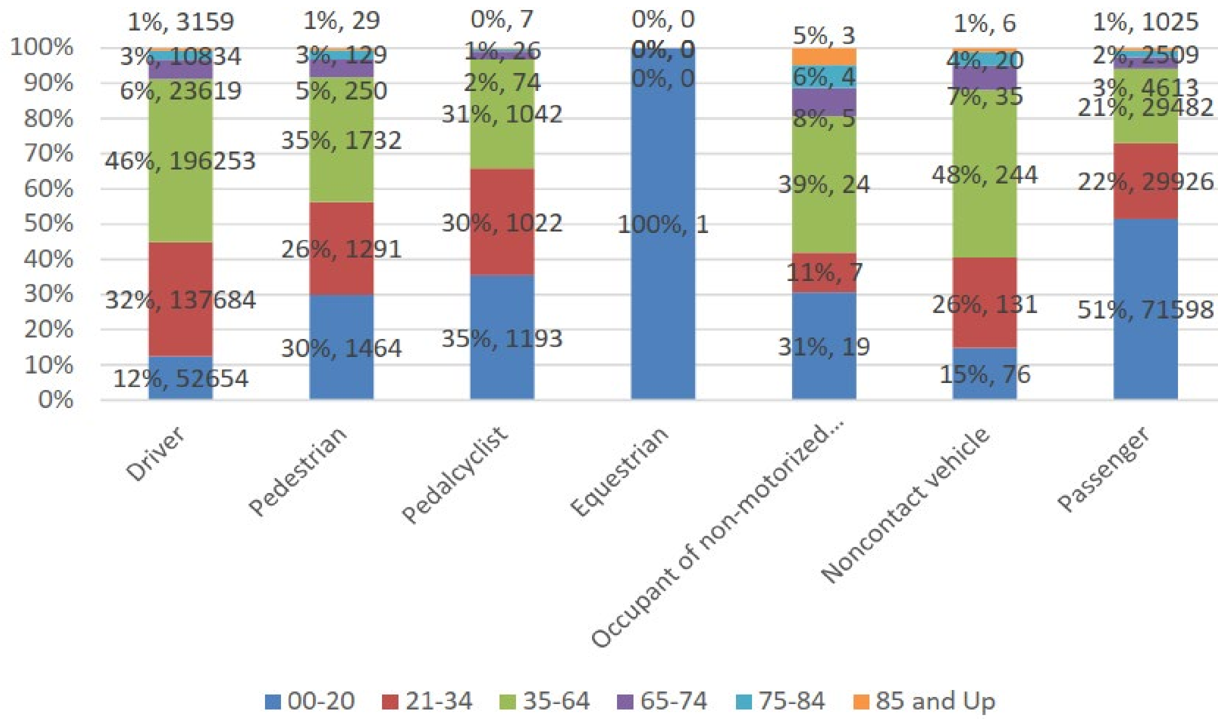


Figure 40. Chart. Type of person vs. age group (2012).

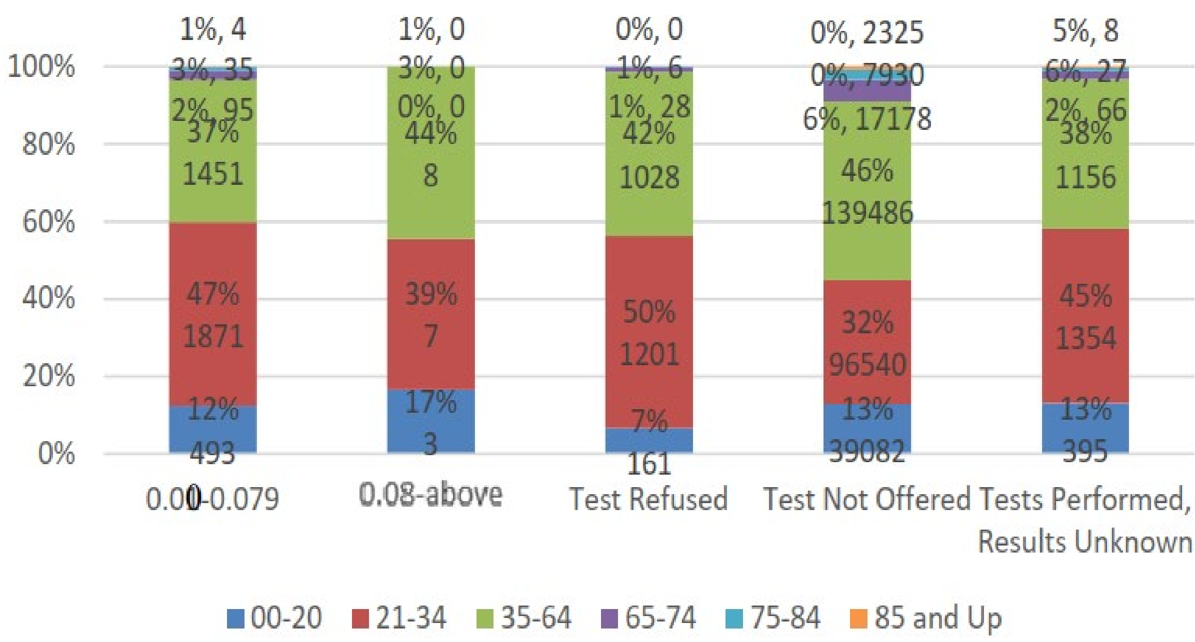


Figure 41. Chart. BAC vs. age group (2012).

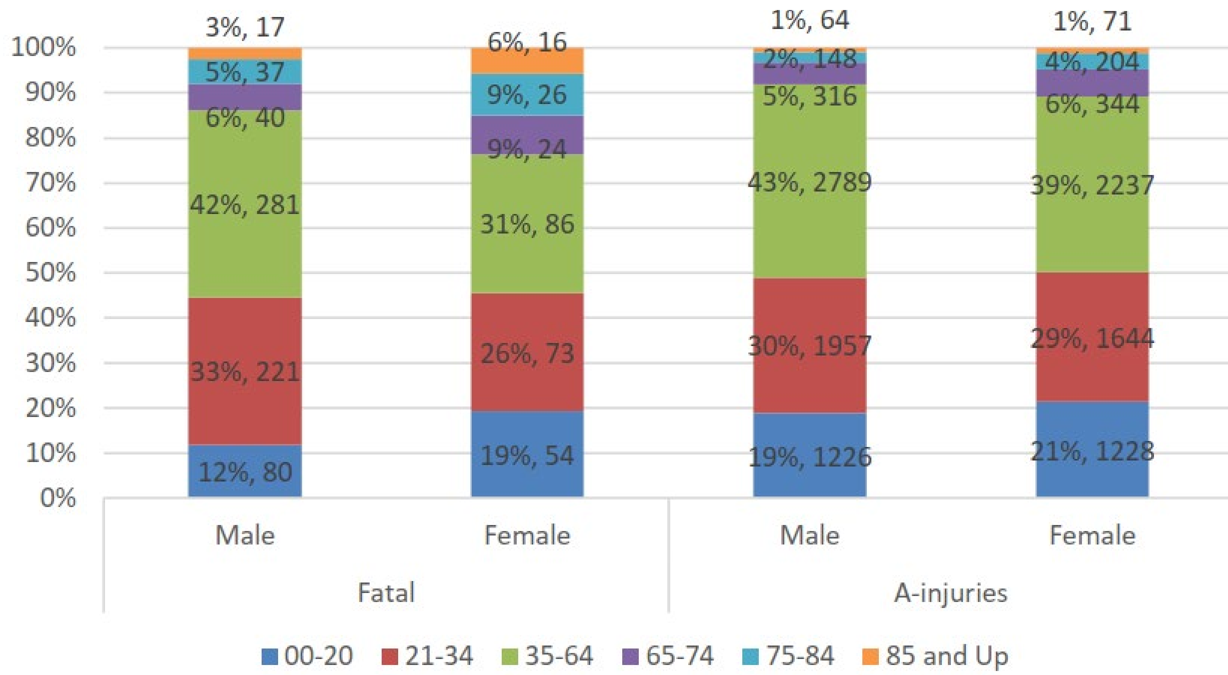


Figure 42. Chart. Crash severity by gender vs. age group.

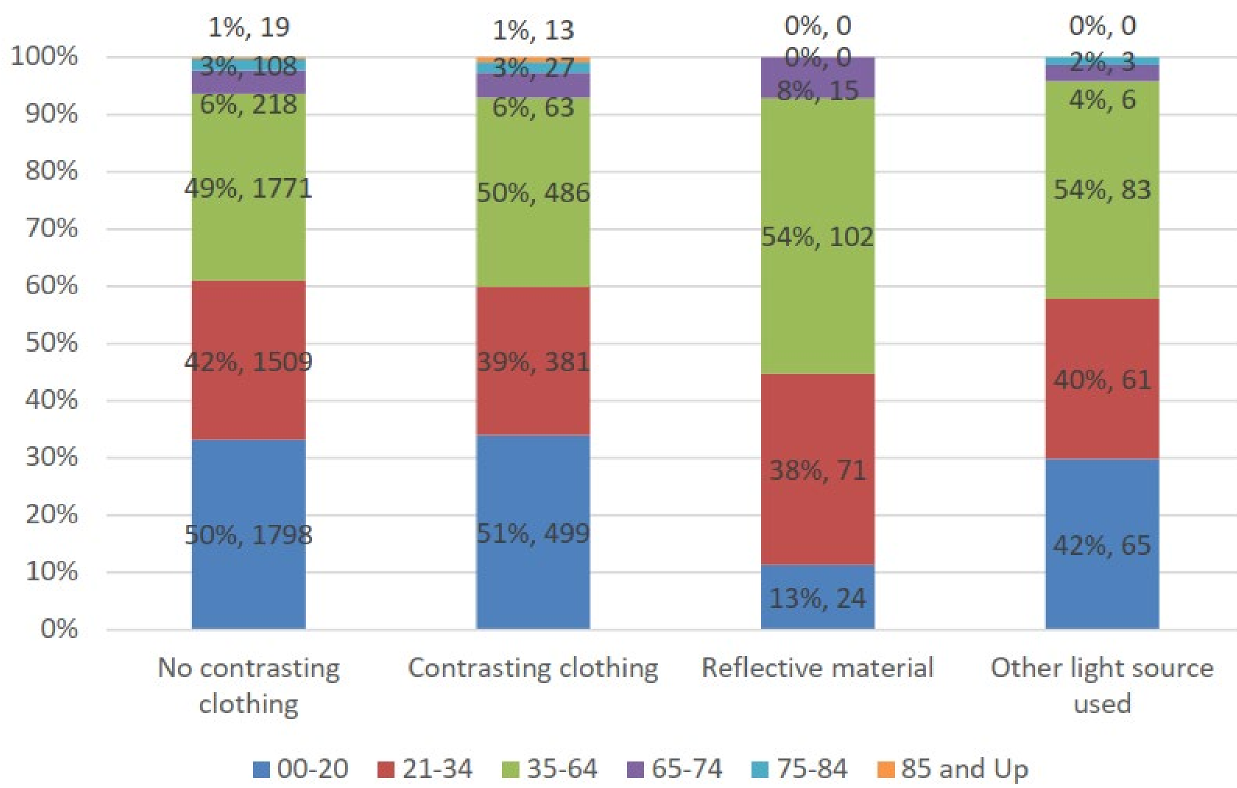


Figure 43. Chart. PEDV by age group (2012).

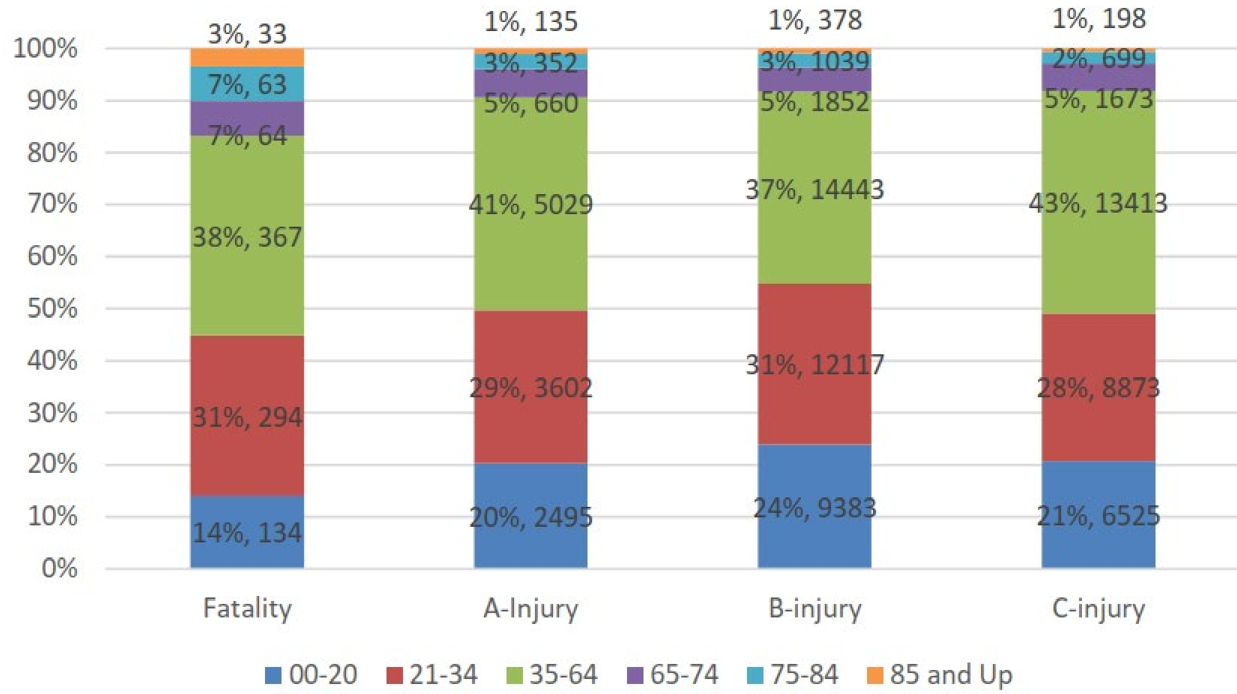


Figure 44. Chart. Injury class vs. age group.

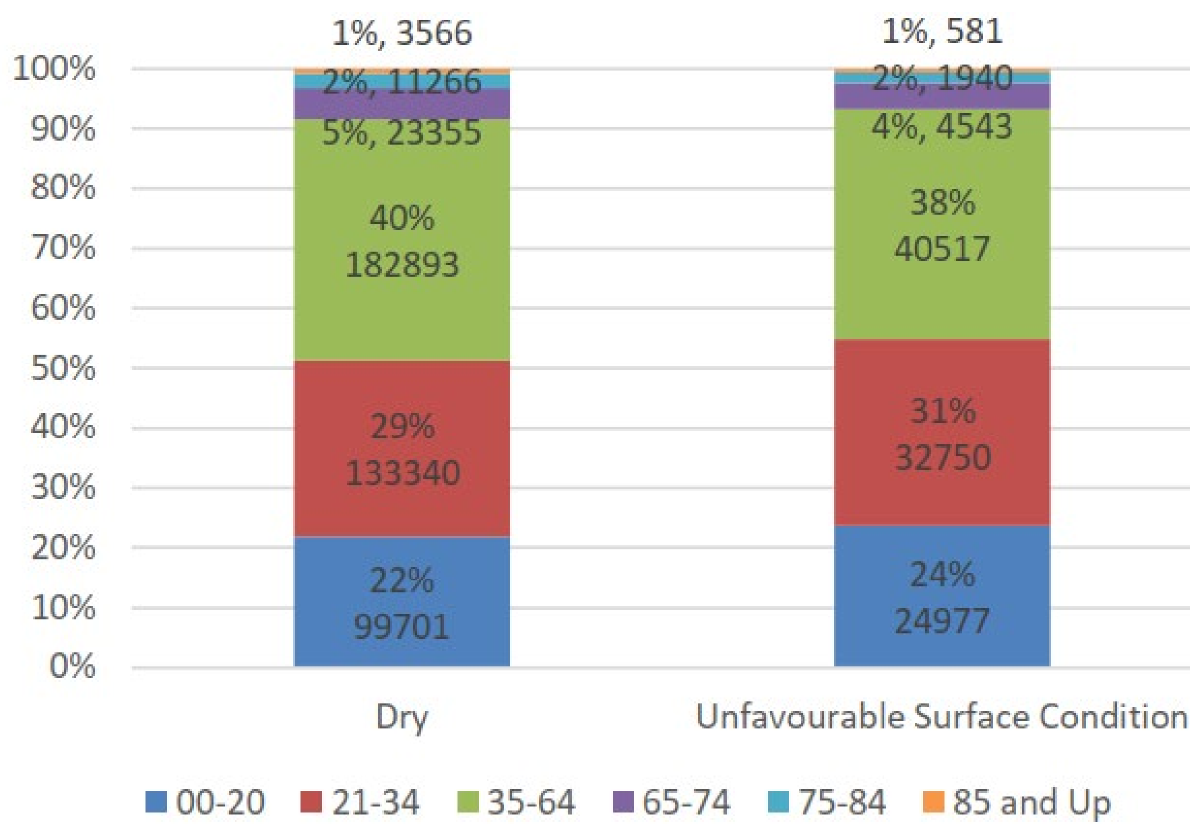


Figure 45. Chart. Surface condition vs. age group (2012).

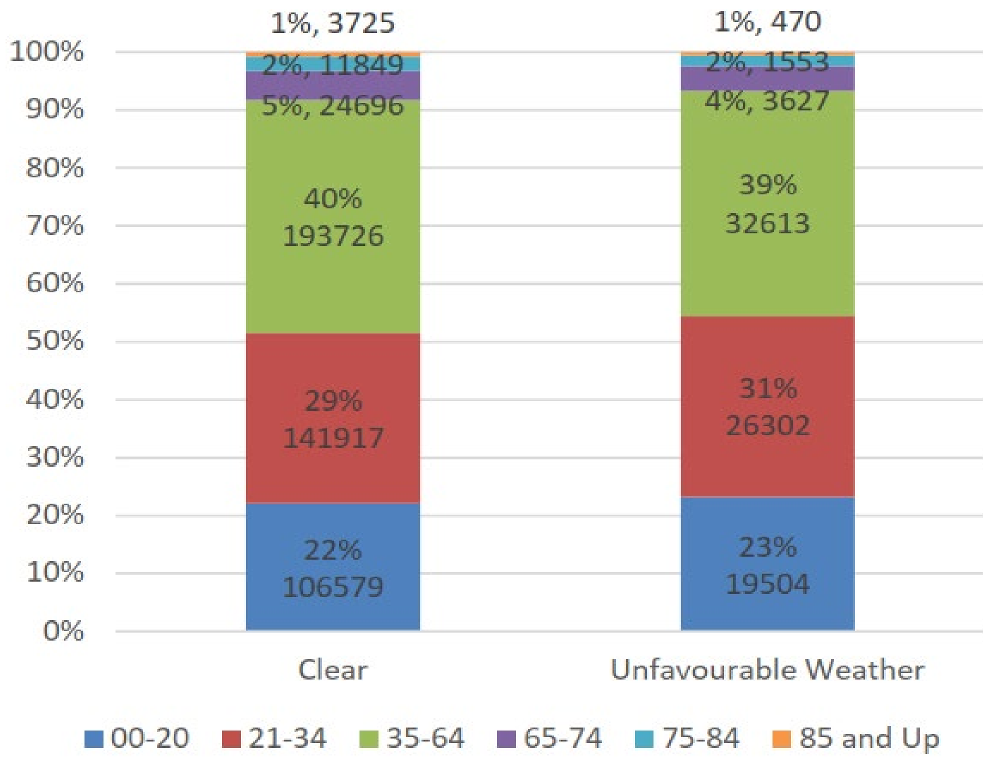


Figure 46. Chart. Weather condition vs. age group.

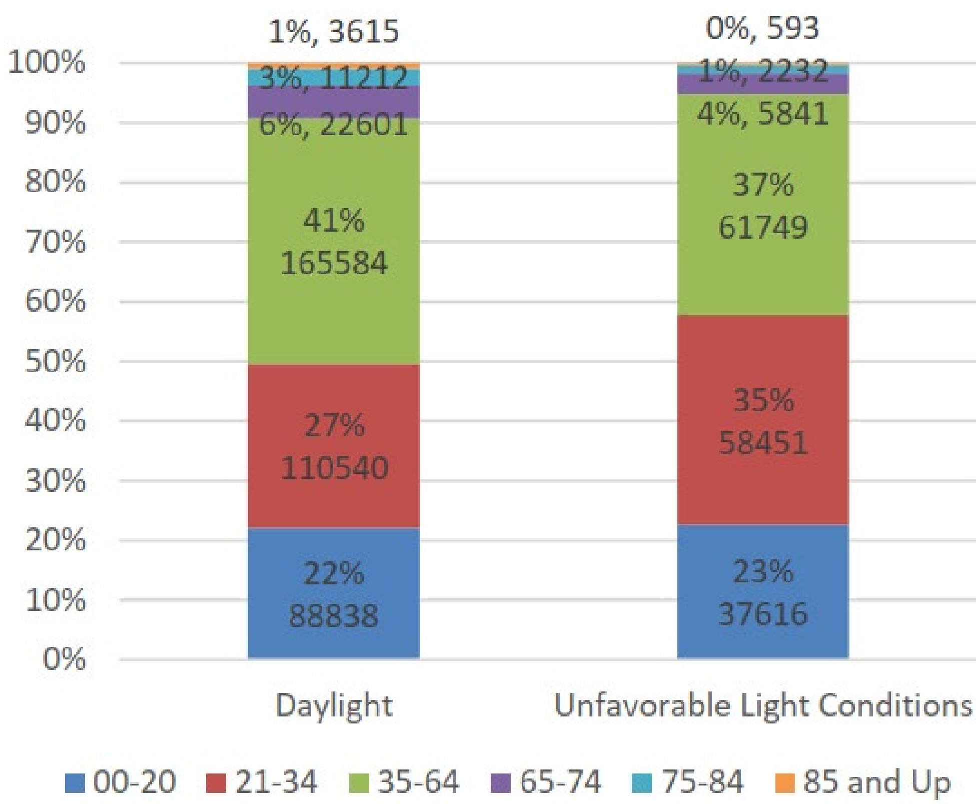


Figure 47. Chart. Light condition vs. age group (2012).

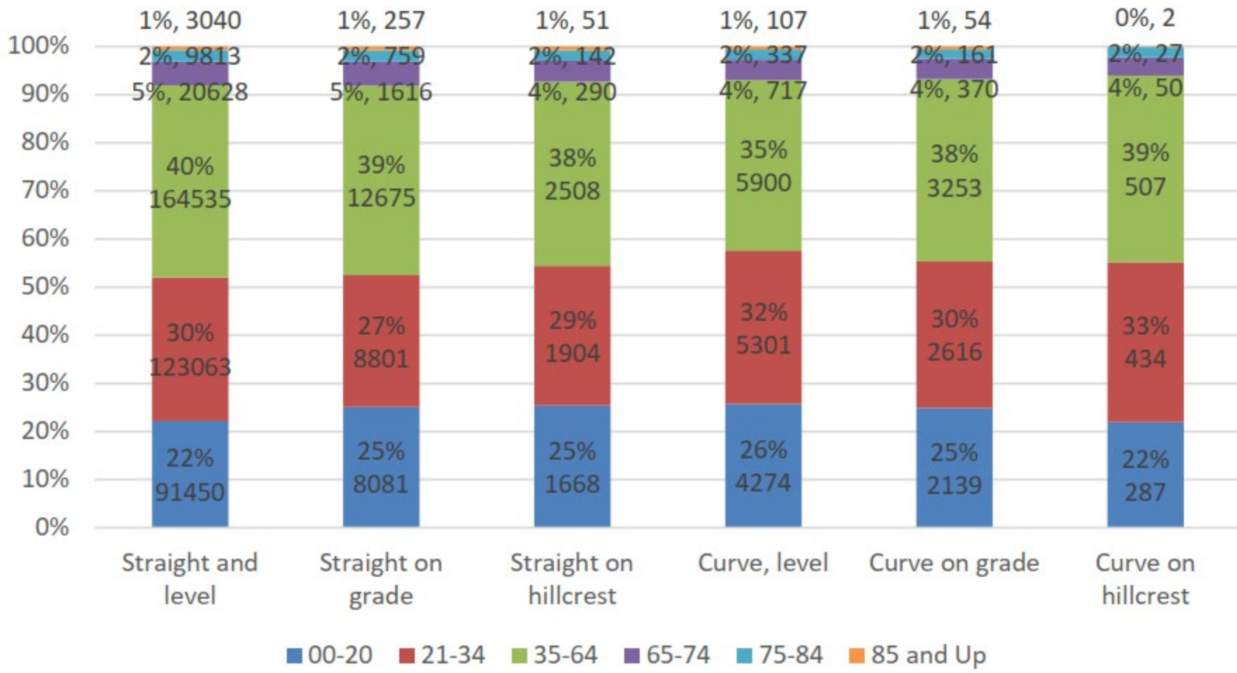


Figure 48. Chart. Alignment condition vs. age group.

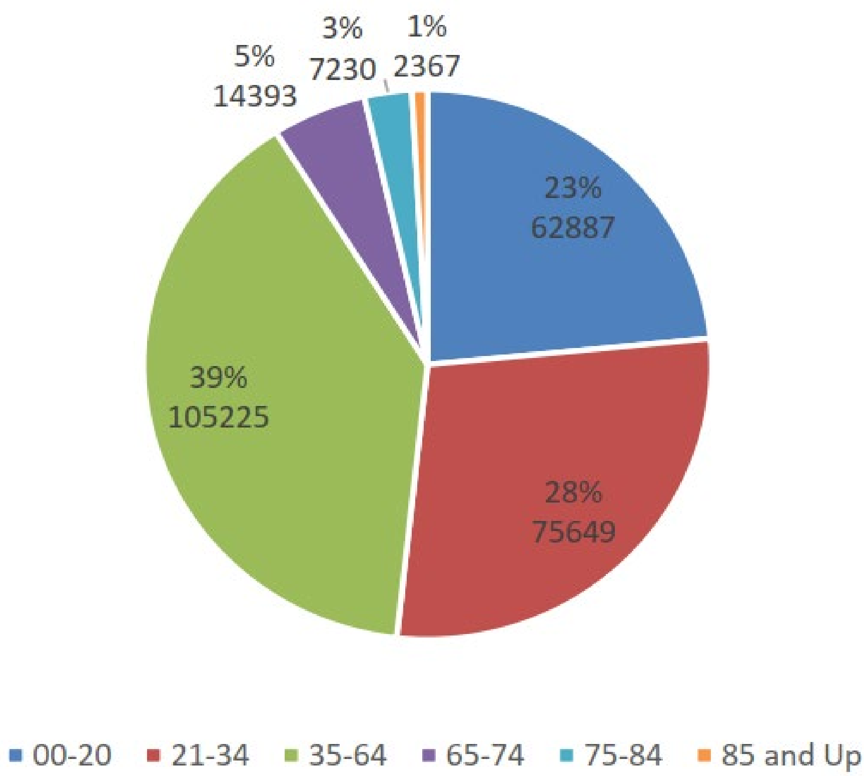


Figure 49. Chart. Intersection-related crashes vs. age group.

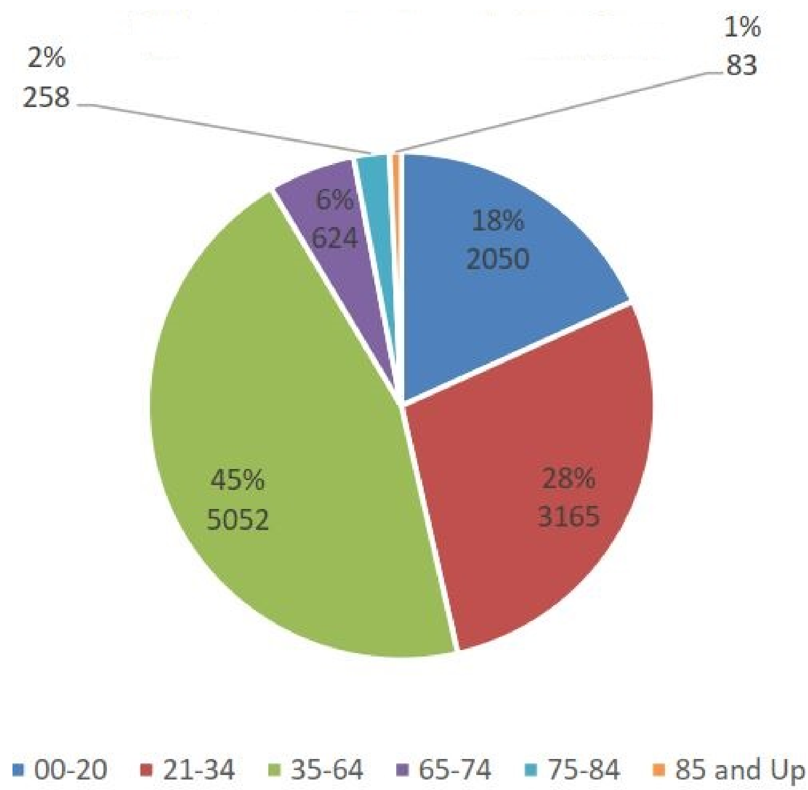


Figure 50. Chart. Work-zone-related crashes vs. age group (2012).

A-02: Year 2013

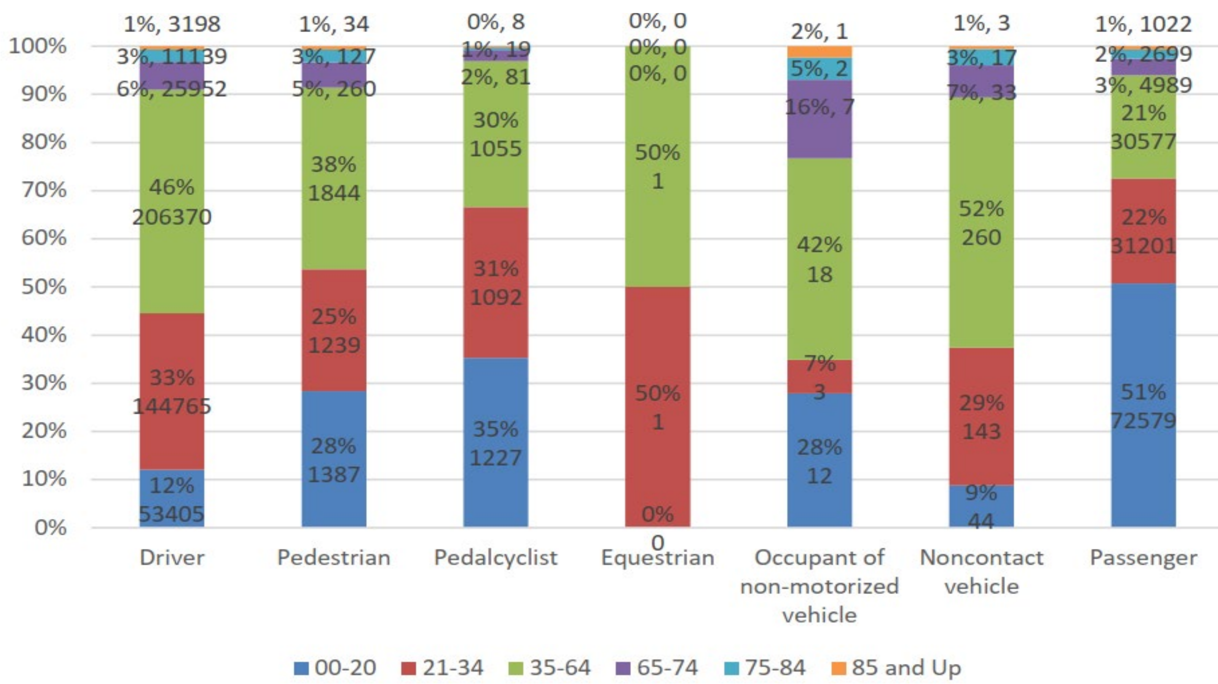


Figure 51. Chart. Type of person vs. age group (2013).

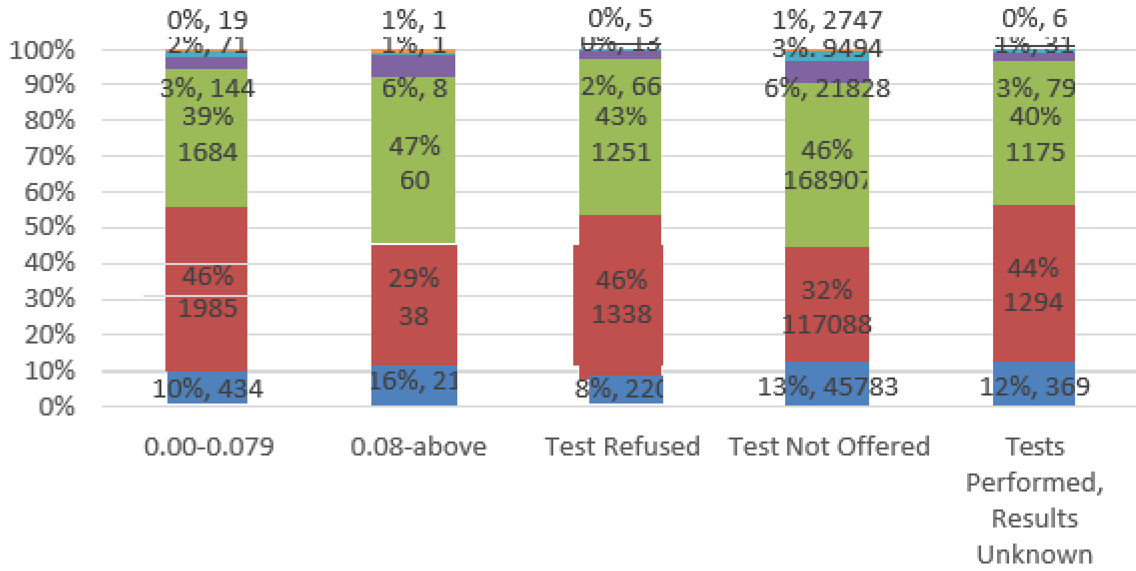


Figure 52. Chart. BAC vs. age group (2013).

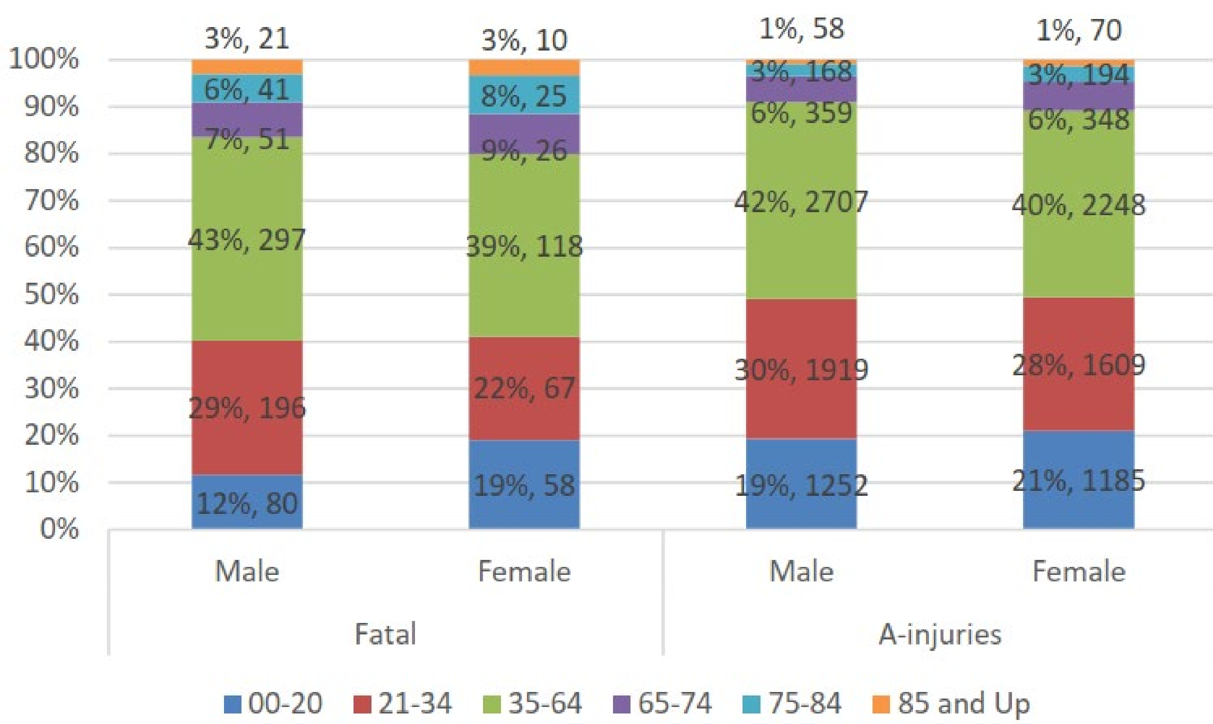


Figure 53. Chart. Crash severity by gender vs. age group (2013).

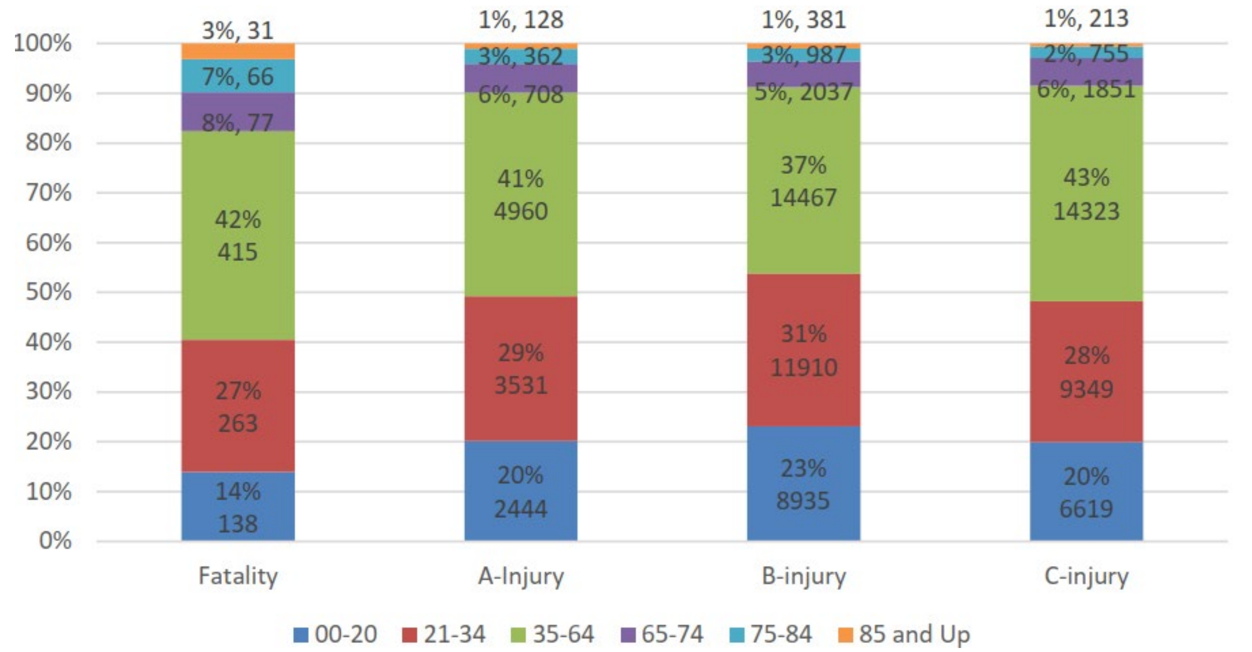


Figure 54. Chart. Injury class vs. age group (2013).

A-03: Year 2014

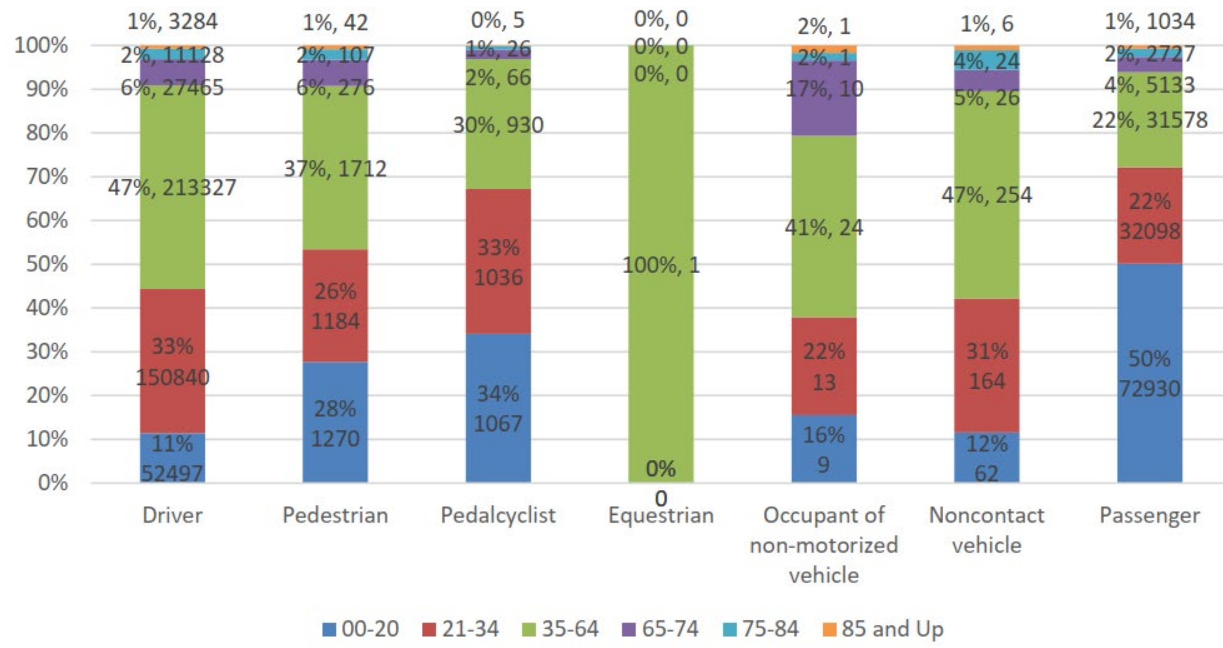


Figure 55. Chart. Type of person vs. age group (2014).

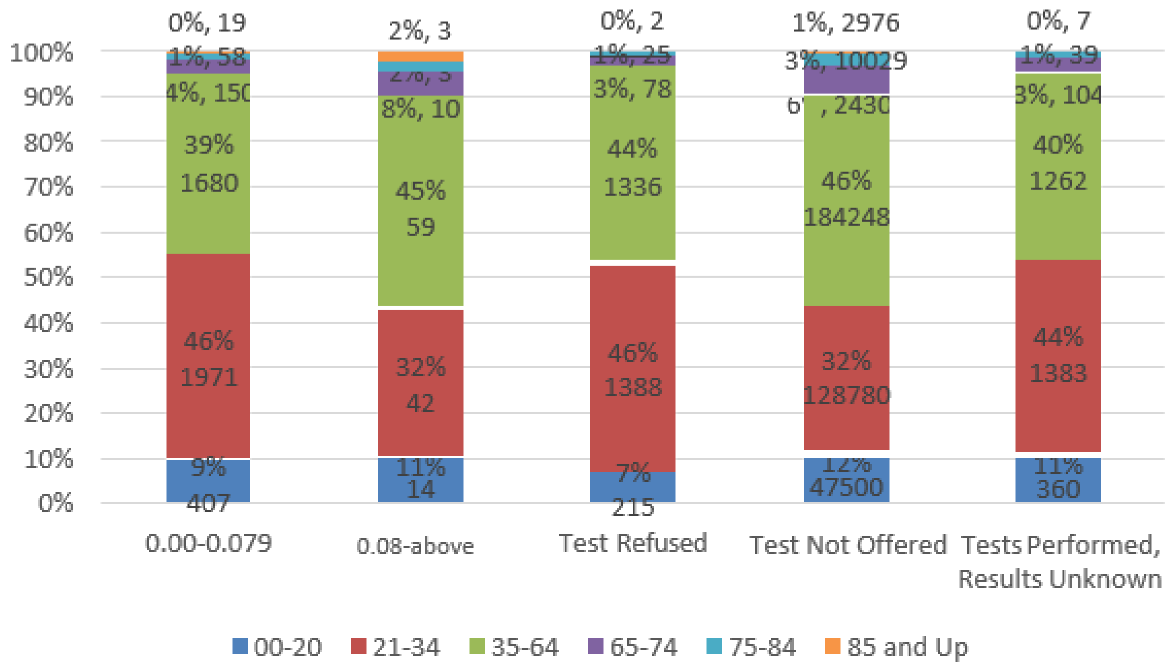


Figure 56. Chart. BAC vs. age group (2014).

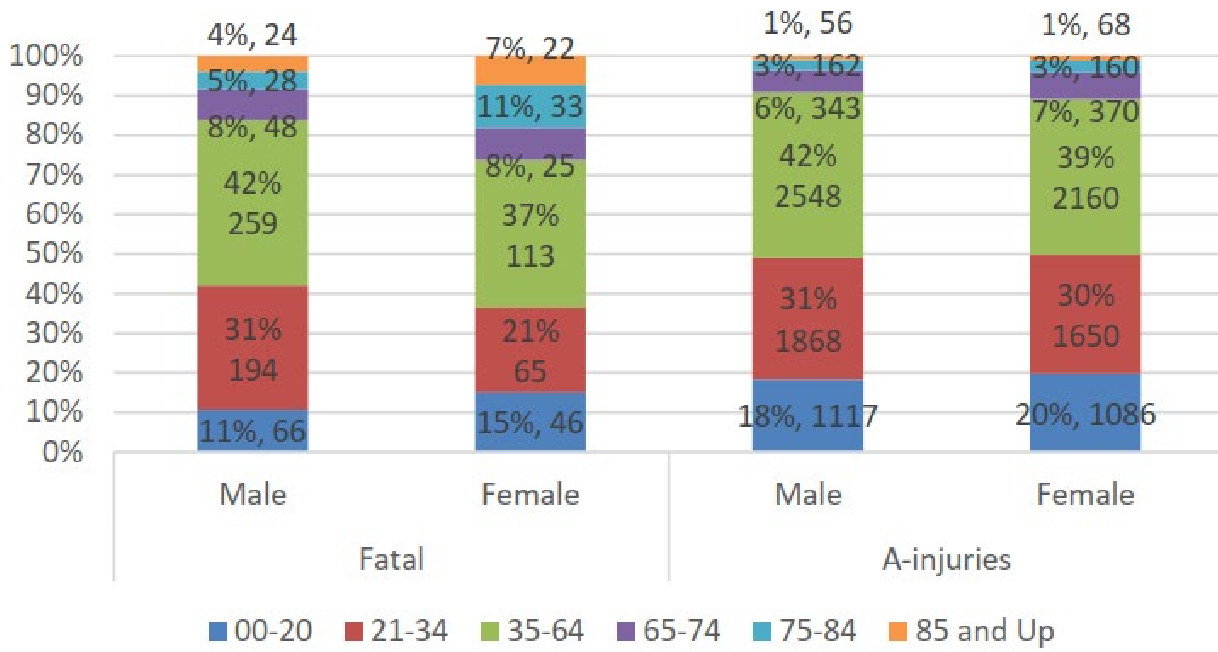


Figure 57. Chart. Crash severity by gender vs. age group (2014).

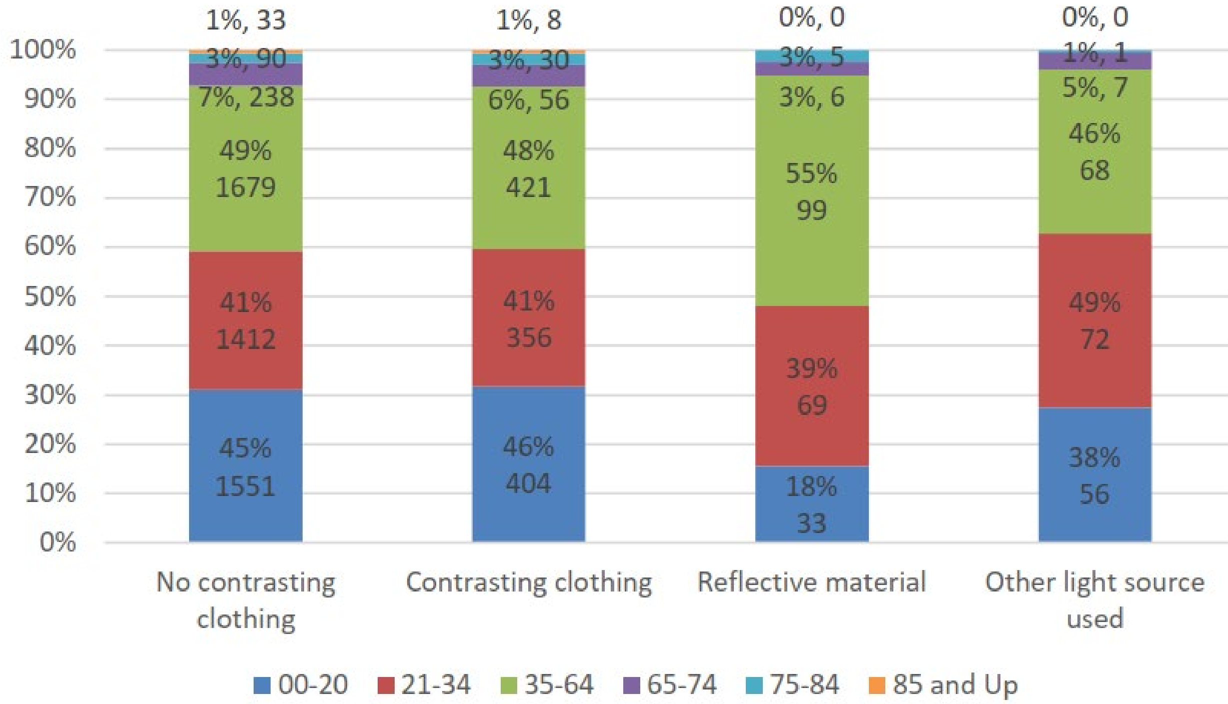


Figure 58. Chart. PEDV vs. age group (2014).

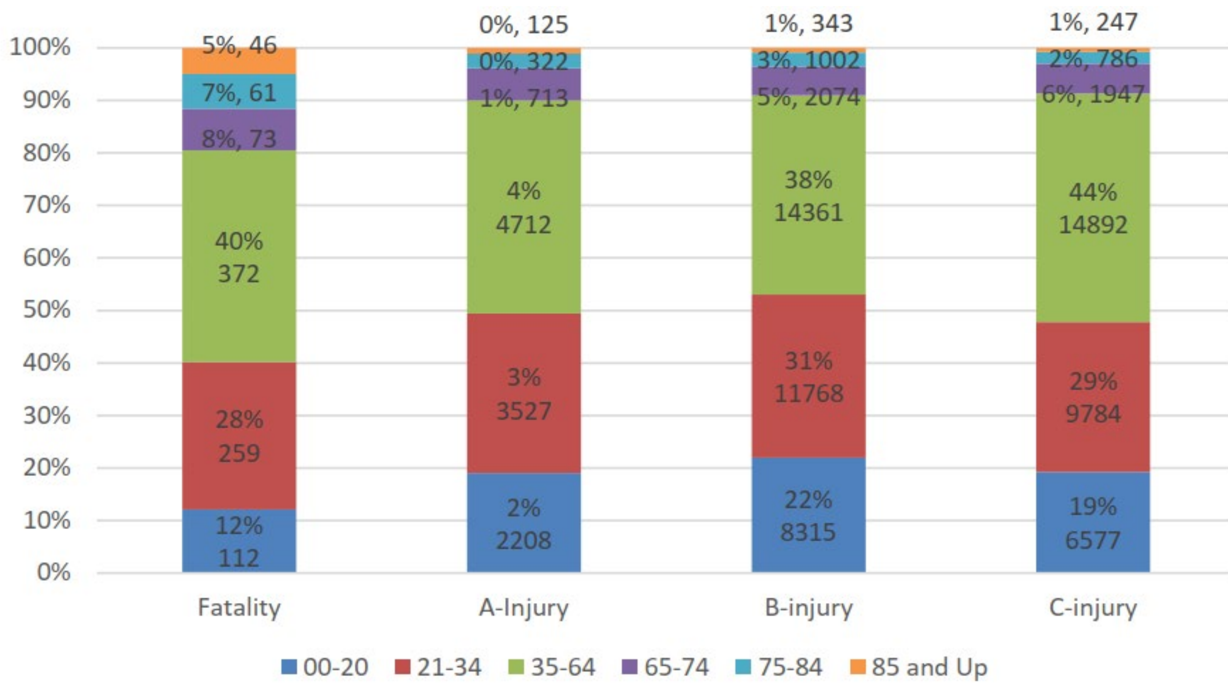


Figure 59. Chart. Injury class vs. age group (2014).

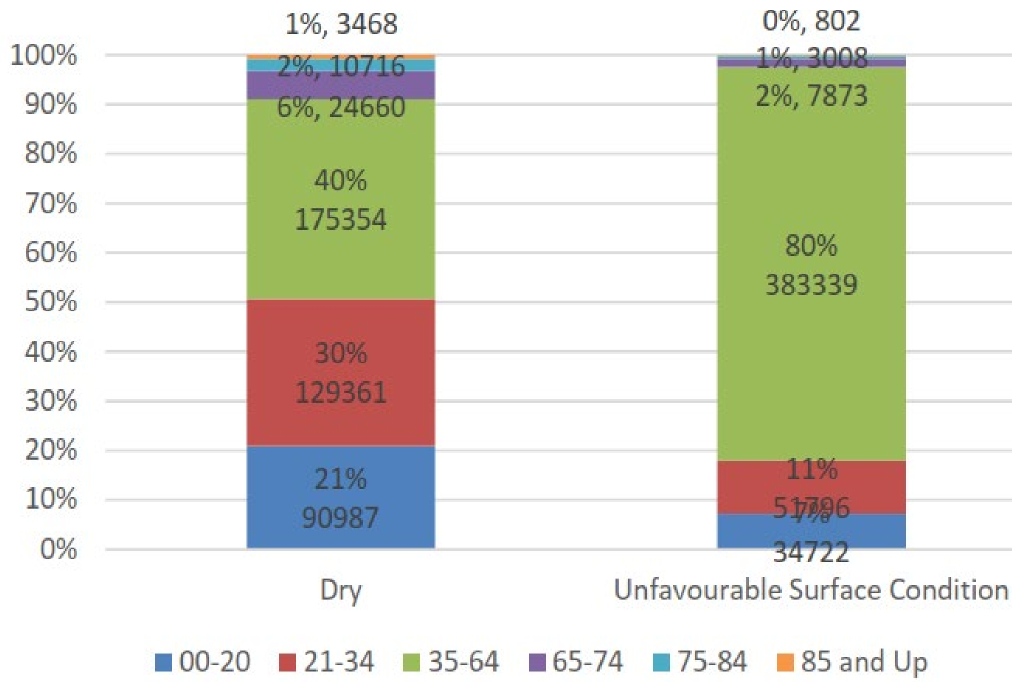


Figure 60. Chart. Surface condition vs. age group (2014).

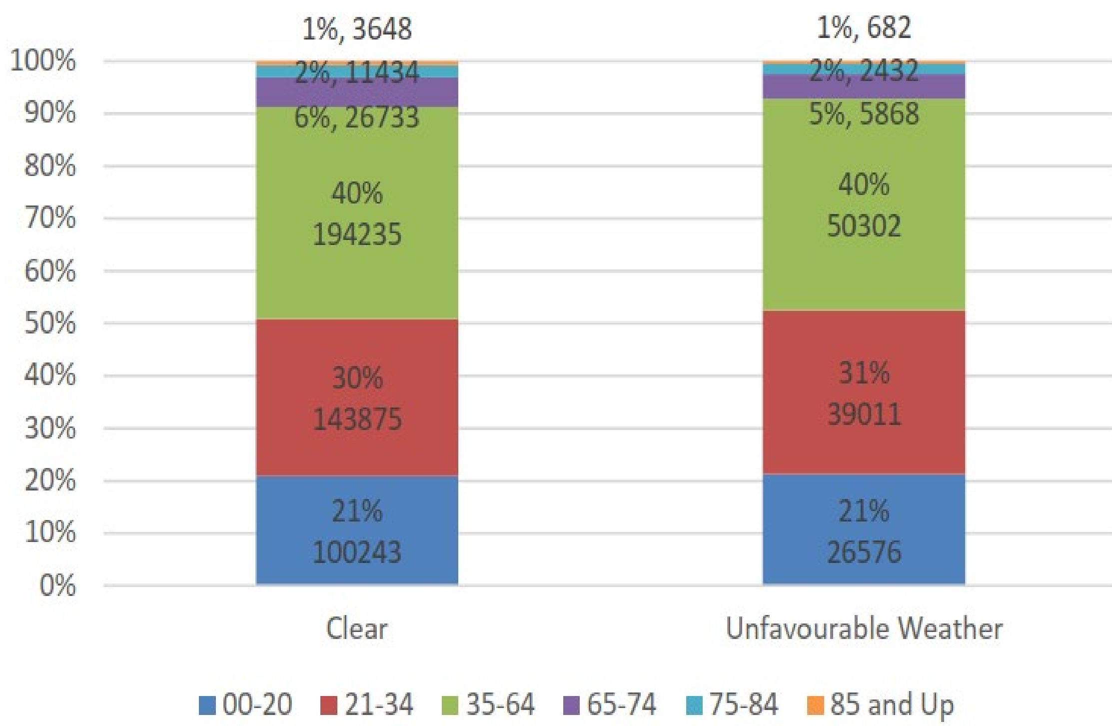


Figure 61. Chart. Weather condition vs. age group (2014).

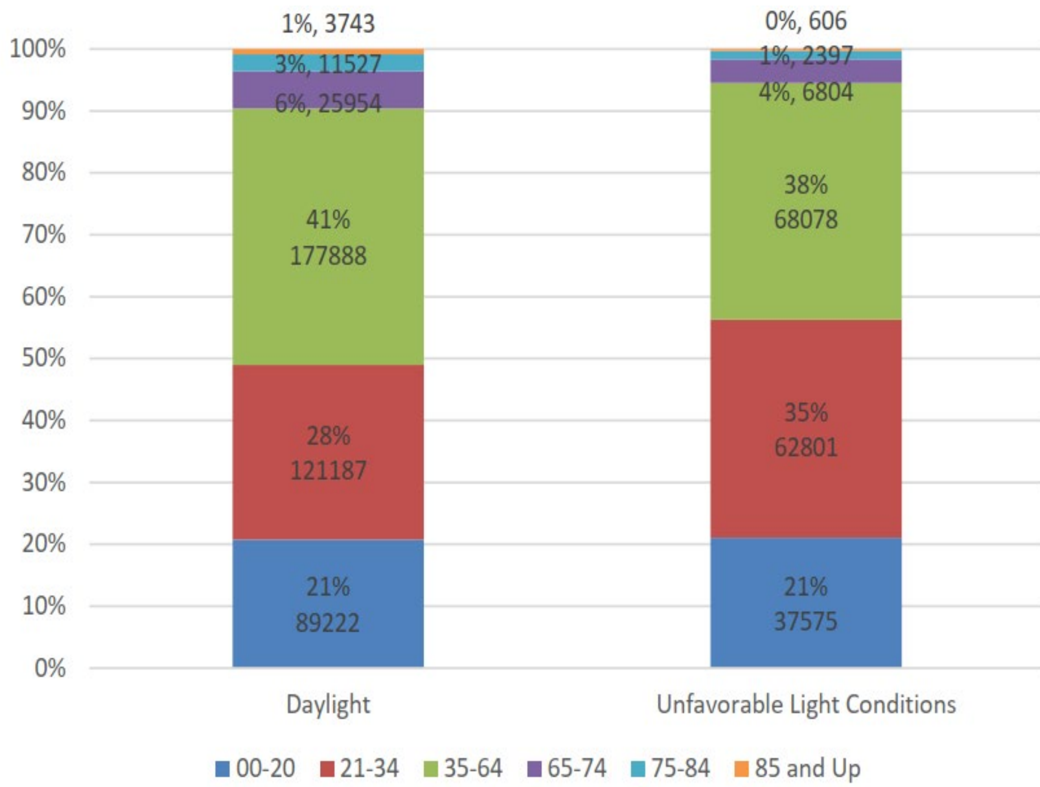


Figure 62. Chart. Light condition vs. age group (2014).

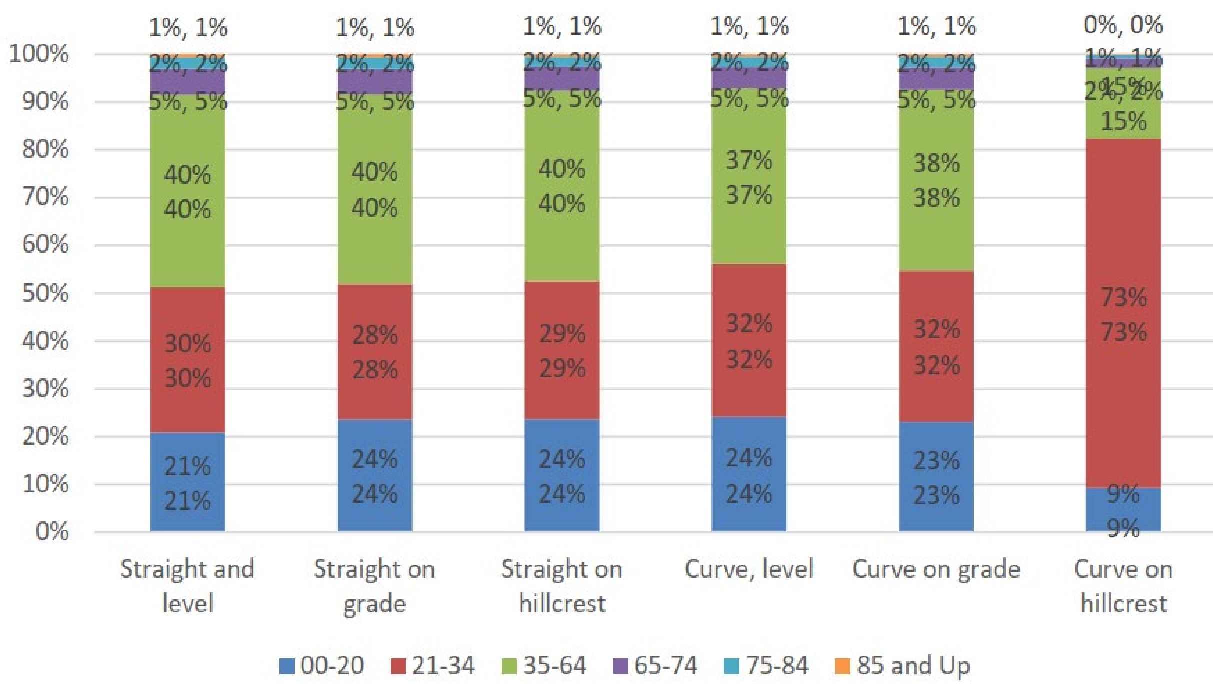


Figure 63. Chart. Alignment condition vs. age group (2014).

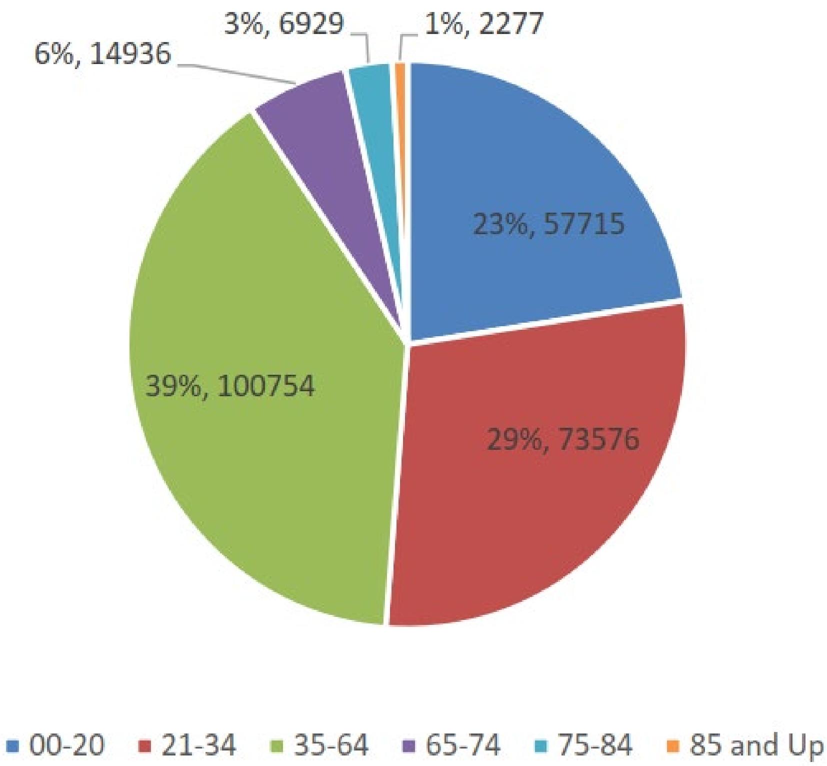


Figure 64. Chart. Intersection-related crashes vs. age group (2014).

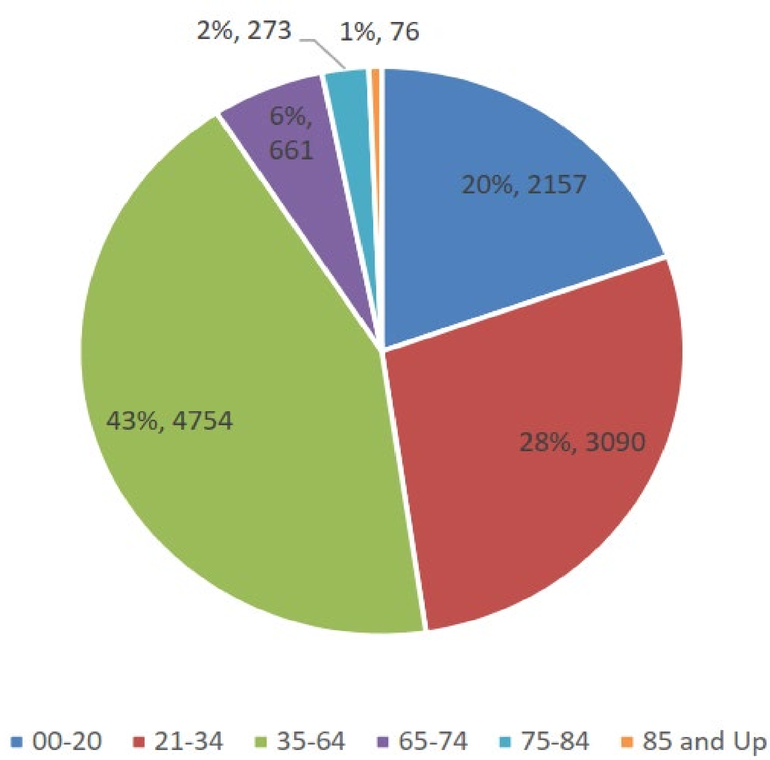


Figure 65. Chart. Work-zone-related crashes vs. age group (2014).

A04: Year 2015

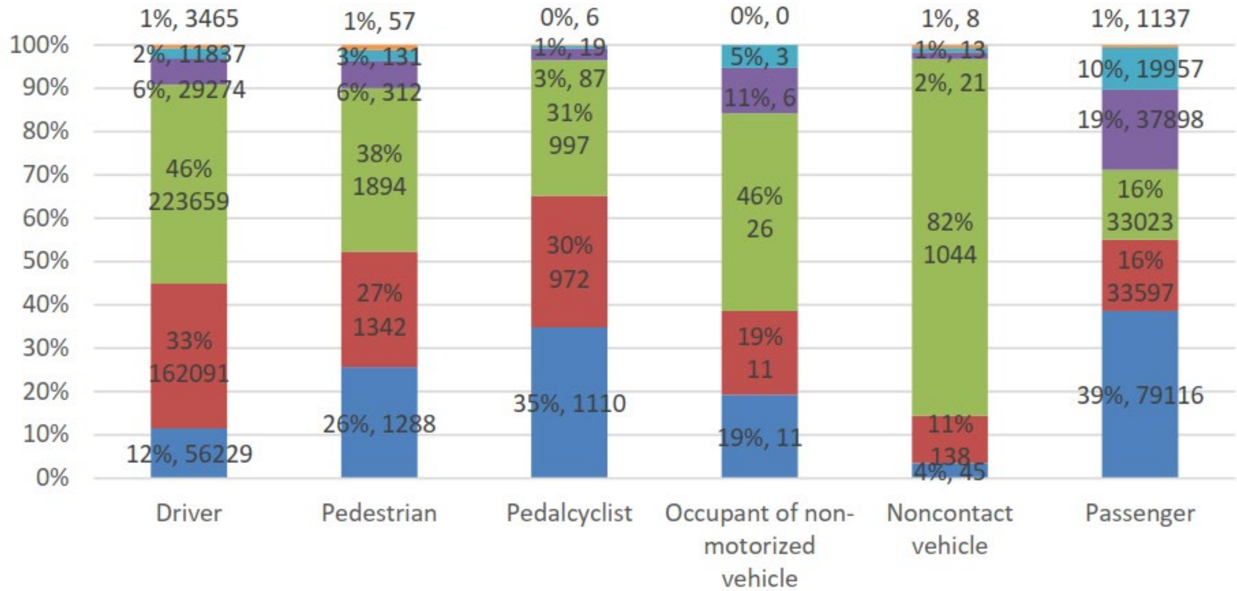


Figure 66. Chart. Type of person vs. age group (2015).

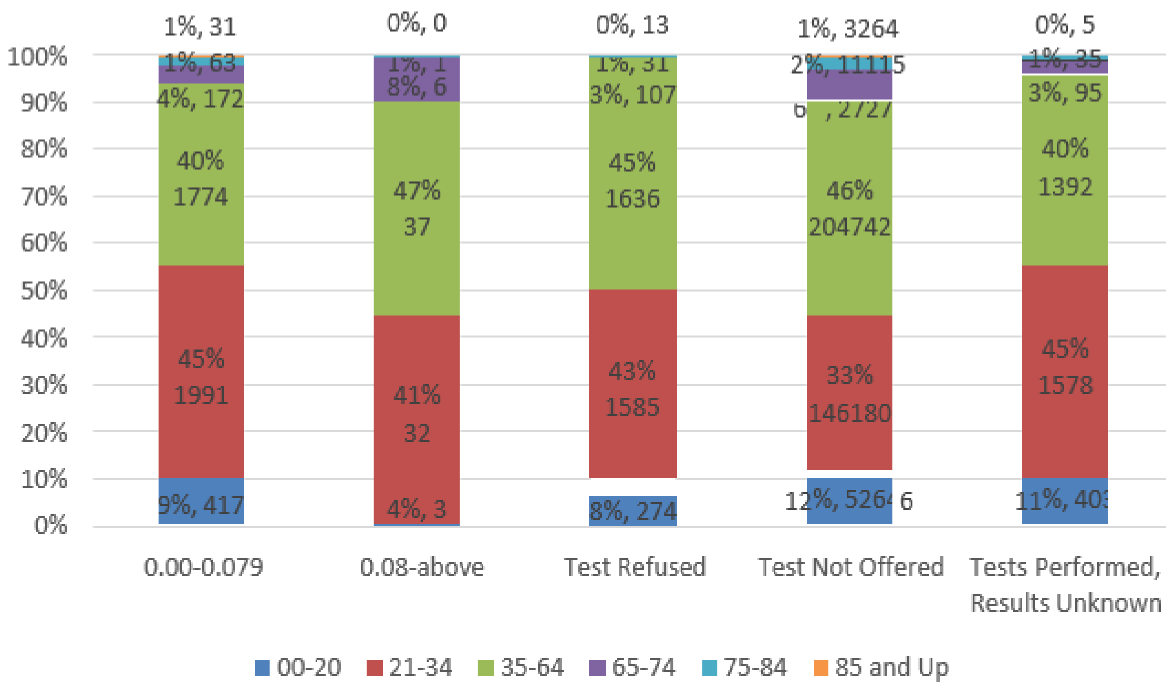


Figure 67. Chart. BAC vs. age group (2015).

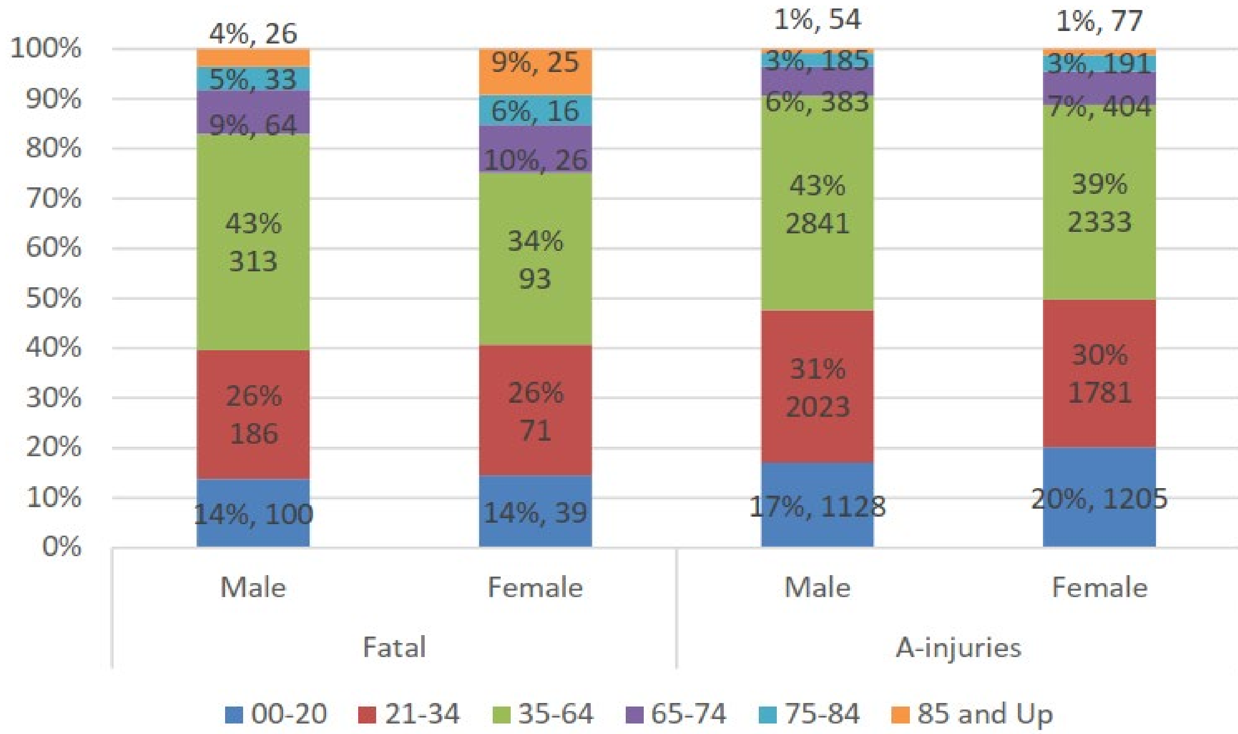


Figure 68. Chart. Crash severity by gender vs. age group (2015).

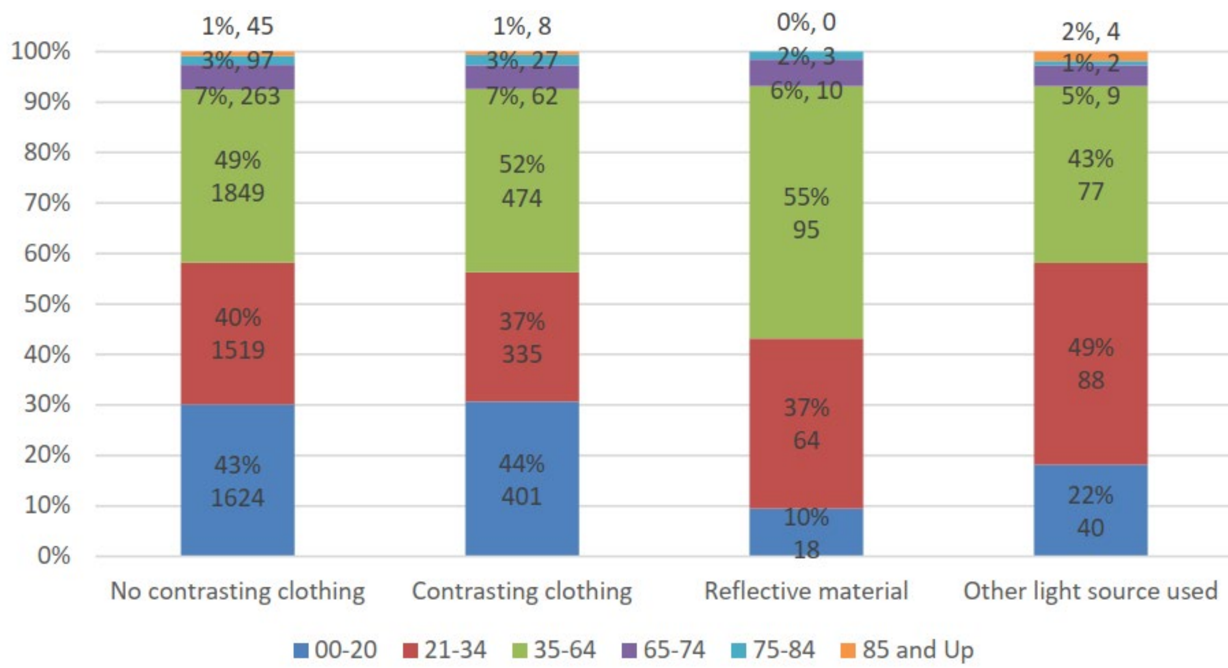


Figure 69. Chart. PEDV vs. age groups (2015).

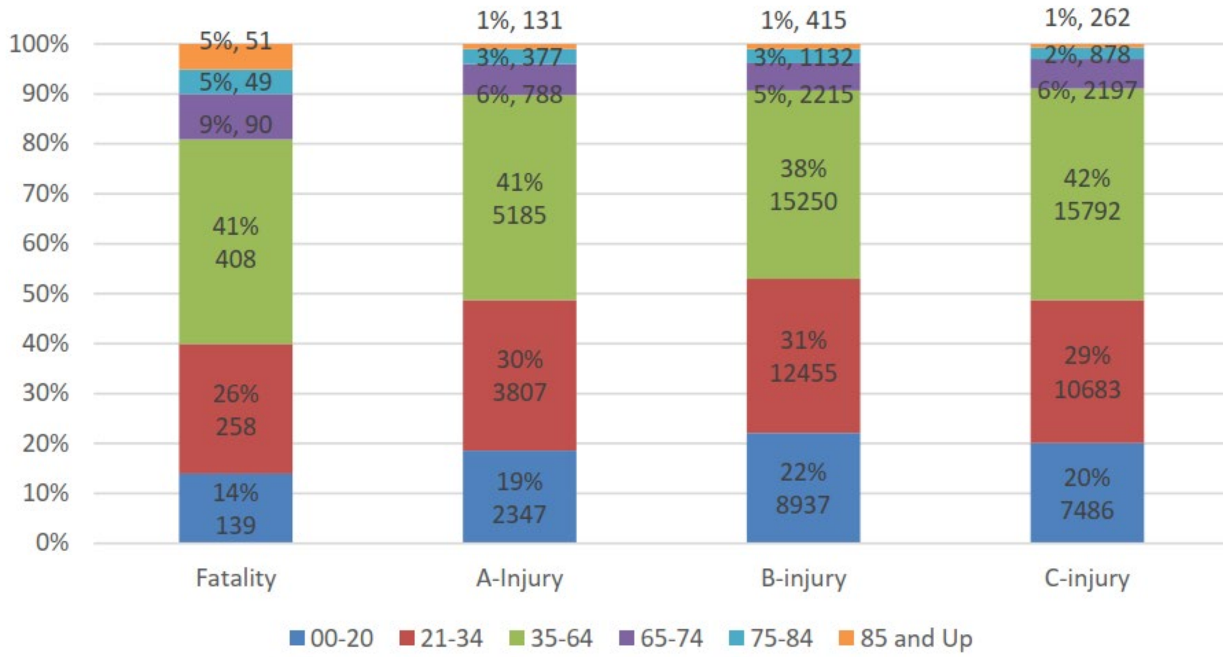


Figure 70. Chart. Injury class vs. age group (2015).

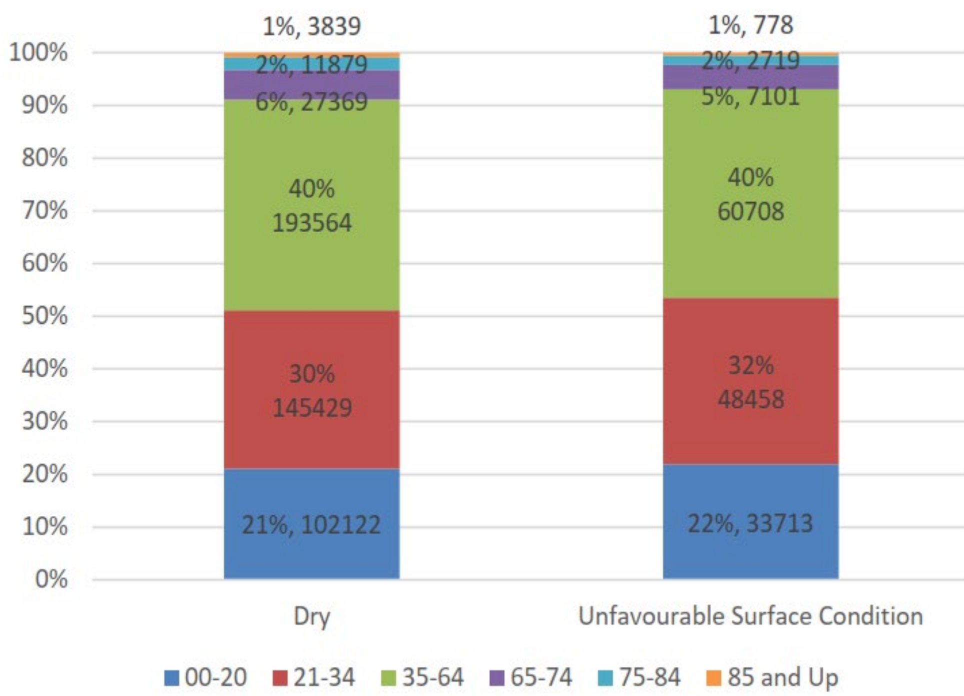


Figure 71. Chart. Surface condition vs. age group (2015).

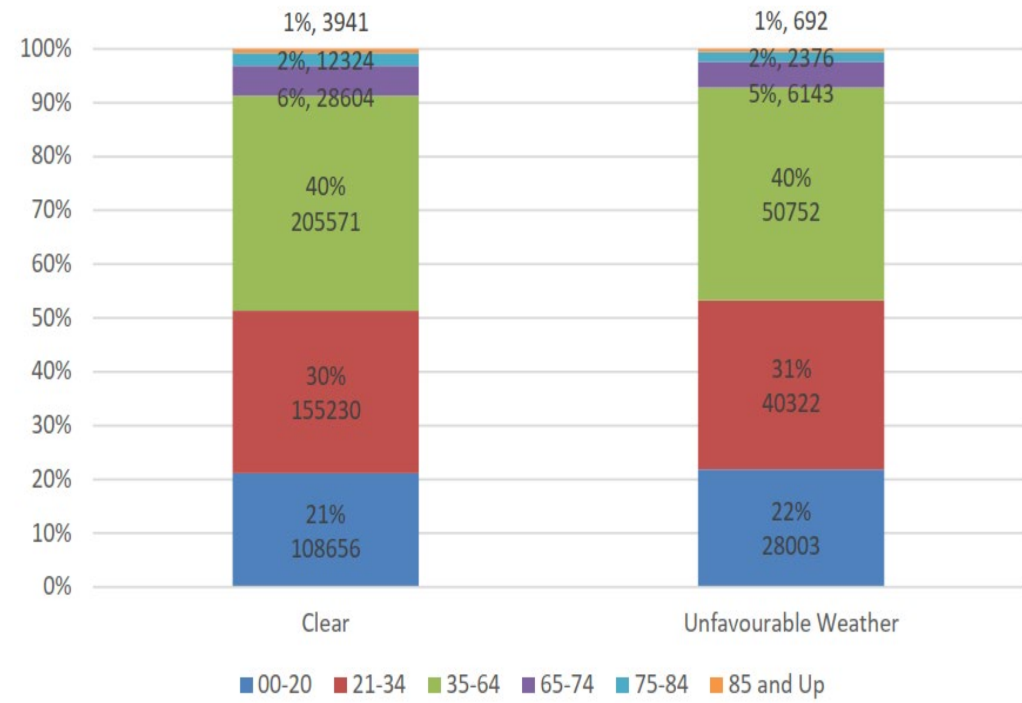


Figure 72. Chart. Weather condition vs. age group (2015).

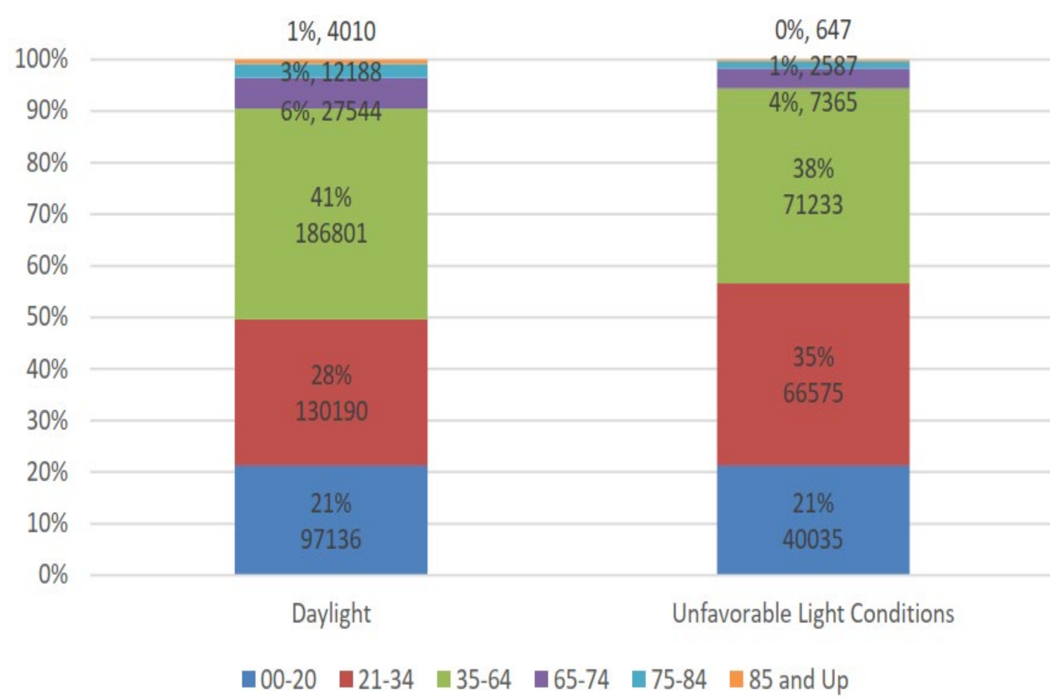


Figure 73. Chart. Light condition vs. age group (2015).

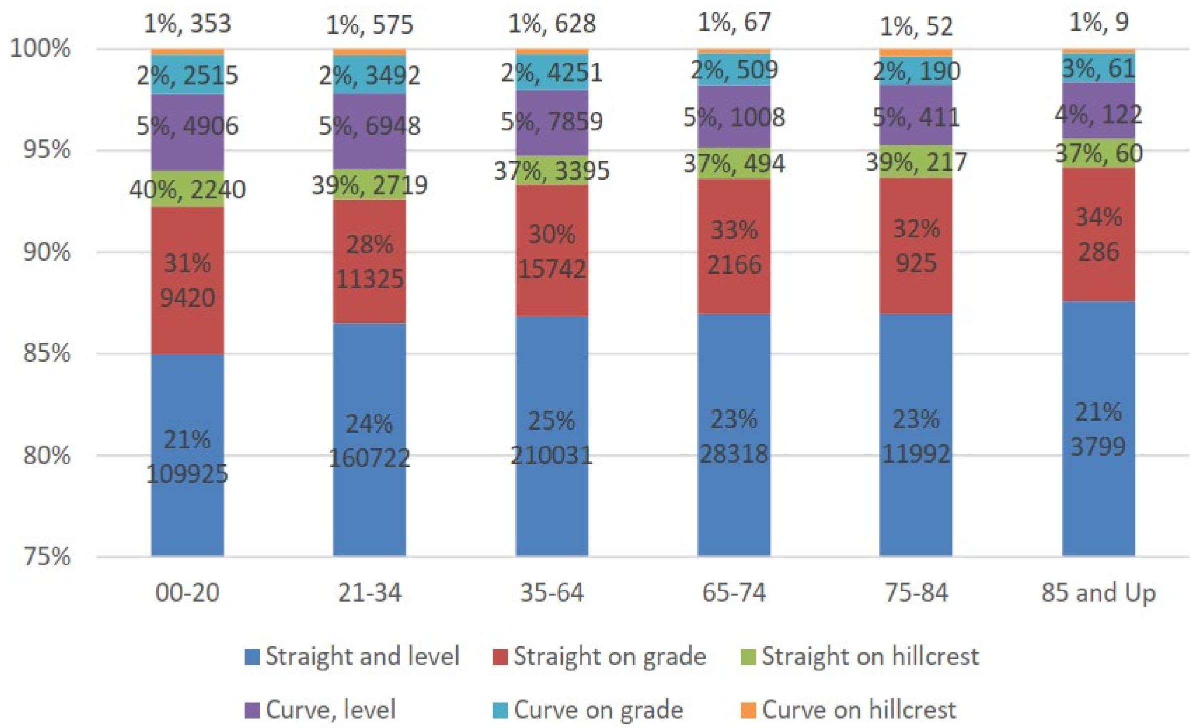


Figure 74. Chart. Alignment condition vs. age group (2015).

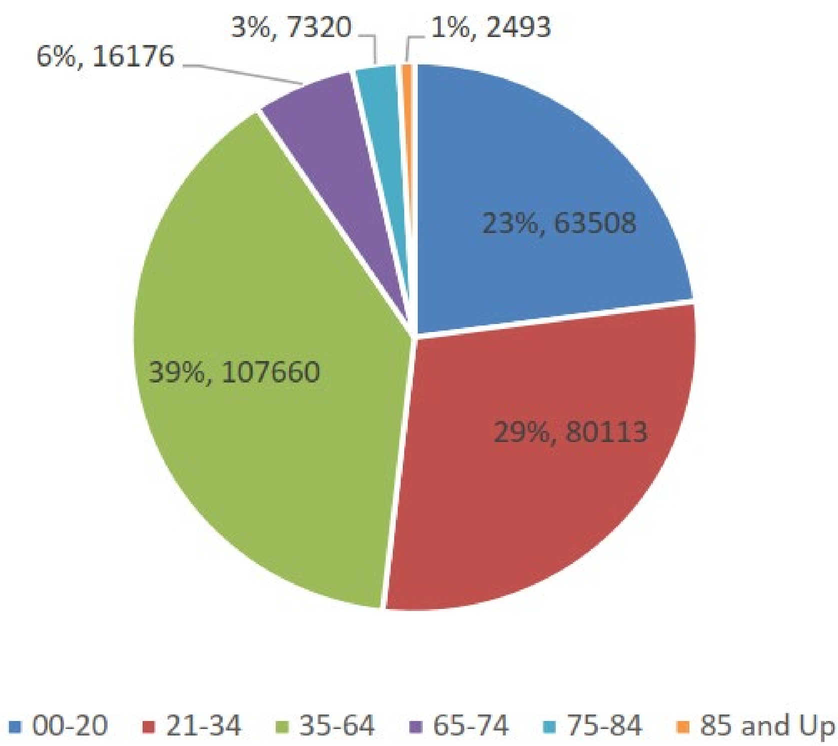


Figure 75. Chart. Intersection-related crashes vs. age group (2015).

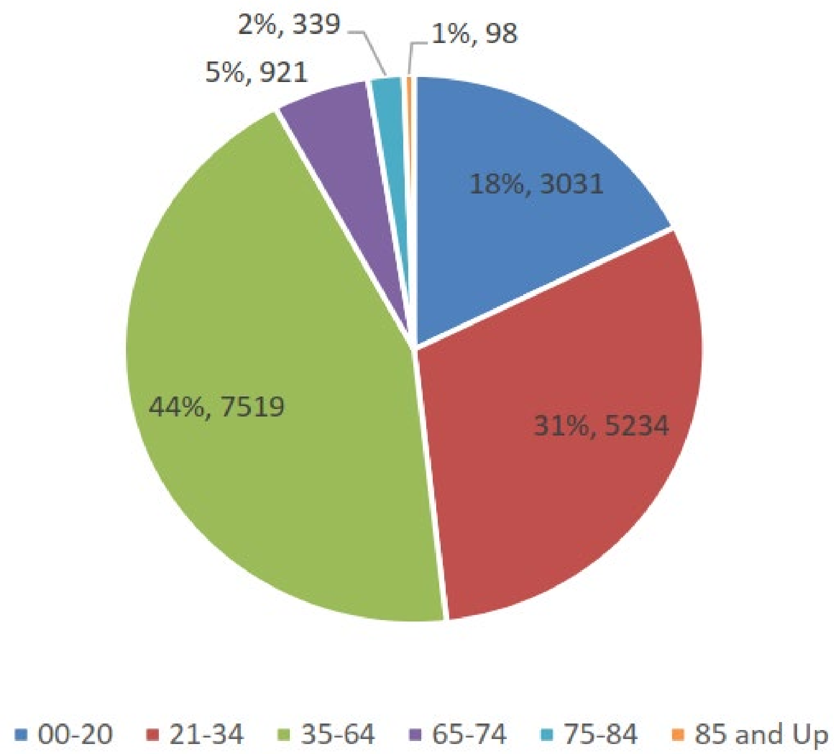


Figure 76. Chart. Work-zone-related crashes vs. age group (2015).

A-05: Year 2016

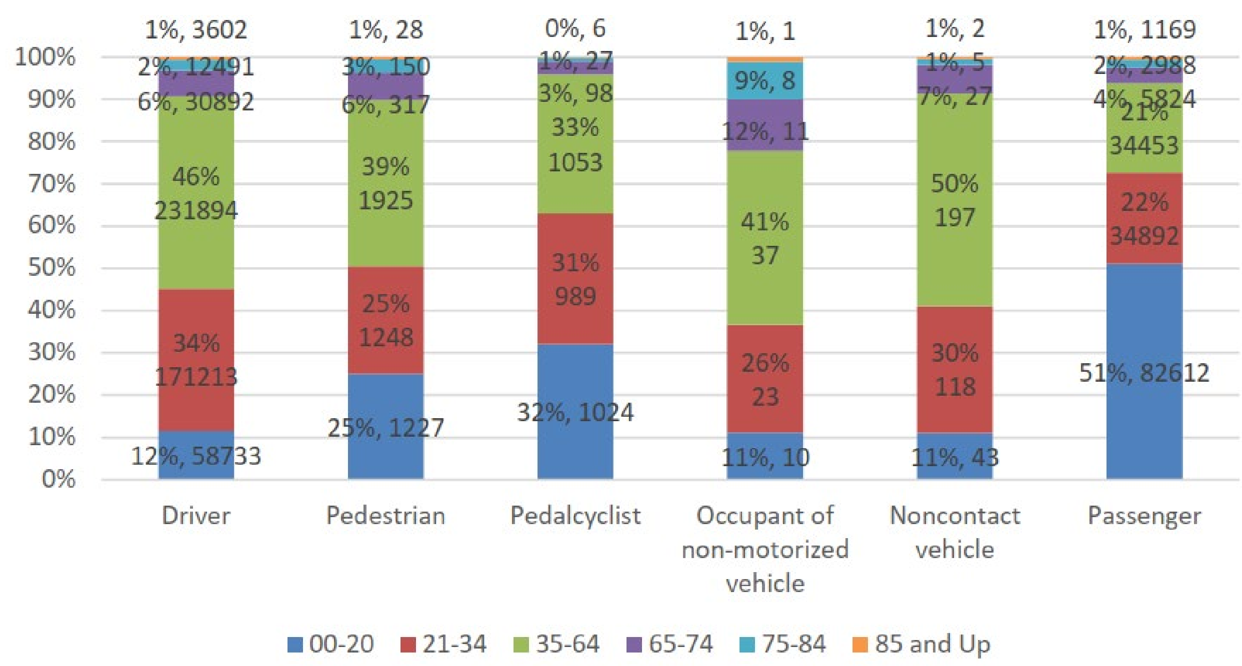


Figure 77. Chart. Type of person vs. age group (2016).

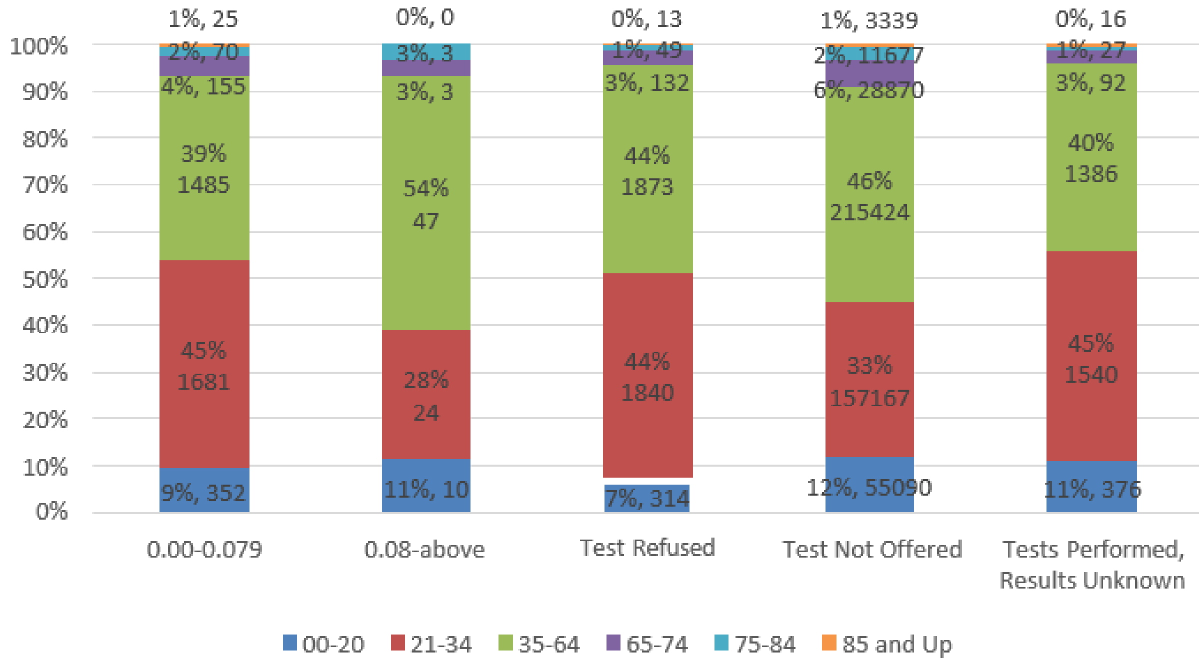


Figure 78. Chart. BAC vs. age group (2016).

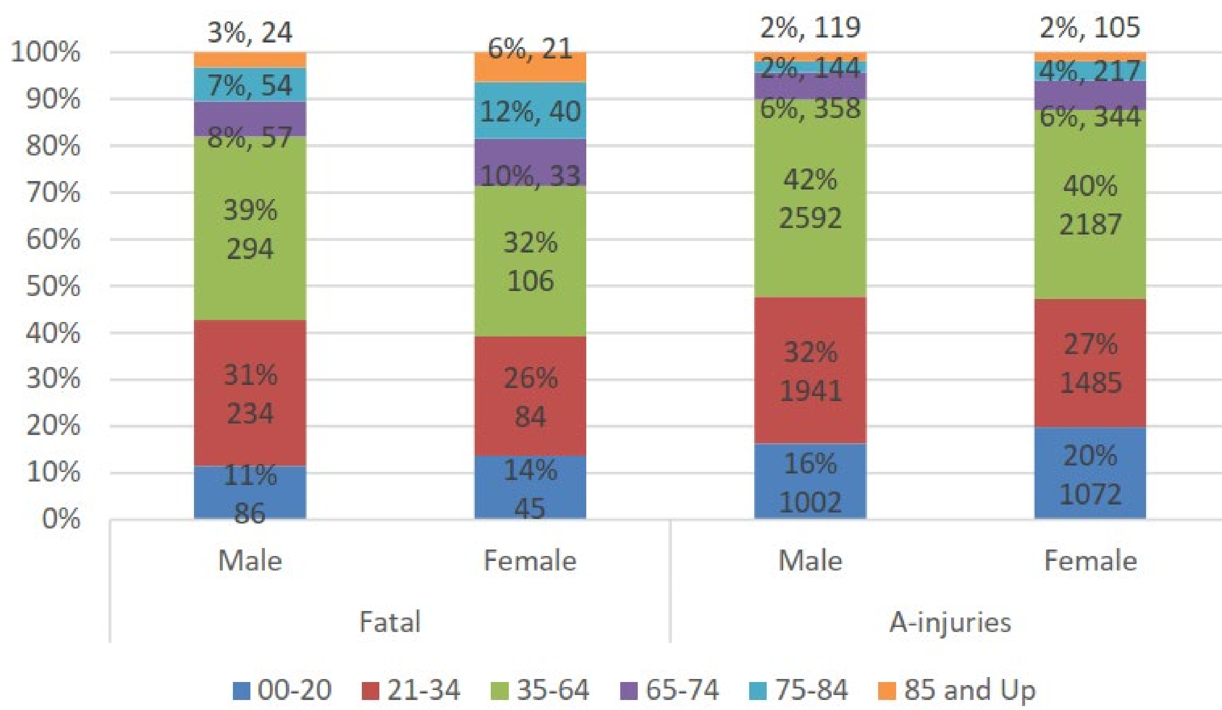


Figure 79. Chart. Crash severity by gender vs. age group (2016).

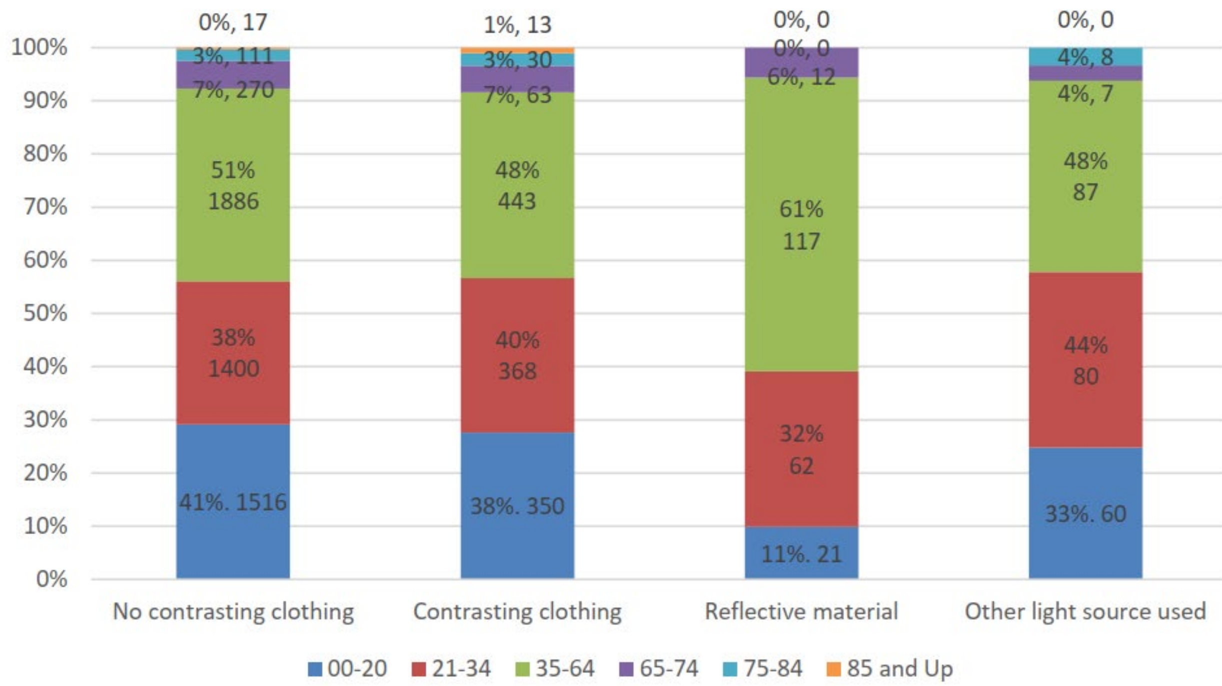


Figure 80. Chart. PEDV vs. age group (2016).

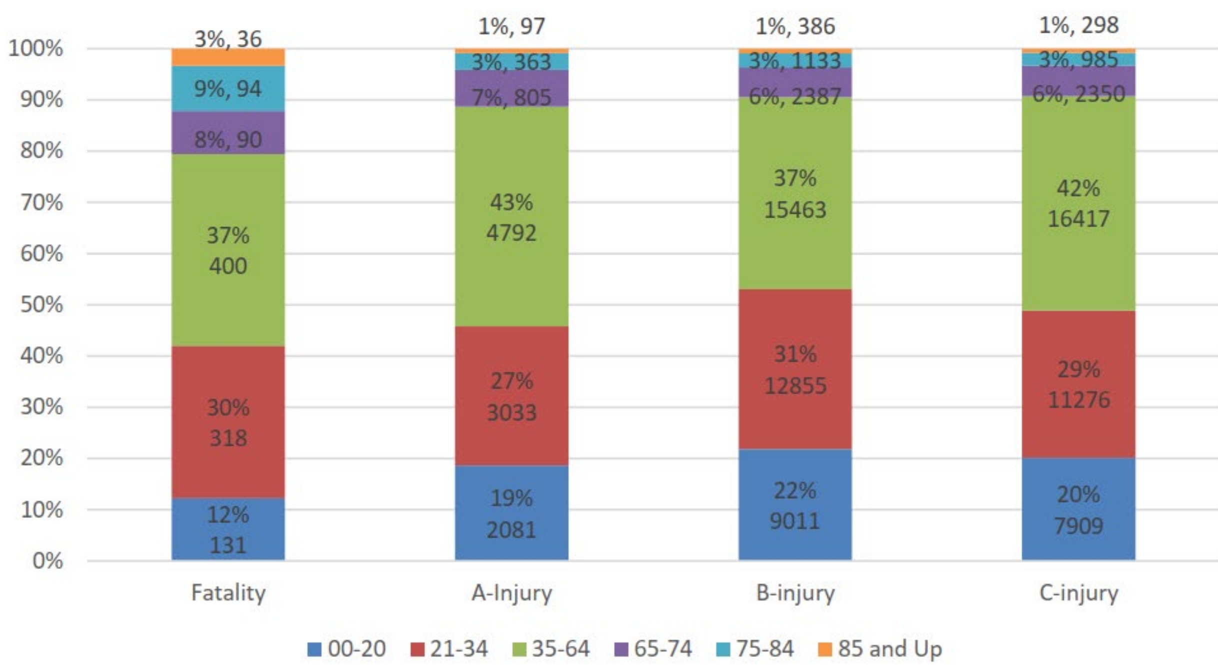


Figure 81. Chart. Injury class vs. age group (2016).

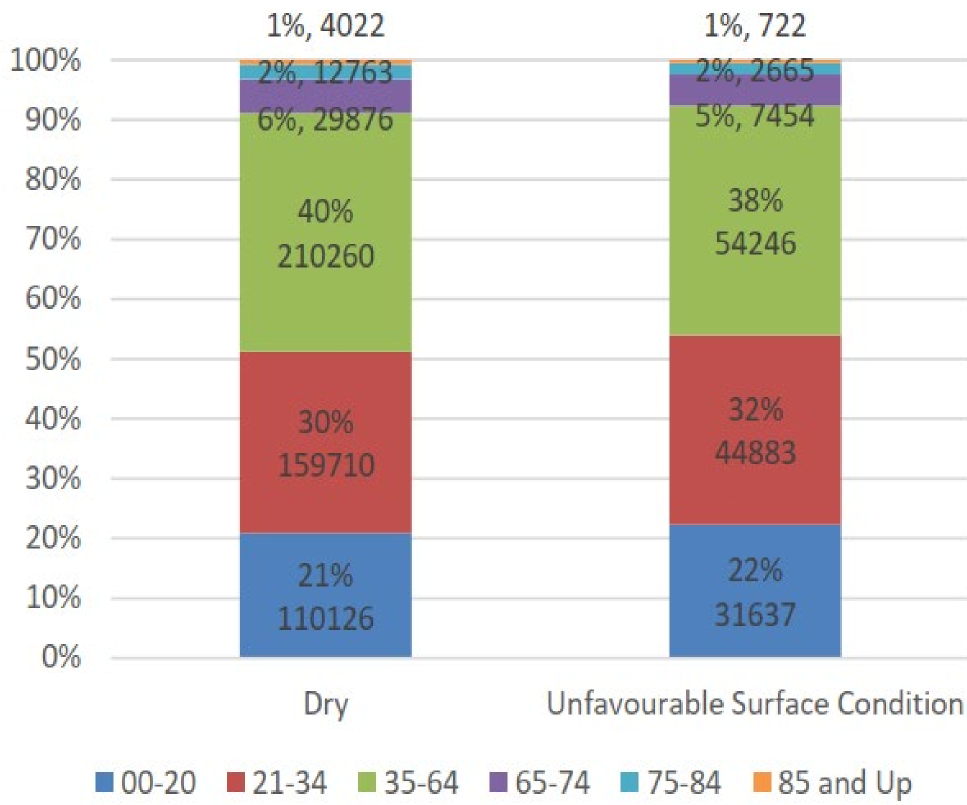


Figure 82. Chart. Surface condition vs. age group (2016).

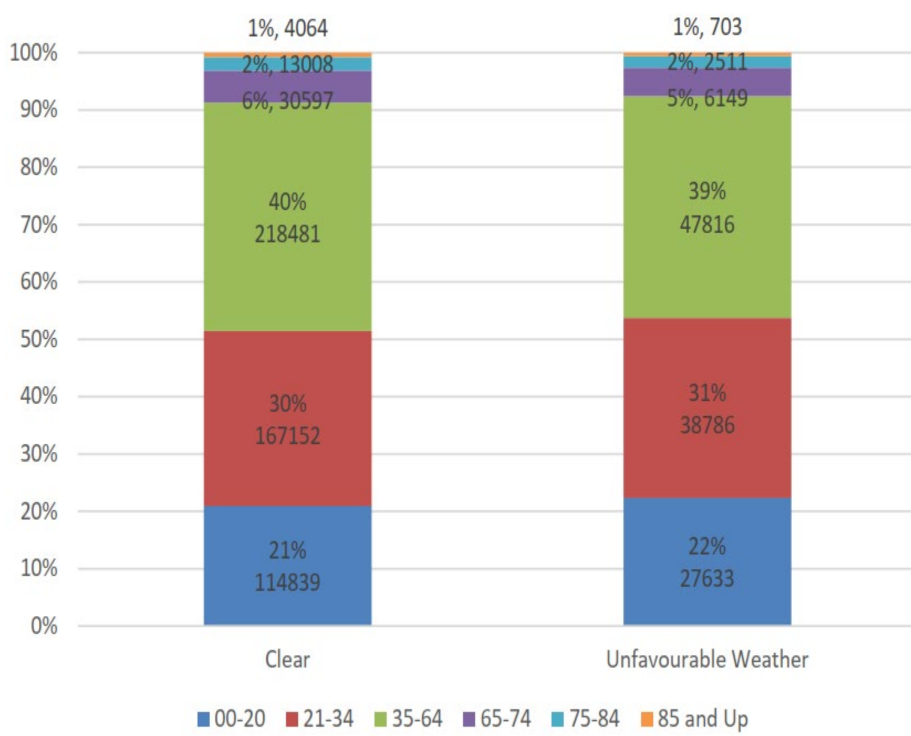


Figure 83. Chart. Weather condition vs. age group (2016).

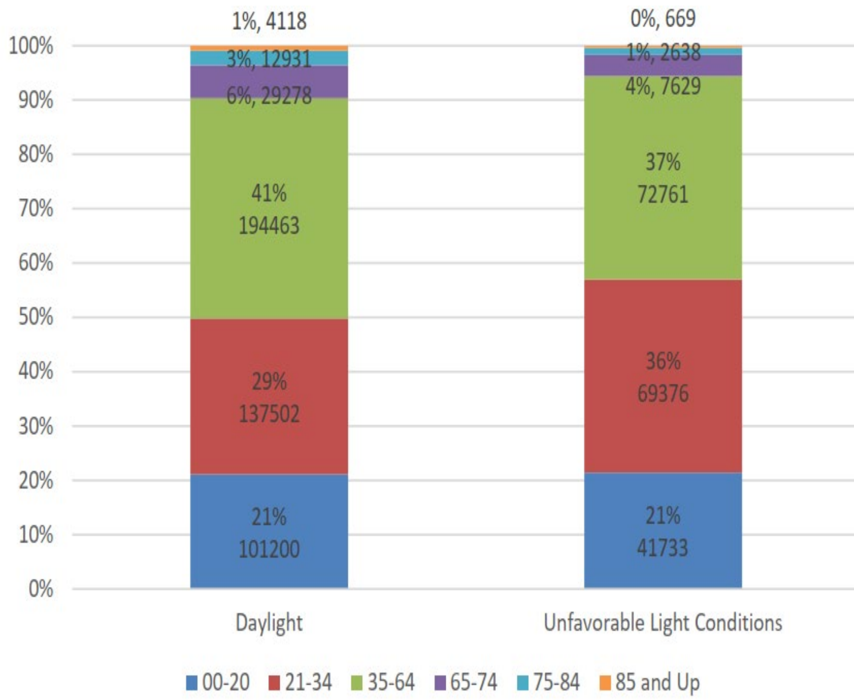


Figure 84. Chart. Light condition vs. age group (2016).

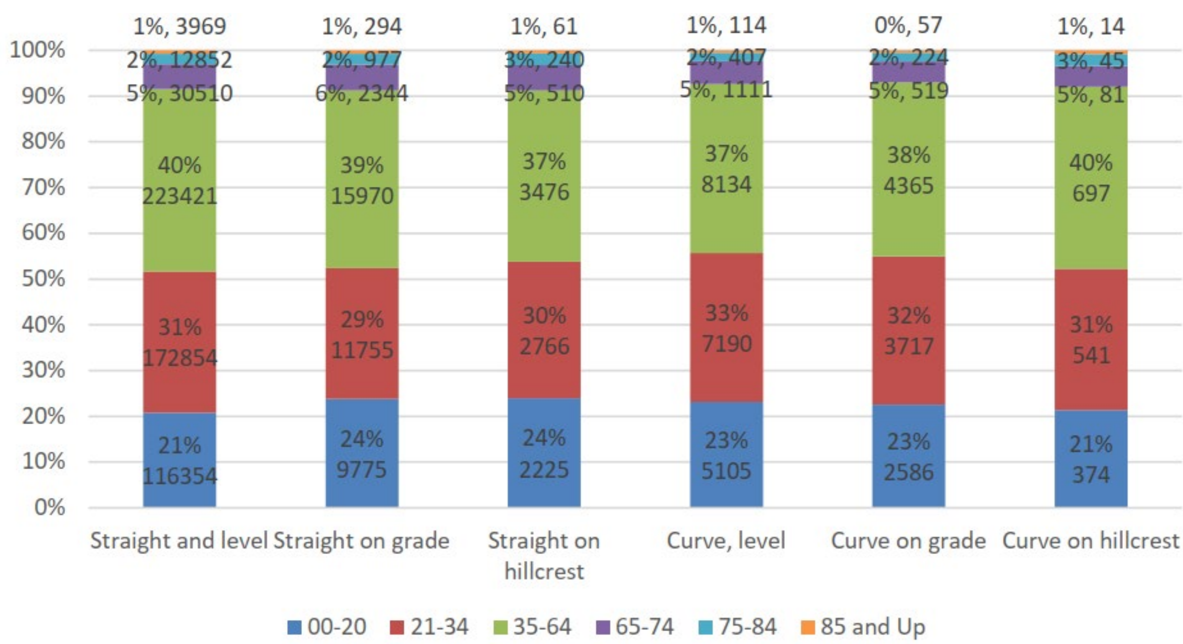


Figure 85. Chart. Alignment condition vs. age group (2016).

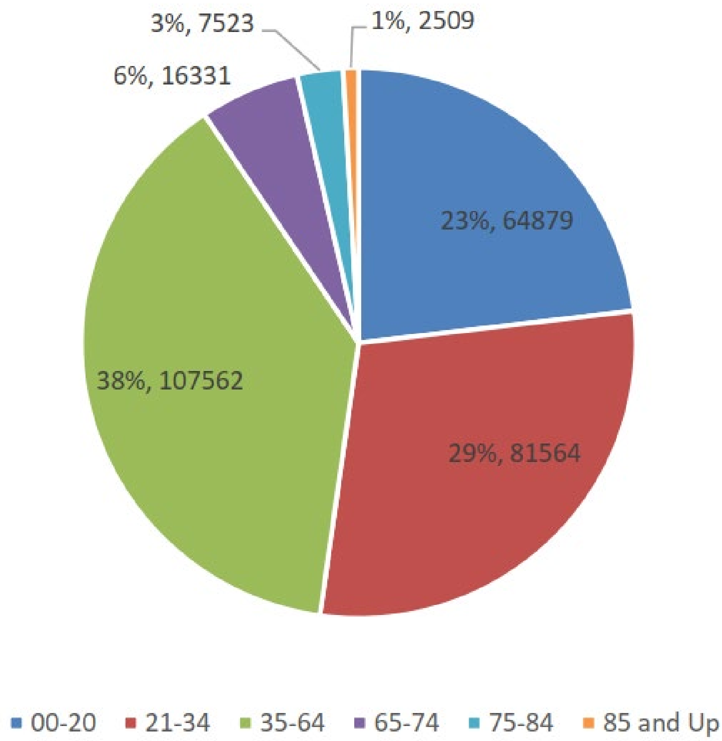


Figure 86. Chart. Intersection-related crashes vs. age group (2016).

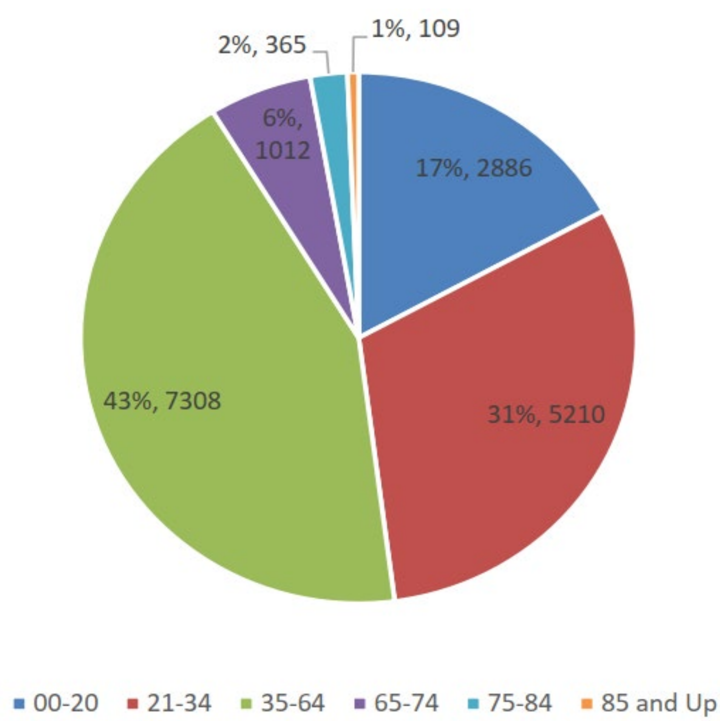


Figure 87. Chart. Work-zone-related crashes vs. age group (2016).

APPENDIX B: CRASH CAUSATION ANALYSIS

Table 40. Total Number of Crashes by County (2011–2016)

No.	County Name	Total Crashes (Older People)					
		2011	2012	2013	2014	2015	2016
1	Adams County, Illinois	331	307	333	317	379	392
2	Alexander County, Illinois	24	29	22	19	20	19
3	Bond County, Illinois	51	41	40	55	53	58
4	Boone County, Illinois	143	136	200	148	177	173
5	Brown County, Illinois	18	27	19	18	27	29
6	Bureau County, Illinois	148	137	159	146	152	153
7	Calhoun County, Illinois	21	18	19	19	30	25
8	Carroll County, Illinois	62	64	61	55	62	57
9	Cass County, Illinois	47	35	37	30	50	51
10	Champaign County, Illinois	526	526	588	643	624	734
11	Christian County, Illinois	121	96	95	127	109	107
12	Clark County, Illinois	65	63	62	70	66	61
13	Clay County, Illinois	37	58	37	54	49	43
14	Clinton County, Illinois	107	105	93	105	109	106
15	Coles County, Illinois	199	204	220	224	214	240
16	Cook County, Illinois	18843	19190	21128	22013	23404	25282
17	Crawford County, Illinois	78	78	92	99	69	91
18	Cumberland County, Illinois	52	37	34	45	45	49
19	DeKalb County, Illinois	223	240	231	261	306	280
20	De Witt County, Illinois	51	62	50	44	81	47
21	Douglas County, Illinois	59	73	52	68	59	58
22	DuPage County, Illinois	3270	3547	3733	3757	4180	4439
23	Edgar County, Illinois	59	71	76	84	84	61
24	Edwards County, Illinois	24	30	25	17	21	24
25	Effingham County, Illinois	245	245	238	216	281	238
26	Fayette County, Illinois	104	84	72	102	96	89
27	Ford County, Illinois	45	51	52	58	48	55
28	Franklin County, Illinois	155	178	178	222	222	216
29	Fulton County, Illinois	159	154	144	157	141	158
30	Gallatin County, Illinois	27	24	18	14	18	24
31	Greene County, Illinois	29	15	28	35	39	26
32	Grundy County, Illinois	149	187	149	191	197	253
33	Hamilton County, Illinois	34	26	23	38	28	16
34	Hancock County, Illinois	75	69	66	63	65	87
35	Hardin County, Illinois	19	5	16	15	8	15
36	Henderson County, Illinois	18	27	32	44	34	24
37	Henry County, Illinois	169	145	187	188	192	200
38	Iroquois County, Illinois	121	88	128	115	140	96

No.	County Name	Total Crashes (Older People)					
		2011	2012	2013	2014	2015	2016
39	Jackson County, Illinois	185	212	216	200	247	292
40	Jasper County, Illinois	39	28	28	30	31	37
41	Jefferson County, Illinois	234	222	247	242	183	237
42	Jersey County, Illinois	83	101	114	102	109	108
43	Jo Daviess County, Illinois	115	98	109	114	146	138
44	Johnson County, Illinois	35	56	58	55	45	65
45	Kane County, Illinois	1471	1427	1657	1756	1845	1850
46	Kankakee County, Illinois	428	426	386	449	468	480
47	Kendall County, Illinois	217	244	282	319	278	333
48	Knox County, Illinois	192	221	224	218	241	215
49	Lake County, Illinois	2029	2077	2339	2442	2598	2569
50	LaSalle County, Illinois	459	467	499	472	541	575
51	Lawrence County, Illinois	57	54	55	83	60	48
52	Lee County, Illinois	165	132	142	169	191	168
53	Livingston County, Illinois	117	131	123	142	146	131
54	Logan County, Illinois	124	120	117	126	154	141
55	McDonough County, Illinois	127	112	128	131	134	122
56	McHenry County, Illinois	860	945	956	887	989	1087
57	McLean County, Illinois	586	571	572	570	662	661
58	Macon County, Illinois	591	547	572	611	583	631
59	Macoupin County, Illinois	139	127	132	148	143	151
60	Madison County, Illinois	1063	975	993	1020	1167	1240
61	Marion County, Illinois	171	187	191	217	193	193
62	Marshall County, Illinois	44	33	40	33	26	43
63	Mason County, Illinois	40	44	44	48	37	30
64	Massac County, Illinois	82	63	88	81	68	62
65	Menard County, Illinois	18	21	20	31	29	24
66	Mercer County, Illinois	35	48	48	50	52	49
67	Monroe County, Illinois	118	104	99	95	122	139
68	Montgomery County, Illinois	101	141	140	115	129	120
69	Morgan County, Illinois	142	145	132	129	164	172
70	Moultrie County, Illinois	42	40	55	44	56	59
71	Ogle County, Illinois	132	129	133	168	163	163
72	Peoria County, Illinois	910	870	839	869	947	911
73	Perry County, Illinois	94	52	67	80	96	87
74	Piatt County, Illinois	30	31	53	51	47	48
75	Pike County, Illinois	102	97	81	86	63	87
76	Pope County, Illinois	14	11	23	15	14	15
77	Pulaski County, Illinois	24	19	16	23	19	15
78	Putnam County, Illinois	19	22	25	19	33	27
79	Randolph County, Illinois	95	118	108	117	103	121
80	Richland County, Illinois	57	62	75	66	70	61

No.	County Name	Total Crashes (Older People)					
		2011	2012	2013	2014	2015	2016
81	Rock Island County, Illinois	687	708	751	796	796	831
82	St. Clair County, Illinois	966	947	909	1047	1204	1320
83	Saline County, Illinois	134	131	157	135	123	116
84	Sangamon County, Illinois	1027	1003	1047	1055	1172	1163
85	Schuyler County, Illinois	45	53	25	33	24	28
86	Scott County, Illinois	24	19	16	15	10	21
87	Shelby County, Illinois	68	79	82	72	75	66
88	Stark County, Illinois	16	24	5	18	17	20
89	Stephenson County, Illinois	215	189	229	205	231	223
90	Tazewell County, Illinois	574	564	584	639	646	677
91	Union County, Illinois	81	56	81	74	97	85
92	Vermilion County, Illinois	321	339	326	343	352	339
93	Wabash County, Illinois	37	36	29	42	33	43
94	Warren County, Illinois	64	62	69	70	54	69
95	Washington County, Illinois	55	58	67	77	92	73
96	Wayne County, Illinois	95	97	92	78	83	91
97	White County, Illinois	77	73	69	87	80	77
98	Whiteside County, Illinois	259	241	278	247	276	255
99	Will County, Illinois	1759	1877	2014	2034	2194	2408
100	Williamson County, Illinois	341	413	370	433	430	456
101	Winnebago County, Illinois	1243	1299	1321	1237	1304	1416
102	Woodford County, Illinois	91	77	110	128	79	88

Table 41. VIS vs. Age Group (2012)

Age		00-20	21-34	35-64	65-74	75-84	85 and Up	Total
VIS	Not obscured	71226	96831	139532	16859	7780	2270	334498
	Moving vehicle	1288	1706	2129	298	145	38	5604
	Windshield (water/ice)	759	823	1048	111	69	24	2834
	Parked vehicles	479	606	774	127	77	19	2082
	Blinded – sunlight	387	460	777	160	94	39	1917
	Trees, plants	163	166	254	59	18	6	666
	Hillcrest	124	112	152	16	9	4	417
	Buildings	60	85	109	9	5	2	270
	Blowing materials	46	69	112	16	6	2	251
	Blinded – headlights	32	27	46	7	8	2	122
	Embankment	29	36	34	7	2	0	108
	Signboard	12	10	23	2	4	1	52

Table 42. VIS vs. Age Group (2013)

Age		00-20	21-34	35-64	65-74	75-84	85 and Up	Total
VIS	Not obscured	781	2109	3302	448	249	93	6982
	Moving vehicle	11	24	51	7	2	0	95
	Windshield (water/ice)	10	27	44	3	4	0	88
	Blinded – sunlight	1	10	15	6	0	0	32
	Hillcrest	5	10	11	1	1	0	28
	Parked vehicles	4	5	9	4	0	0	22
	Trees, plants	6	6	7	0	0	2	21
	Blinded – headlights	2	1	2	0	0	0	5
	Buildings	2	1	0	1	0	0	4
	Embankment	0	0	2	0	0	0	2
	Blowing materials	0	0	1	0	0	0	1
	Signboard	0	0	0	0	0	0	0

Table 43. VIS vs. Age Group (2014)

Age		00-20	21-34	35-64	65-74	75-84	85 and Up	Total
VIS	Not obscured	40664	112409	160052	20942	8546	2488	345101
	Windshield (water/ice)	490	1158	1394	176	80	27	3325
	Trees, plants	91	154	259	38	16	0	558
	Buildings	27	77	106	10	8	1	229
	Embankment	27	51	81	7	8	1	175
	Signboard	1	14	17	5	3	1	41
	Hillcrest	82	114	170	20	15	6	407
	Parked vehicles	281	637	820	122	65	18	1943
	Moving vehicle	716	1680	2192	327	126	29	5070
	Blinded – headlights	24	32	52	18	10	0	136
	Blinded – sunlight	232	502	720	121	63	41	1679
	Blowing materials	52	153	193	24	7	3	432

Table 44. VIS vs. Age Group (2015)

Age		00-20	21-34	35-64	65-74	75-84	85 and Up	Total
VIS	Not obscured	46095	129863	181185	23753	9597	2769	393262
	Windshield (water/ice)	512	1311	1495	195	72	24	3609
	Trees, plants	93	166	236	43	26	8	572
	Buildings	27	96	103	22	6	2	256
	Embankment	20	40	44	10	3	3	120
	Signboard	4	14	14	2	2	0	36
	Hillcrest	92	142	157	29	17	7	444
	Parked vehicles	282	711	881	145	56	22	2097
	Moving vehicle	735	1954	2378	376	157	54	5654
	Blinded – headlights	21	45	77	19	12	2	176
	Blinded – sunlight	261	539	876	178	85	32	1971
	Blowing materials	32	79	122	16	2	1	252

Table 45. VIS vs. Age Group (2016)

Age		00-20	21-34	35-64	65-74	75-84	85 and Up	Total
VIS	Not obscured	49229	140949	192900	25509	10274	2956	421817
	Windshield (water/ice)	522	1154	1370	203	69	33	3351
	Trees, plants	97	186	236	42	24	8	593
	Buildings	34	74	101	17	7	0	233
	Embankment	9	29	37	7	4	0	86
	Signboard	8	14	13	1	3	0	39
	Hillcrest	86	139	166	20	63	3	477
	Parked vehicles	266	742	946	144	70	16	2184
	Moving vehicle	768	2094	2613	399	172	43	6089
	Blinded – headlights	23	34	62	18	11	3	151
	Blinded – sunlight	261	532	905	186	102	41	2027
	Blowing materials	38	58	79	7	5	0	187

Table 46. Collision Types (2011)

Age		Under 20	21–34	35–64	65–74	75–84	85 and Up	Total
Collision Types	Rear-end	47107	63268	91824	9291	3699	979	**216168**
	Turning	27073	32112	43008	6034	3528	1179	**112934**
	Angle	18790	21540	29249	4292	2636	880	**77387**
	Sideswipe-same direction	9587	16644	24283	2763	1275	402	**54954**
	Fixed Object	11079	14467	12488	1206	626	208	**40074**
	Animal	4133	6317	12469	1480	498	65	**24962**
	Parked Motor vehicle	4356	6447	7573	942	541	225	**20084**
	Pedestrian	2236	2515	3596	499	249	77	**9172**
	Sideswipe-opposite direction	1529	2157	3267	345	183	51	**7532**
	Pedal cyclist	1654	1747	2293	288	112	35	**6129**
	Head-on	1349	1781	2264	276	138	35	**5843**
	Overturned	1753	1749	1764	156	41	7	**5470**
	Other non-collision	715	1198	1668	130	54	15	**3780**
	Other Object	562	983	1363	139	74	11	**3132**
	Train	22	13	32	2	6	1	**76**

Table 47. Collision Types vs. Age Group (2012)

Age		00-20	21-34	35-64	65-74	75-84	85 and Up	Total
Collision Type	Fixed Object	662	1004	904	122	59	37	2788
	Rear-end	349	596	1026	121	64	22	2178
	Angle	353	544	961	154	103	33	2148
	Turning	322	511	849	135	71	40	1928
	Pedestrian	246	229	402	56	46	13	992
	Overturned	188	284	329	29	5	2	837
	Head-on	104	234	261	31	25	8	663
	Pedal cyclist	151	104	177	16	8	2	458
	Sideswipe-same direction	81	134	188	14	12	1	430
	Parked Motor vehicle	47	90	100	9	7	3	256
	Sideswipe-opposite direction	42	58	92	16	5	3	216
	Other non-collision	44	55	87	6	2	1	195
	Animal	19	22	72	8	5	1	127
	Other Object	13	24	42	7	2	0	88
	Train	8	7	6	0	1	0	22

Table 48. Collision Types vs. Age Group (2013)

Age		00-20	21-34	35-64	65-74	75-84	85 and Up	Total
Collision Type	Fixed Object	604	892	840	110	66	27	2539
	Turning	351	600	867	141	84	31	2074
	Rear-end	65	628	1124	144	72	16	2049
	Angle	367	524	783	157	88	42	1961
	Pedestrian	240	205	392	72	35	16	960
	Overturned	183	267	316	28	14	5	813
	Head-on	143	193	313	48	31	4	732
	Pedalcyclist	139	118	157	13	5	3	435
	Sideswipe-same direction	61	145	182	19	13	4	424
	Parked Motor vehicle	55	104	111	21	5	5	301
	Sideswipe-opposite direction	28	35	95	14	8	2	182
	Other non-collision	22	42	79	8	2	0	153
	Animal	13	12	74	6	2	0	107
	Other Object	10	13	37	2	1	1	64
	Train	1	4	5	1	2	1	14

Table 49. Collision Types vs. Age Group (2014)

Age		00-20	21-34	35-64	65-74	75-84	85 and Up	Total
Collision Type	Rear-end	46240	67877	96454	11125	3859	1080	226635
	Turning	25171	32441	42436	6800	3474	1225	111547
	Angle	17933	22611	30269	5044	2569	867	79293
	Sideswipe-same direction	9991	19703	28293	3556	1474	409	63426
	Fixed Object	11148	16320	13699	1531	685	246	43629
	Animal	3432	5579	10386	1412	414	60	21283
	Parked Motor vehicle	1434	7237	8298	1170	657	212	19008
	Sideswipe-opposite direction	1738	2740	3877	537	181	69	9142
	Pedestrian	1863	2346	3385	532	223	82	8431
	Head-on	1348	2046	2795	370	134	43	6736
	Pedalcyclist	1540	1896	2341	303	132	31	6243
	Overturned	1500	1850	1823	168	52	8	5401
	Other non-collision	903	1367	1942	211	63	13	4499
	Other Object	777	1292	1770	209	91	25	4164
	Train	17	30	58	8	5	2	120

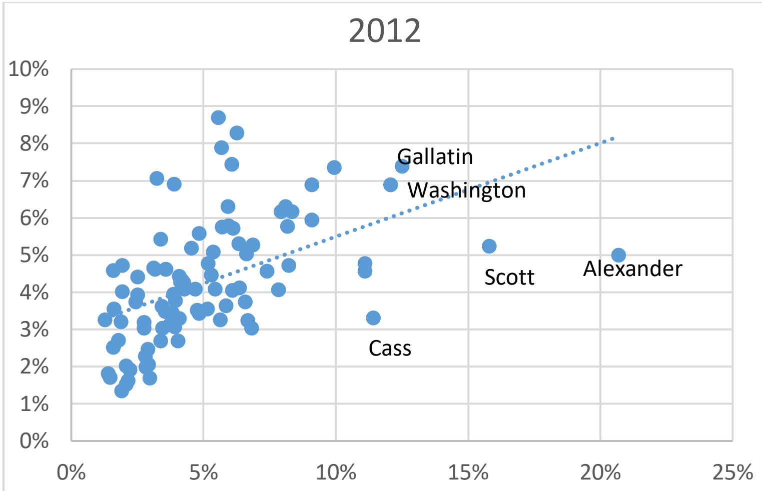
Table 50. Collision Types vs. Age Group (2015)

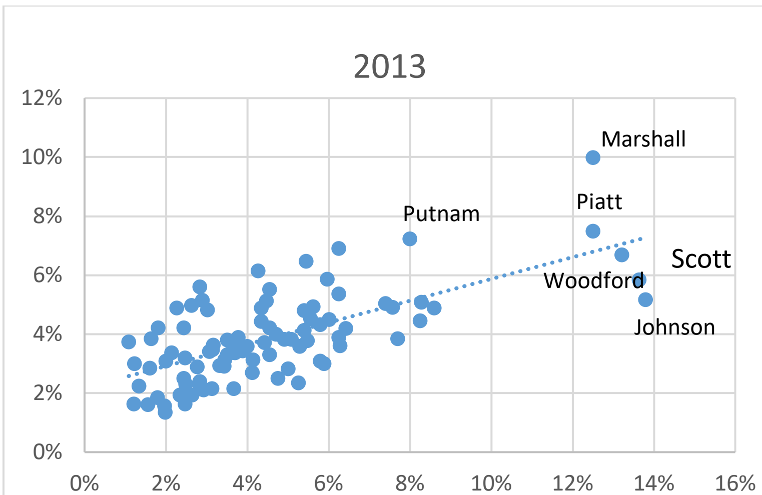
Age		00-20	21-34	35-64	65-74	75-84	85 and Up	Total
Collision Type	Rear-end	50206	73346	101132	11954	4261	1145	242044
	Turning	28965	37092	48037	7689	3746	1319	126848
	Angle	18811	23281	30397	5034	2563	932	81018
	Sideswipe-same direction	10847	21463	30350	3869	1549	440	68518
	Fixed Object	10521	15665	13057	1528	640	221	41632
	Parked Motor vehicle	4786	7576	8381	1147	658	241	22789
	Animal	3688	5894	10599	1529	480	68	22258
	Pedestrian	1985	2585	3735	602	267	96	9270
	Sideswipe-opposite direction	1660	2594	3656	477	183	56	8626
	Head-on	1404	2075	2717	366	159	70	6791
	Pedal cyclist	1566	1881	2405	339	125	43	6359
	Overturned	1726	1943	1687	160	52	9	5577
	Other Object	930	1592	2087	250	114	23	4996
	Other non-collision	683	1120	1488	168	52	10	3521
	Train	21	44	45	2	5	0	117

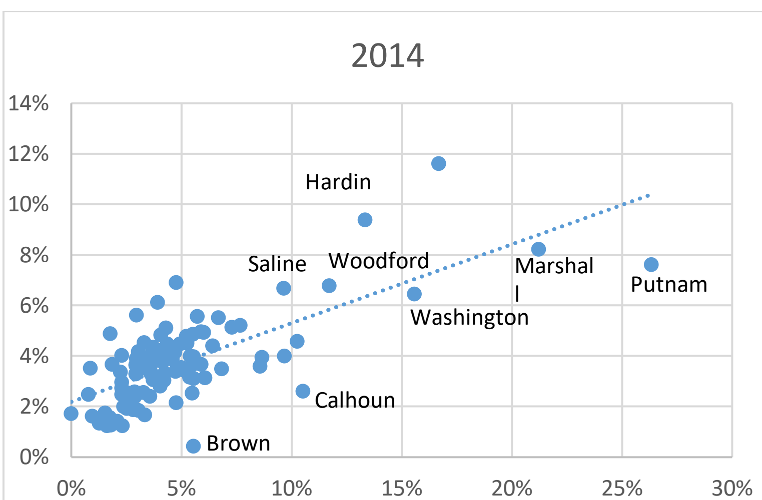
Table 51. Collision Types vs. Age Group (2016)

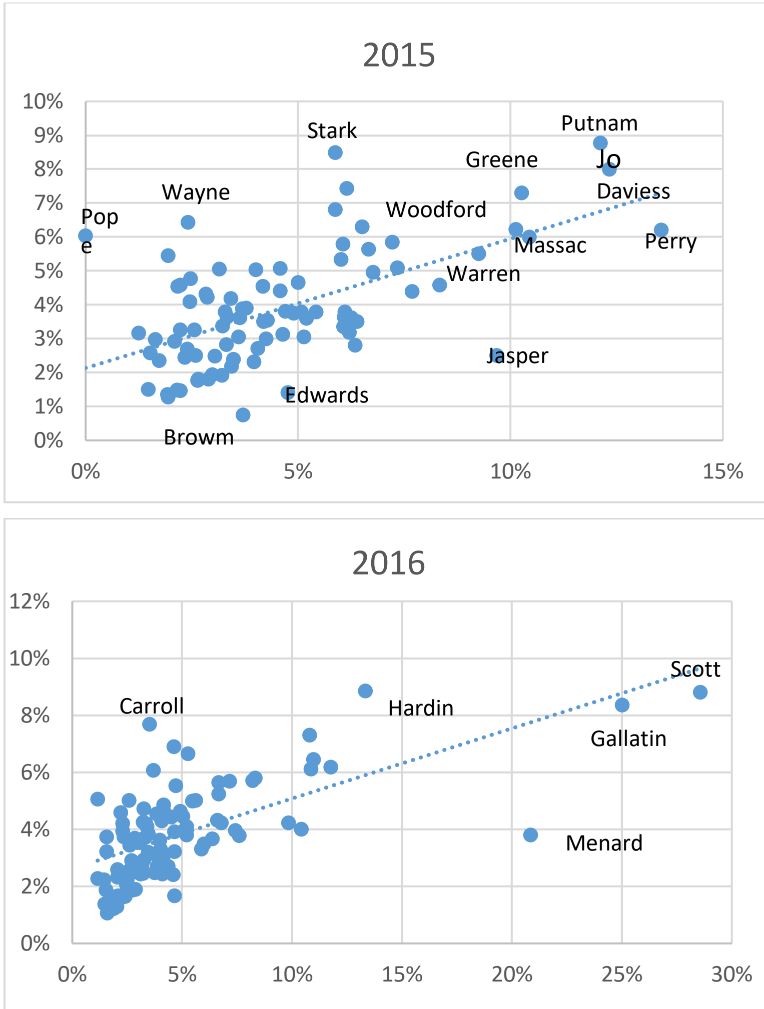
Age		00-20	21-34	35-64	65-74	75-84	85 and Up	Total
Collision Type	Turning	30283	388688	49857	7957	4001	1392	482178
	Rear-end	53219	78802	106292	12936	4406	1172	256827
	Angle	19669	15011	32073	5384	2829	984	75950
	Sideswipe-same direction	11780	23648	32787	4288	1660	451	74614
	Fixed Object	10823	15361	12377	1428	681	237	40907
	Parked Motor vehicle	4963	7729	8671	1290	632	231	23516
	Animal	3347	5472	9749	1421	455	73	20517
	Pedestrian	1790	2441	3718	659	288	59	8955
	Sideswipe-opposite direction	1613	2523	3434	491	188	57	8306
	Head-on	1467	2258	2808	382	155	49	7119
	Pedal cyclist	1462	1863	2525	350	131	41	6372
	Overturned	1580	1858	1566	144	46	9	5203
	Other Object	905	1596	2146	258	134	35	5074
	Other non-collision	733	1210	1503	176	59	16	3697
	Train	15	23	53	5	4	2	102

APPENDIX C: SOCIOECONOMIC DATA CAUSATION ANALYSIS

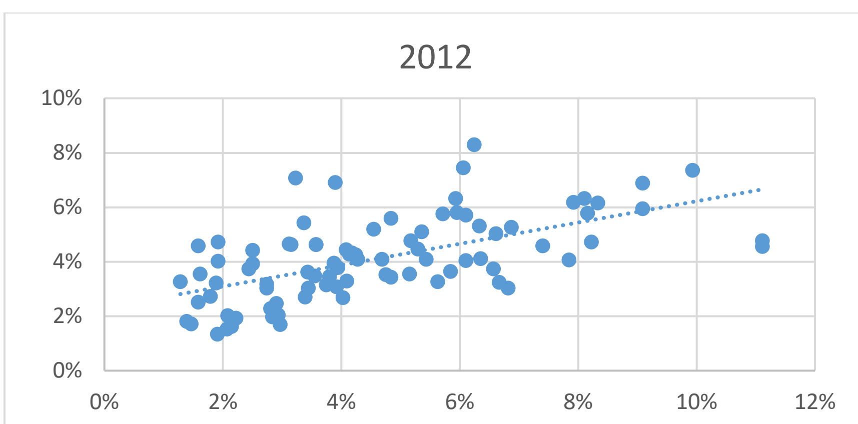


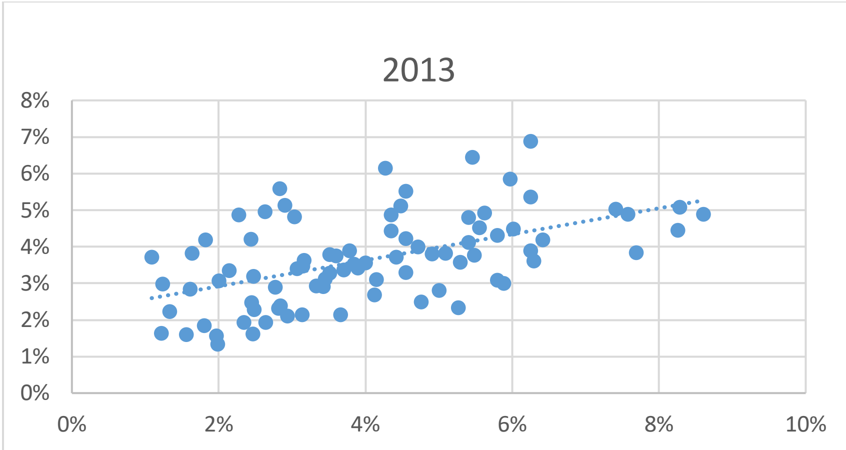






(A) With outlier counties




2013
8%
7%
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4%
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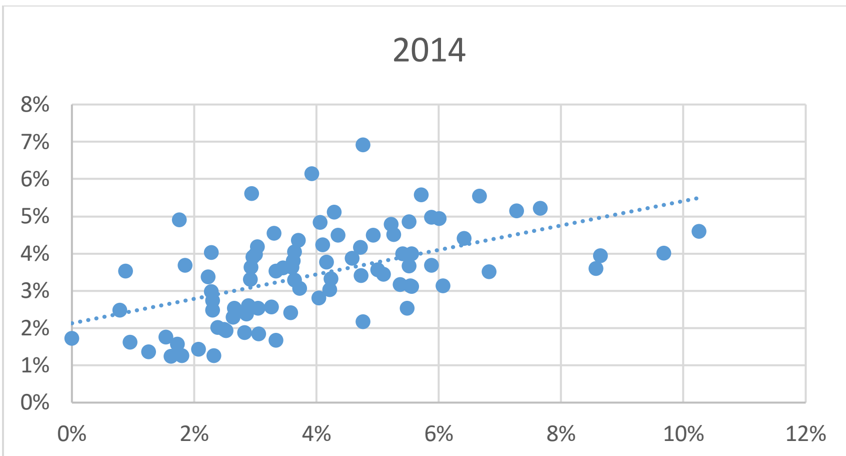
4%
6%
8%
10%


2014
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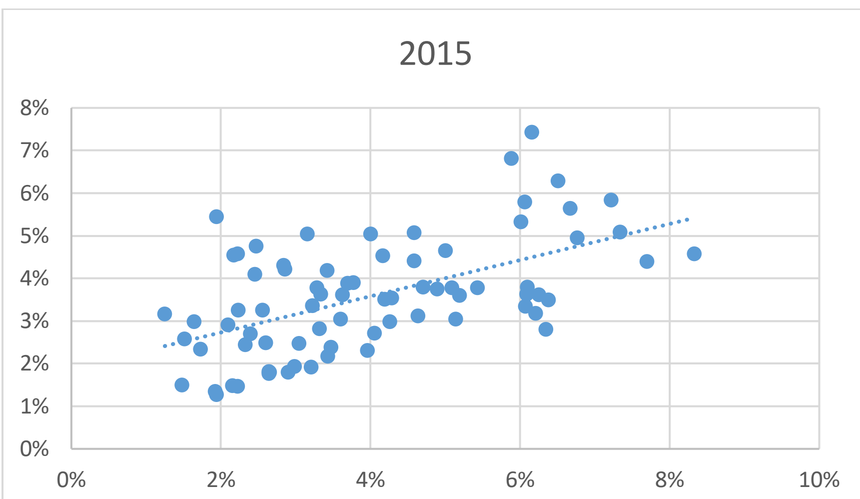
10%
12%


2015
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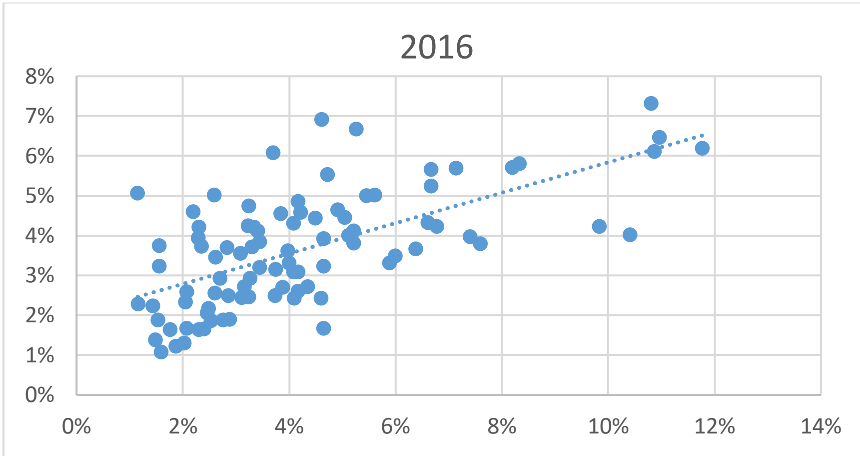
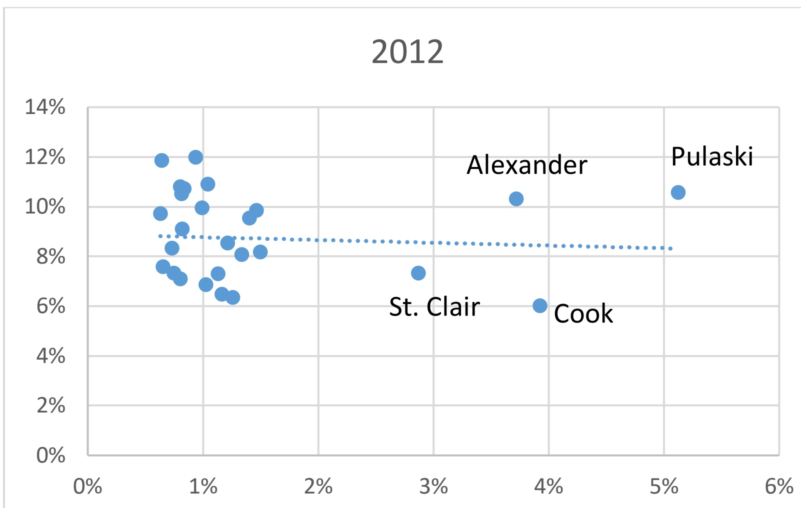
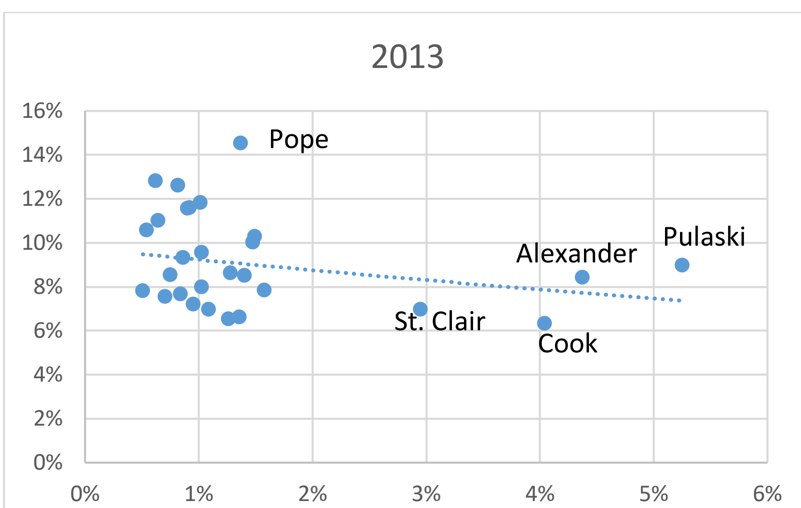
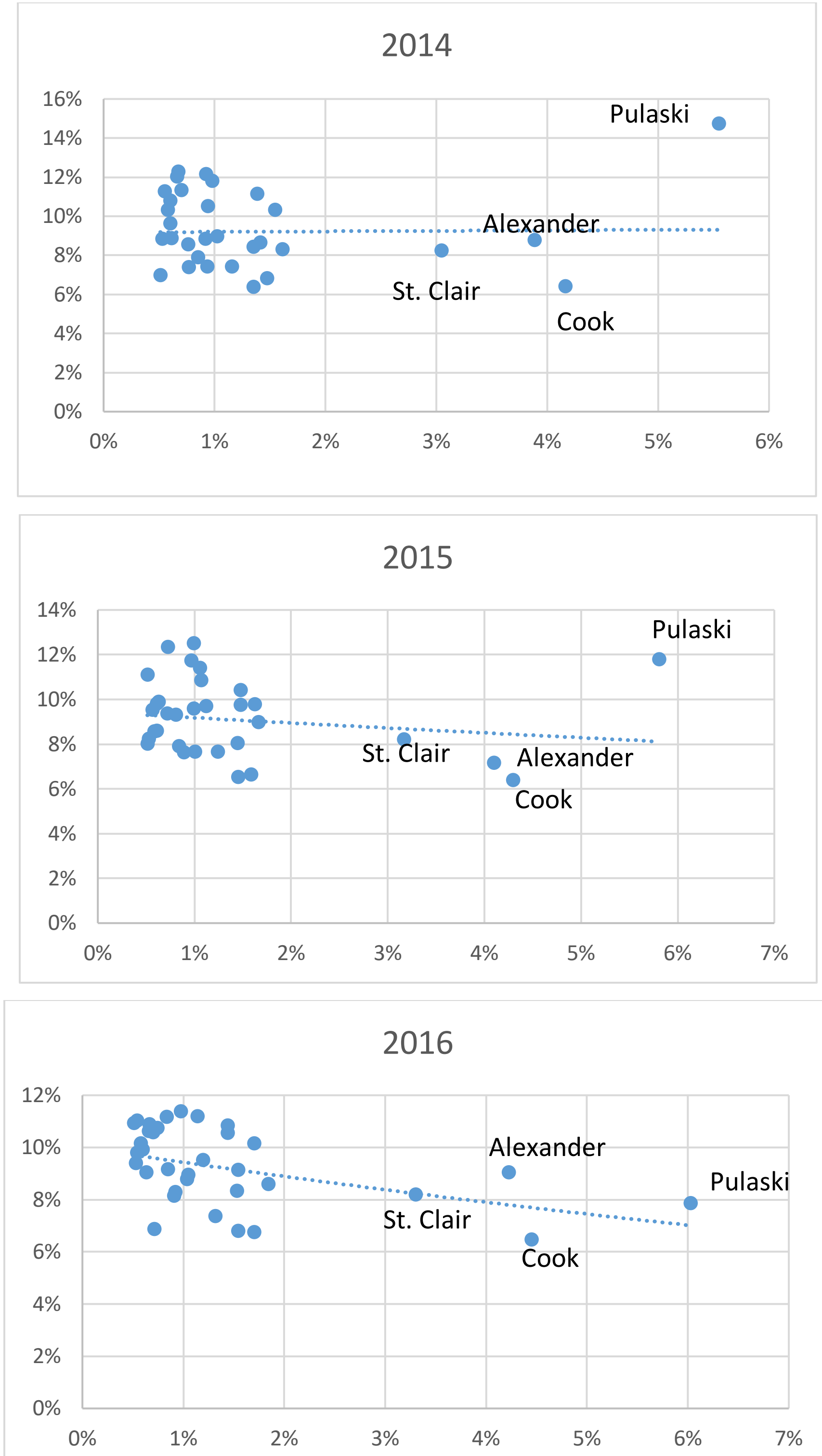


(B) Without outlier counties

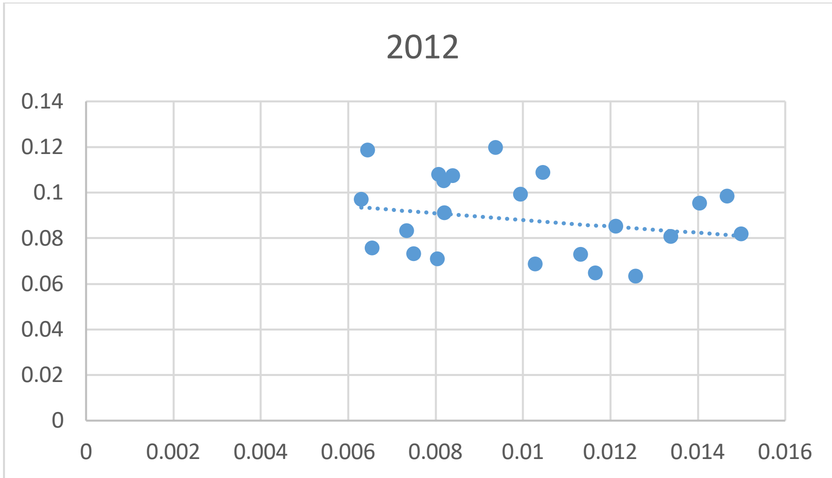
Figure 88. Graph. Severe crashes among total older population vs. severe crashes among total population (2012–2016).







(A) With outlier counties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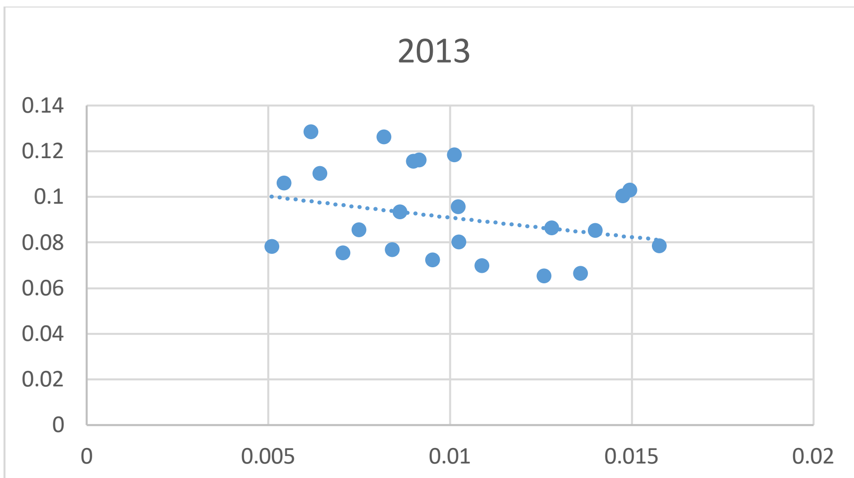
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016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0.08
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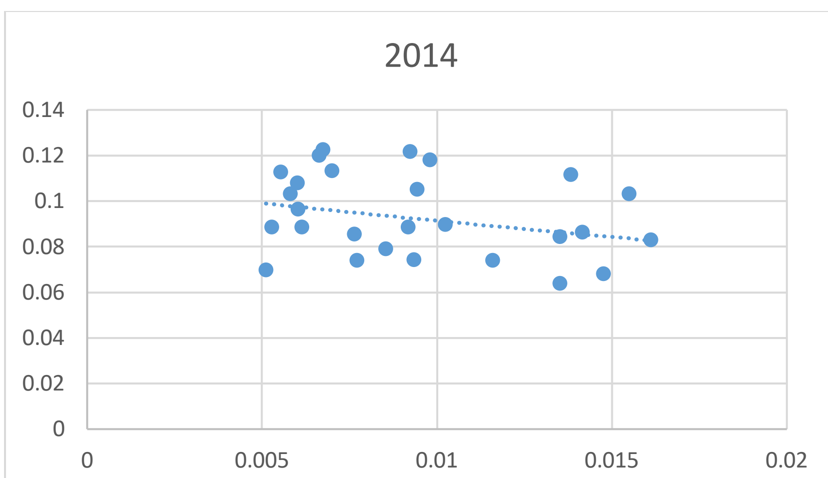
0.02
0
0
0.005
0.01
0.015
0.02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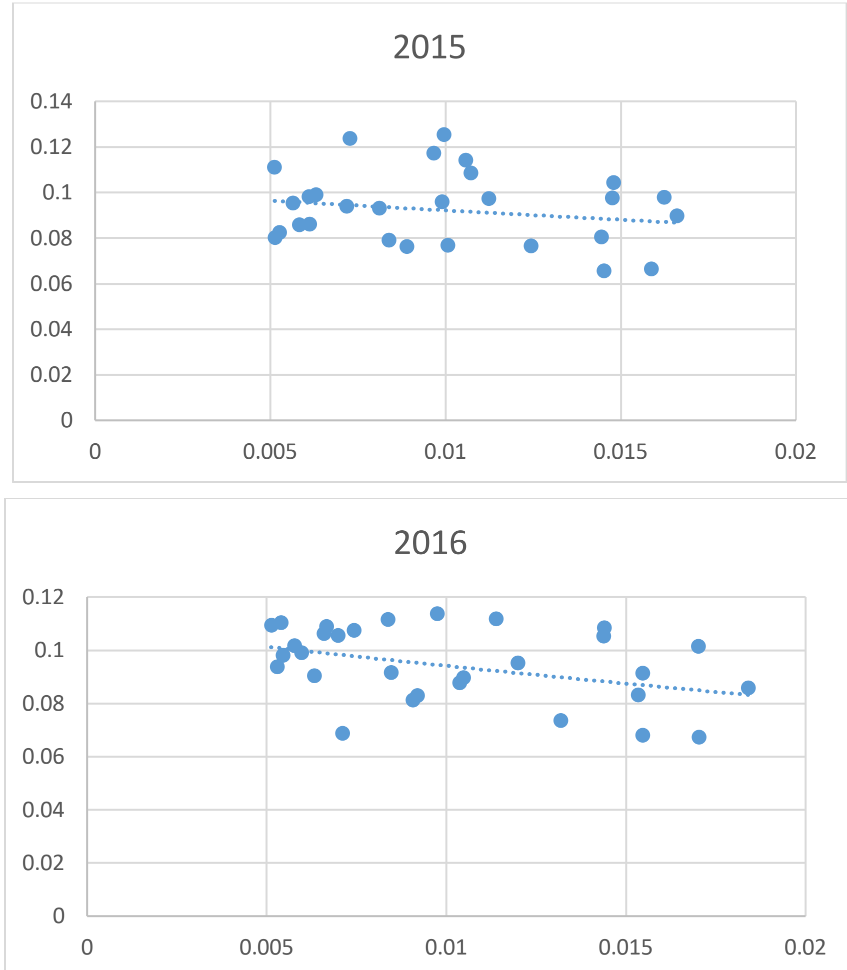
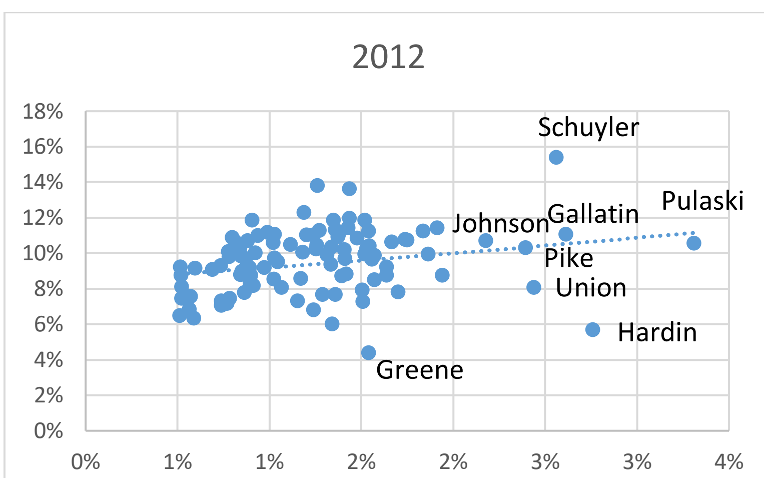
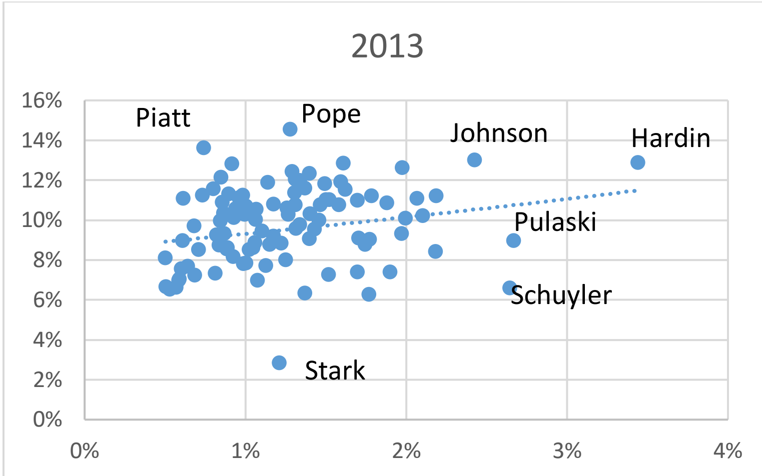


(B) Without outlier counties

Figure 89. Graph. Older black and Hispanic population among total population vs. crashes involving older people among total crashes (2012–2016).




2013
16%
14%
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8%
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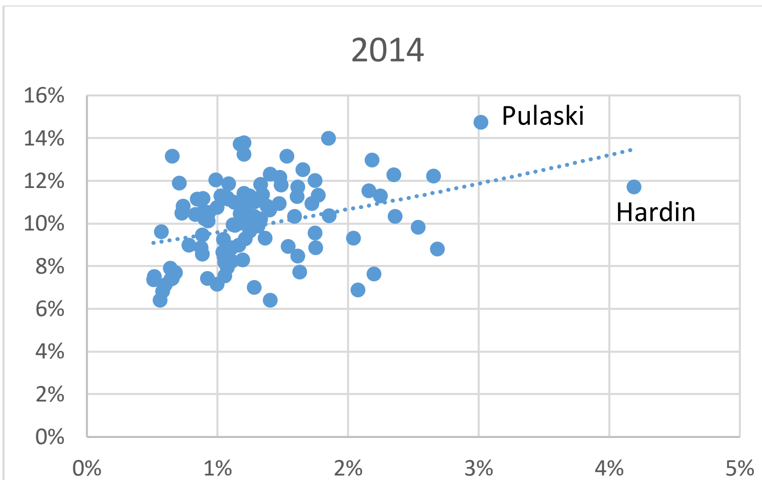
Piatt
Pope
Johnson
Hardin
Pulaski
Schuyler
Stark


2014
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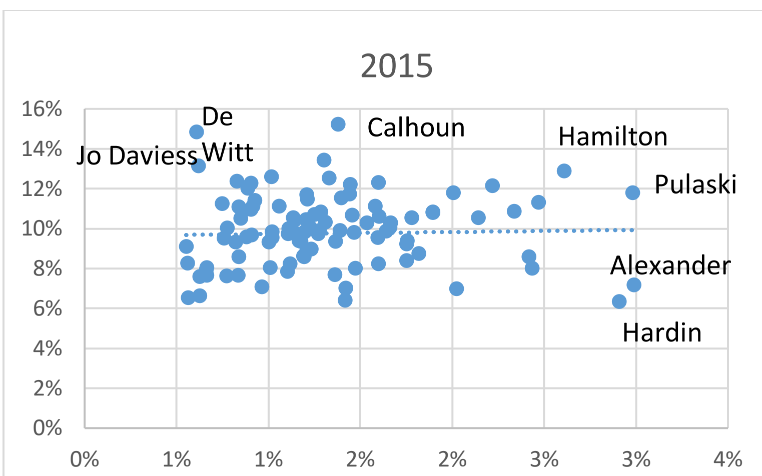
Pulaski
Hardin


2015
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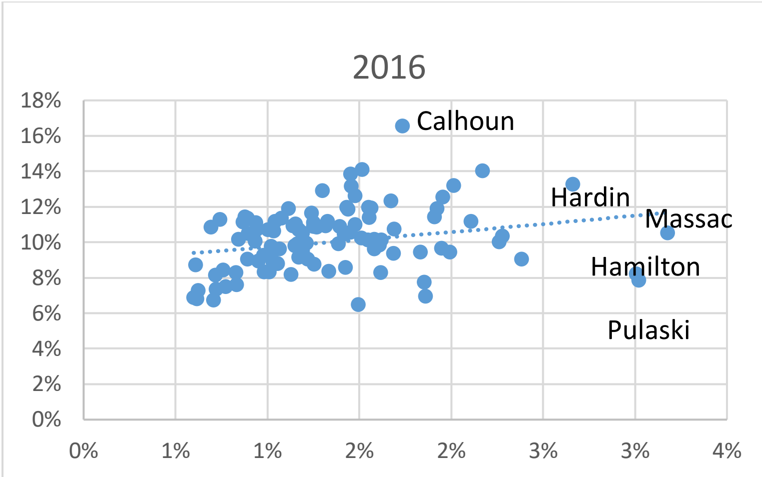
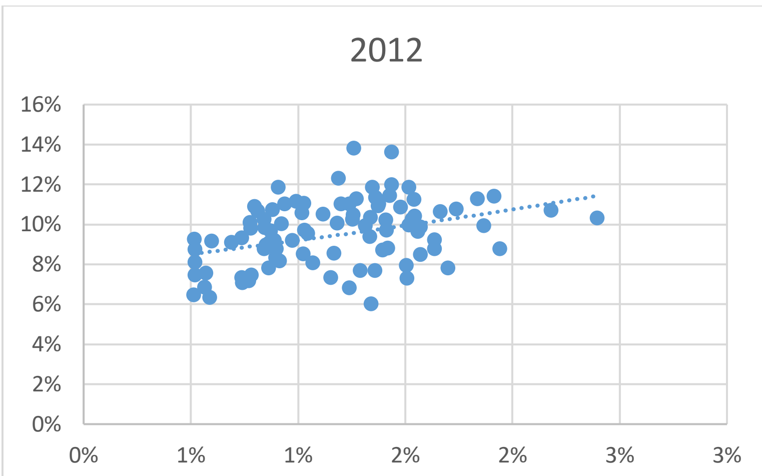
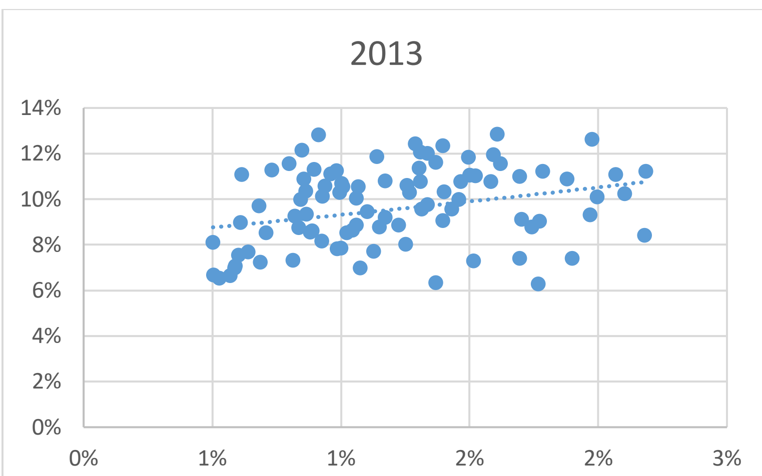
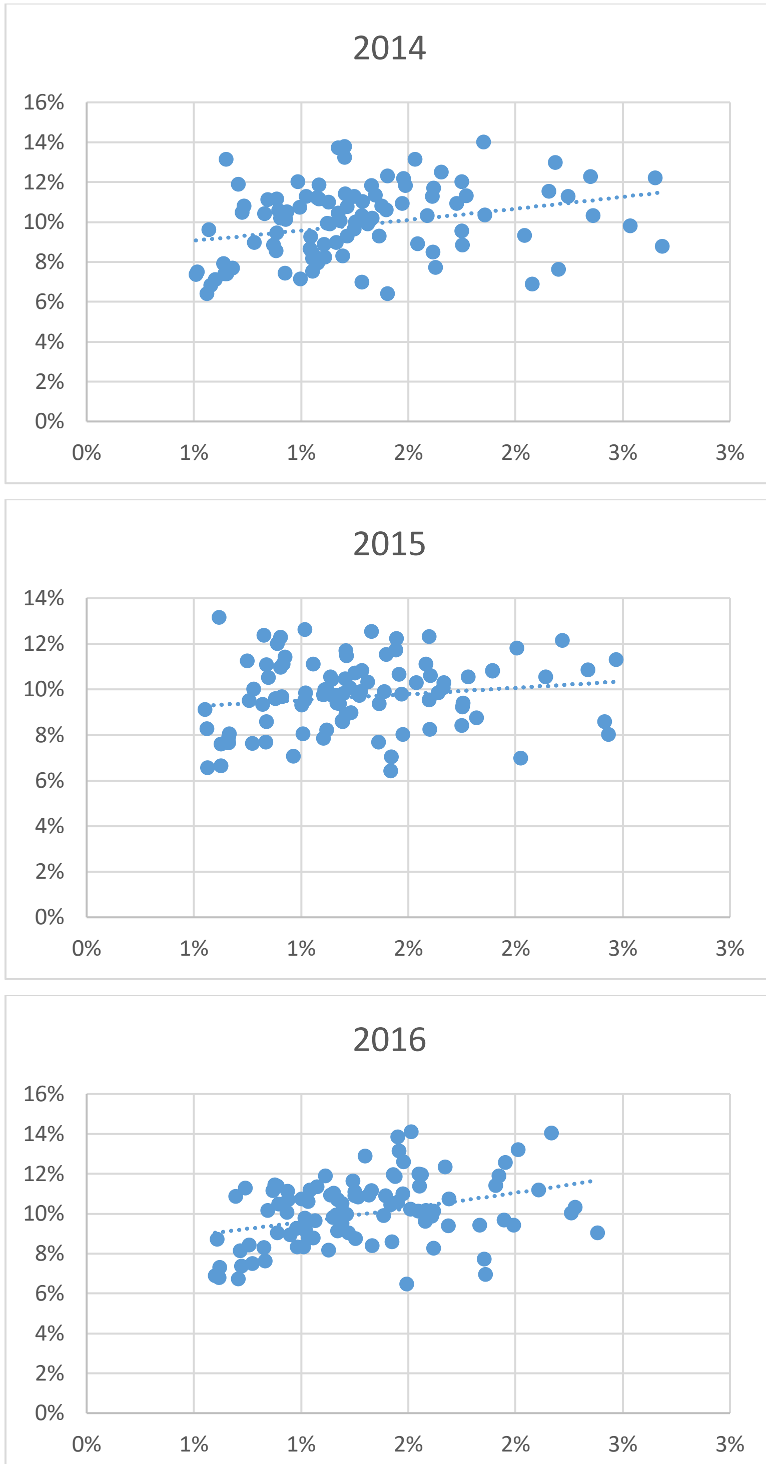
Jo Daviess
De Witt
Calhoun
Hamilton
Pulaski
Alexander
Hardin



(A) With outlier counties

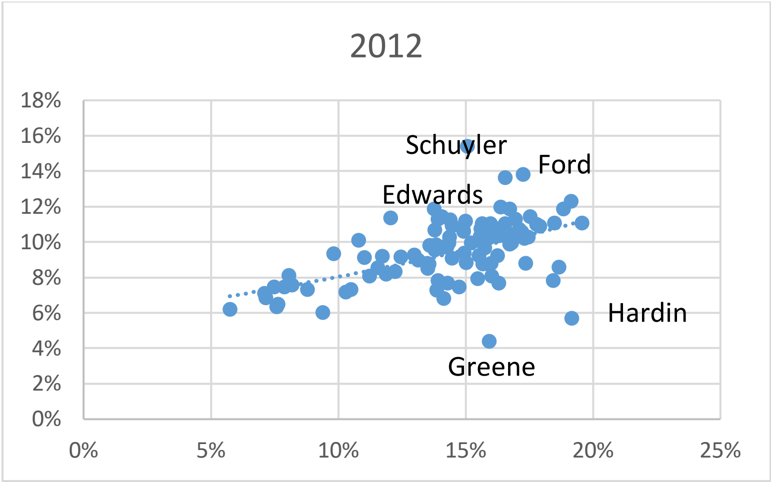






(B) Without outlier counties

Figure 90. Graph. Older people under the poverty level among total population vs. crashes involving older people among total crashes (2012–2016).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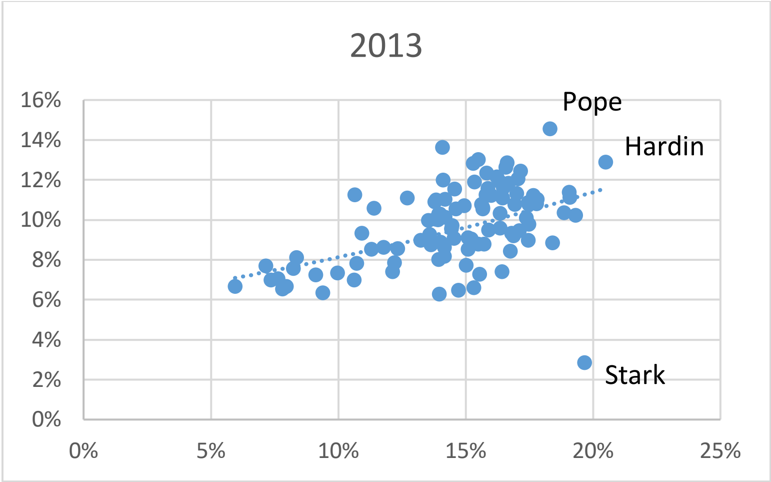
Schuyler
Ford
Edwards
Hardin
Greene


2013
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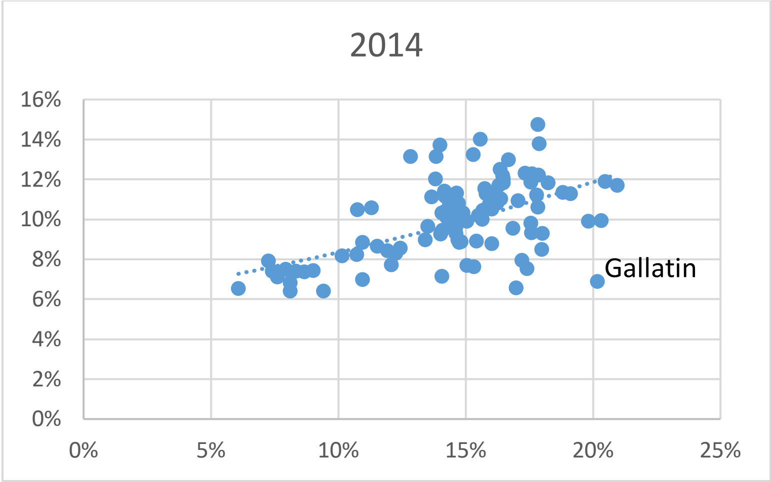
Pope
Hardin
Stark


2014
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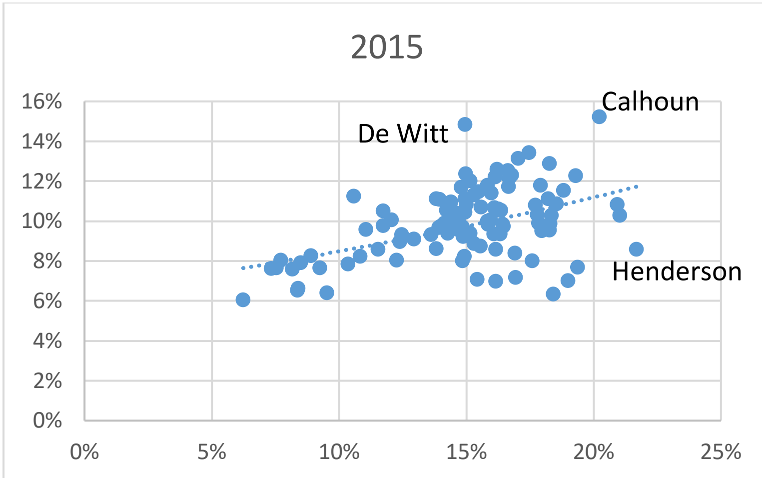
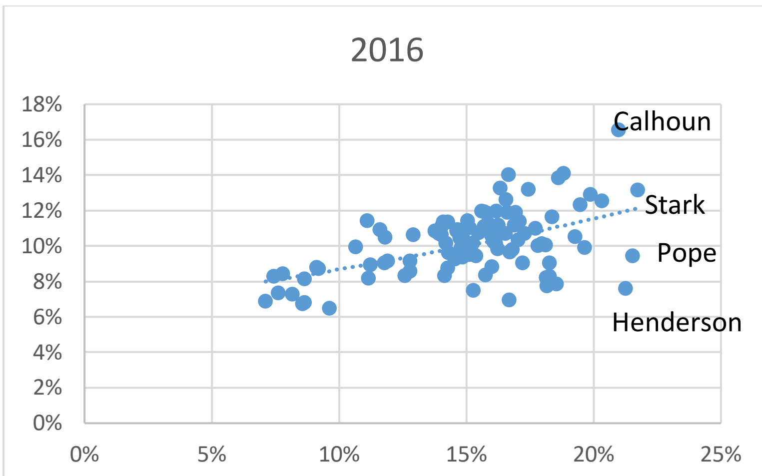
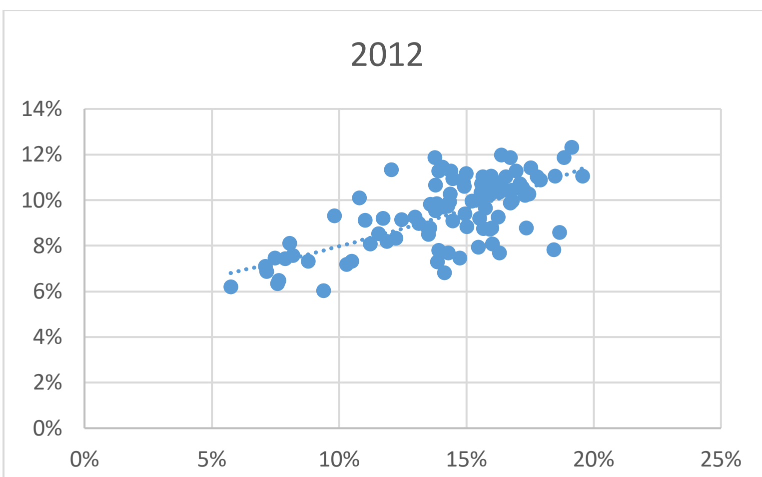
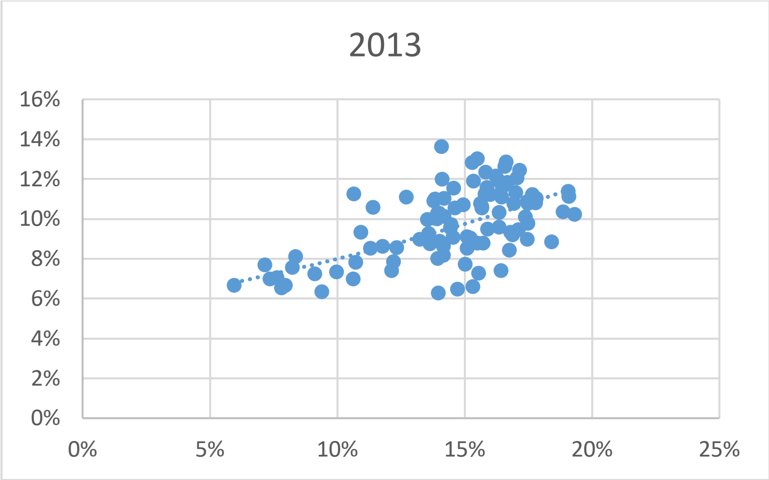




(A) With outlier counties





2013
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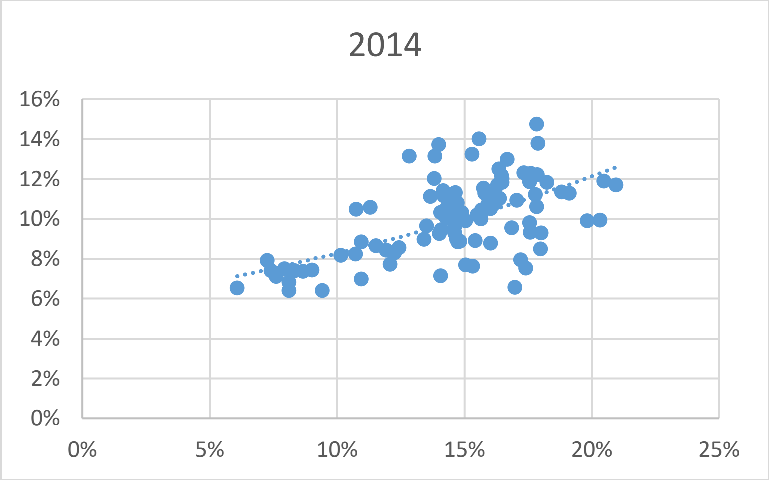

2014
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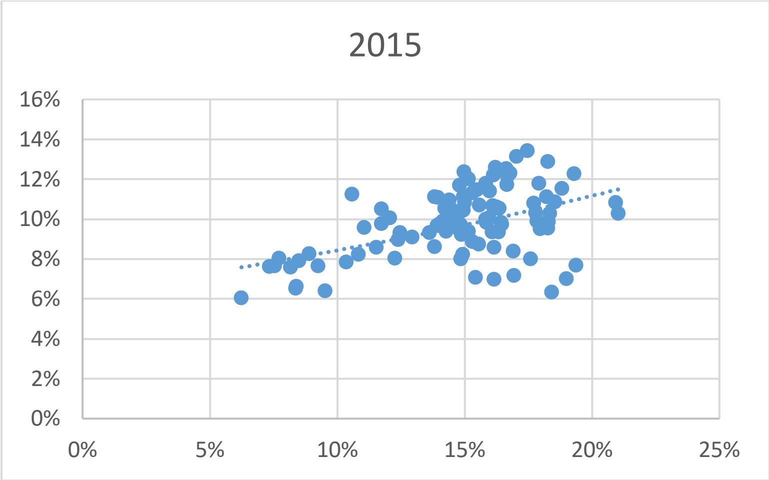

2015
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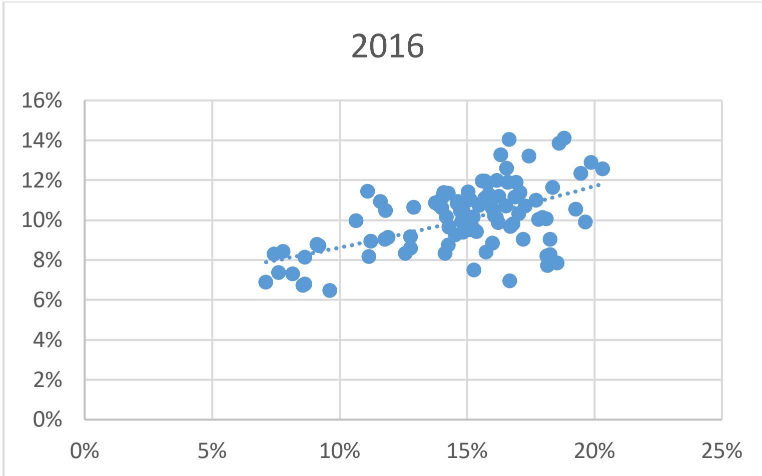
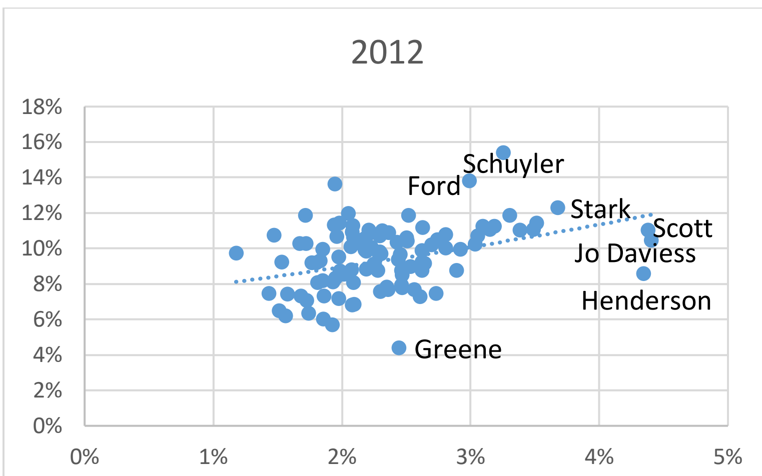
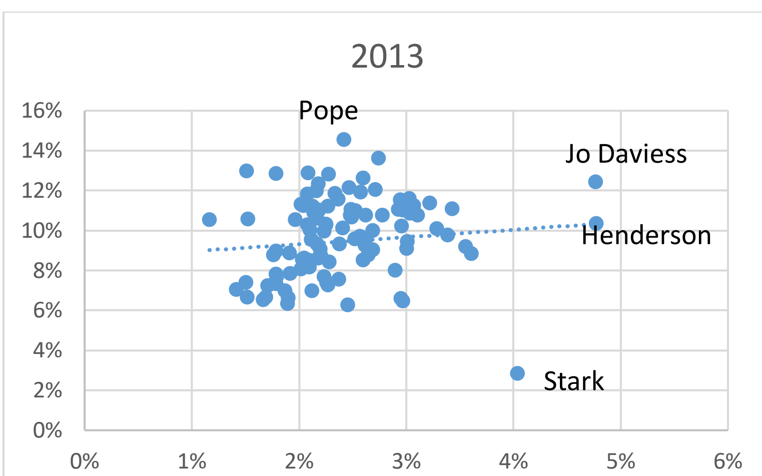
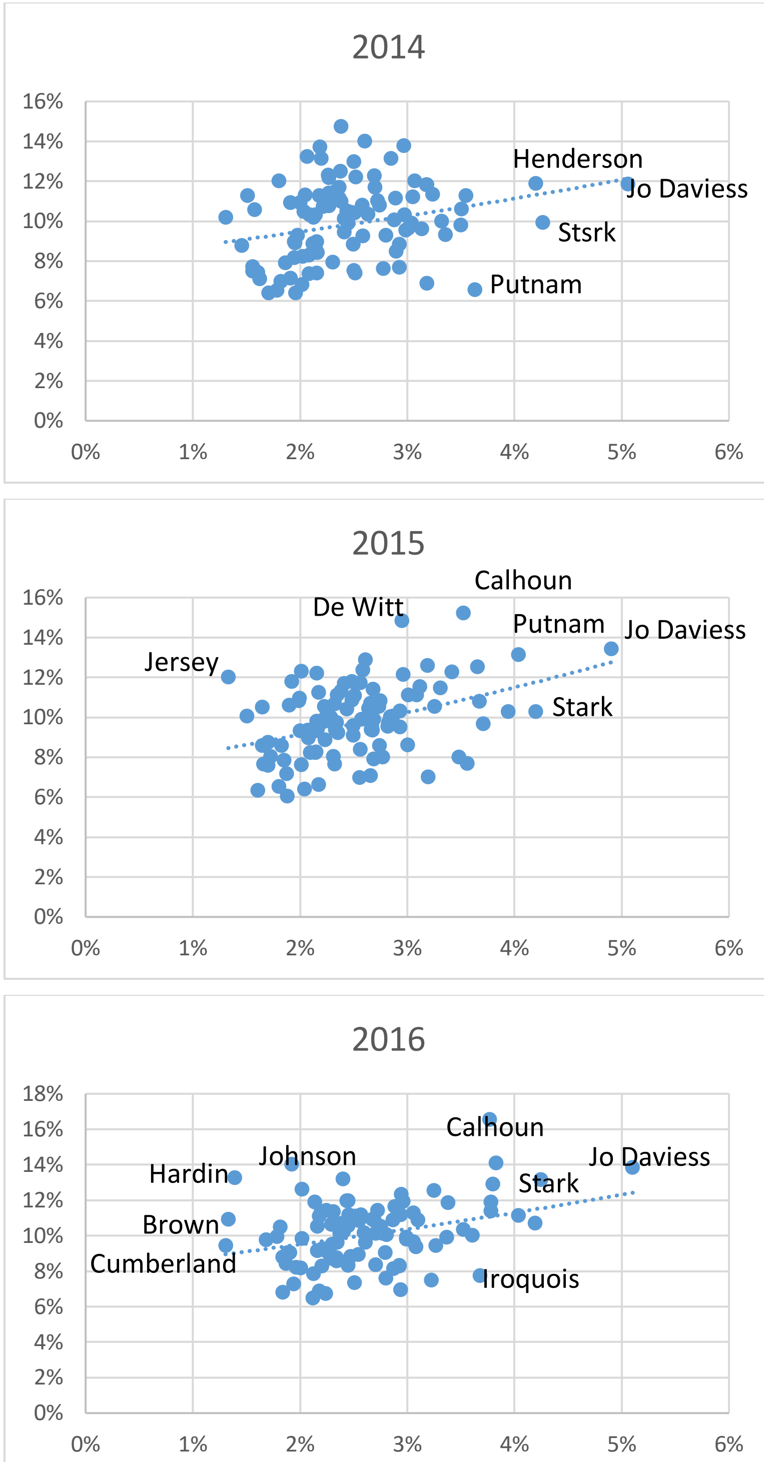


(B) Without outlier counties

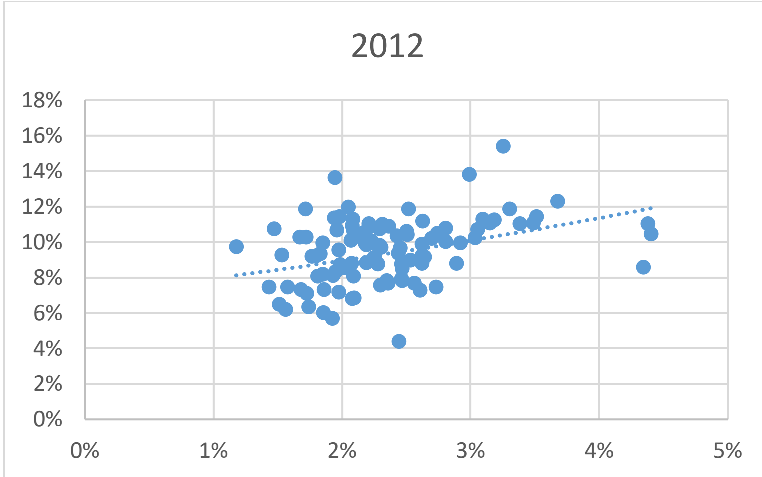
Figure 91. Graph. Older population with up to college education (among total population) vs. crashes involving older people (among total crashes) (2012–2016).







(A) With outlier counties


2012
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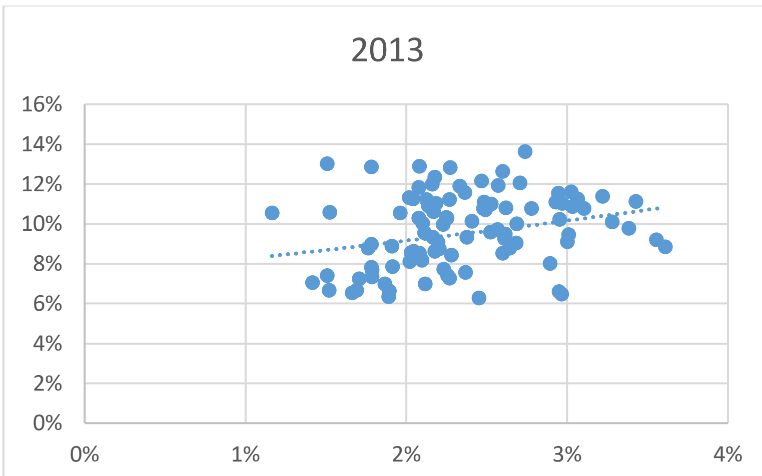
2013
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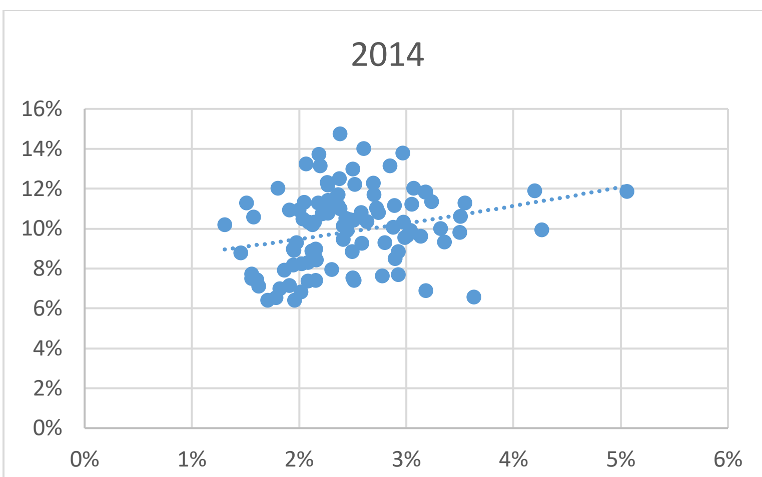
2014
16%
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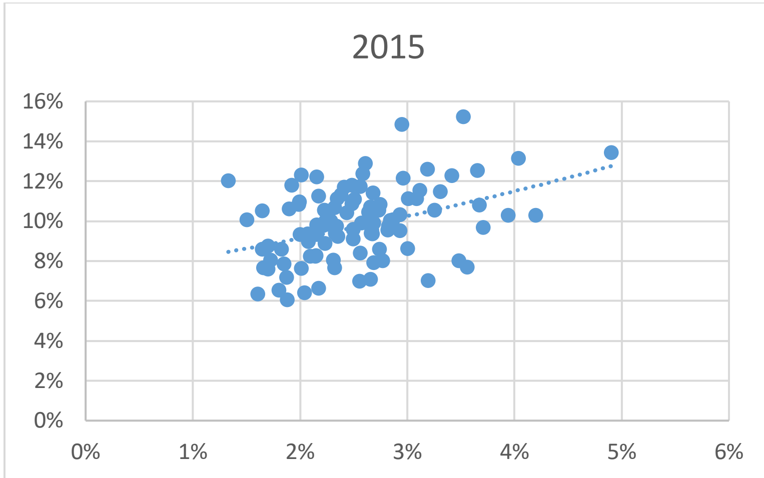

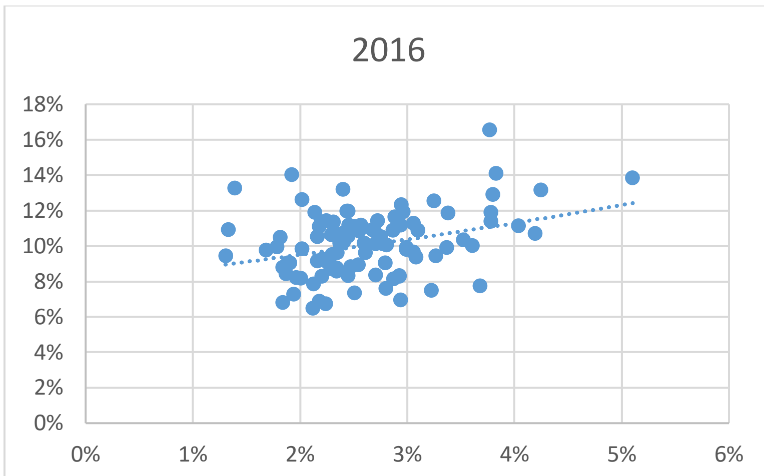

(B) Without outlier counties

Figure 92. Graph. Employment of older population (among total population) vs. crashes involving older people (among total crashes) (2012–2016).

APPENDIX D: SURVEY QUESTIONNAIRE

Survey on Motor Vehicle Crashes among Drivers Age 65+

The Illinois Department of Transportation (IDOT) is interested in your opinion on driving safety and mobility issues, particularly the safety and mobility of drivers age 65 and older in Illinois. Your answers to the following questions are voluntary and anonymous. Please complete the survey and mail it back using the prepaid envelop provided. If you have any questions or need additional information, please send an email to Rebecca.Dieken@illinois.gov.

Demographic Characteristics

1. **Your Gender:** ☐ Male ☐ Female
2. **Your Age:** ☐ 64 or less ☐ 65-74 ☐75-84 ☐ 85 or older
3. **Your Ethnicity:** ☐ Caucasian ☐ African American ☐ Asian ☐ Hispanic ☐ Other
4. **Your Education:** ☐ Up to high school ☐ Some college ☐ College degree and above
5. **Your ZIP Code**: ___________________________

Driving Exposure

6. **How often do you drive in a week?**
   ☐ Every day ☐ 3-5 days ☐ 1-2 days ☐ weekend only
7. **How many miles did you drive last year?**
   ☐ Less than 5,000 ☐ 5,000-10,000 ☐ 10,001-15,000 ☐ More than 15,000
8. **What type of vehicle do you drive most often?**
   ☐ Passenger Car ☐ Pickup Truck ☐ SUV ☐ Minivan ☐ Other
9. **What type of roadway do you travel most often?**
   ☐ Local roads (up to 35 mph) ☐ Highway (40-55mph) ☐Freeway (70mph and above)

Driving Behavior and Habits

10. **How often do you use seat belts while driving?**
    ☐ All the time☐ some of the time ☐ Rarely ☐ Never
11. **How often do you drive over 5 mph faster than the posted speed limit?**
    ☐ All the time☐ Some of the time ☐ Rarely ☐ Never
12. **In the past 60 days, have you driven a motor vehicle within 2 hours after drinking alcoholic beverages?**
    ☐ Yes ☐ No
13. **Which driving condition do you usually try to avoid (check all those apply)?**
    ☐Nighttime ☐Bad weather ☐ High-speed roads ☐Heavy traffic ☐Driving alone
    ☐Left turn across traffic ☐Long trips ☐Unfamiliar roads ☐Rush hour ☐Other_____________

1

Physical Conditions and Medications

14. **Did you experience fall in last year?** ☐ Yes ☐ No
15. **If yes to Q14, how many times did you fall?** ☐Once ☐ twice ☐ 3 or more
16. **Do you experience difficulty in any of the following daily lift activities (check all that apply)?**
    ☐ Bathing self ☐ Dressing and undressing ☐ Using restroom ☐ Feeding self
    ☐ Getting in and out of bed ☐ Walking between rooms ☐ Other ☐ None
17. **Do you experience any of the following mobility difficulties (check all those apply) ?**
    ☐ Using stairs ☐Walking more than ¼ mile ☐ Carrying heavy objects ☐ Other ☐ None
18. **What do you believe impairs your driving abilities the most?**
    ☐ Stiff joints and muscles ☐ Trouble seeing ☐ Trouble hearing
    ☐ Slower reaction time ☐ Medication ☐ Other
19. **Are you currently on prescription drugs in any of the following medication classes (check all those apply)?**
    ☐ Barbiturates ☐Benzodiazepines ☐ Hypnotics ☐Antidepressants ☐ Opioid and nonsteroidal analgesics ☐ Anticonvulsants ☐ Antipsychotics ☐ Antiparkinsonian agents ☐Skeletal muscle relaxants ☐Antihistamines ☐ Anticholinergic medications ☐ Hypoglycemic agents
    ☐Other_______________
20. **Are you aware of or have you been warned by any healthcare provider on the possible driving impairing side effect of prescribe drugs you take?** ☐ Yes ☐ No

Driving Safety

21. **Have you experienced a crash or a near miss crash of the following crash types in the last two years (check all that apply)?**
    ☐Overturned ☐Fixed objective ☐ Parked vehicle ☐Turning ☐Rear-end
    ☐Sideswipe ☐Head-on ☐Angle ☐Pedestrian/bicyclist ☐Other_______________
22. **What circumstances do you think as a risk when your drive (check all that apply)?**
    ☐ Reading signs ☐ Insufficient sight distance ☐ Headlight glare at night ☐ Blowing materials☐ Speed of other drivers ☐ Blind spots ☐ Left turn at intersections
    ☐ Short merging/diverging segment ☐ Small turn radius ☐Other_______________
23. **What improvement in roadway design and operation do you think will improve safe driving (check all that apply)?**
    ☐ Larger font on signs ☐ Longer left-turn signal ☐ Longer non-parking zone at intersections
    ☐ Longer turn radius ☐ Advanced warning of curves and embankments
    ☐Longer merging/diverging segments ☐Enhanced crosswalks ☐Other______________

2

APPENDIX E: SURVEY SAMPLE

DP_COUNTY_NAME	GENDER	AGE_65_74	AGE_75_84	AGE_85	NO_ADDR
ADAMS	FEMALE	3927	2587	2195	0
ADAMS	MALE	3631	2208	1564	1
ALEXANDER	FEMALE	418	299	197	0
ALEXANDER	MALE	427	266	145	0
BOND	FEMALE	966	587	500	0
BOND	MALE	954	532	352	0
BOONE	FEMALE	2573	1563	827	0
BOONE	MALE	2561	1521	708	0
BROWN	FEMALE	288	191	133	0
BROWN	MALE	277	175	103	0
BUREAU	FEMALE	2170	1422	1172	0
BUREAU	MALE	2097	1319	892	1
CALHOUN	FEMALE	315	229	154	1
CALHOUN	MALE	321	249	133	0
CARROLL	FEMALE	1114	755	536	0
CARROLL	MALE	1181	696	444	0
CASS	FEMALE	643	453	350	0
CASS	MALE	695	395	261	1
CHAMPAIGN	FEMALE	8633	4635	3453	0
CHAMPAIGN	MALE	8037	3929	2672	0
CHRISTIAN	FEMALE	2025	1392	1138	0
CHRISTIAN	MALE	1867	1247	818	0
CLARK	FEMALE	996	677	525	0
CLARK	MALE	931	627	376	0
CLAY	FEMALE	858	532	474	0
CLAY	MALE	823	475	308	4
CLINTON	FEMALE	1887	1280	1024	0
CLINTON	MALE	1881	1126	735	0
COLES	FEMALE	2566	1778	1313	0
COLES	MALE	2409	1453	930	0
COOK	FEMALE	213951	115907	72634	1
COOK	MALE	213555	110107	66351	4
CRAWFORD	FEMALE	1182	818	652	0
CRAWFORD	MALE	1106	696	431	0
CUMBERLAND	FEMALE	658	402	325	0
CUMBERLAND	MALE	653	377	240	0
DE KALB	FEMALE	4391	2552	1736	0
DE KALB	MALE	4258	2260	1300	0

DP_COUNTY_NAME	GENDER	AGE_65_74	AGE_75_84	AGE_85	NO_ADDR
DE WITT	FEMALE	978	671	454	0
DE WITT	MALE	938	569	344	0
DOUGLAS	FEMALE	991	708	590	0
DOUGLAS	MALE	999	616	442	0
DU PAGE	FEMALE	48026	24077	15513	0
DU PAGE	MALE	47067	22395	12419	0
EDGAR	FEMALE	1116	799	608	0
EDGAR	MALE	1143	690	428	0
EDWARDS	FEMALE	433	304	264	0
EDWARDS	MALE	416	244	172	2
EFFINGHAM	FEMALE	1902	1296	988	0
EFFINGHAM	MALE	1851	1048	692	0
FAYETTE	FEMALE	1188	834	629	0
FAYETTE	MALE	1151	735	511	2
FORD	FEMALE	753	561	523	0
FORD	MALE	752	464	300	0
FRANKLIN	FEMALE	2526	1757	1250	0
FRANKLIN	MALE	2455	1597	907	0
FULTON	FEMALE	2256	1517	1209	0
FULTON	MALE	2155	1355	893	1
GALLATIN	FEMALE	405	275	176	0
GALLATIN	MALE	363	261	131	2
GREENE	FEMALE	819	519	414	0
GREENE	MALE	767	484	341	0
GRUNDY	FEMALE	2519	1403	933	0
GRUNDY	MALE	2504	1333	654	0
HAMILTON	FEMALE	507	364	302	0
HAMILTON	MALE	523	342	210	0
HANCOCK	FEMALE	1218	857	741	0
HANCOCK	MALE	1231	738	541	2
HARDIN	FEMALE	331	194	118	0
HARDIN	MALE	319	214	108	1
HENDERSON	FEMALE	474	362	238	0
HENDERSON	MALE	501	351	180	1
HENRY	FEMALE	3152	2038	1648	0
HENRY	MALE	3050	1843	1155	0
IROQUOIS	FEMALE	1763	1237	1039	0
IROQUOIS	MALE	1737	1191	753	0
JACKSON	FEMALE	2779	1604	1133	0
JACKSON	MALE	2762	1410	894	1

DP_COUNTY_NAME	GENDER	AGE_65_74	AGE_75_84	AGE_85	NO_ADDR
JASPER	FEMALE	568	390	347	1
JASPER	MALE	602	363	252	0
JEFFERSON	FEMALE	2265	1428	994	0
JEFFERSON	MALE	2181	1345	748	1
JERSEY	FEMALE	1327	877	574	0
JERSEY	MALE	1319	788	456	1
JO DAVIESS	FEMALE	1835	1162	719	0
JO DAVIESS	MALE	1889	1175	632	1
JOHNSON	FEMALE	785	523	297	0
JOHNSON	MALE	773	546	231	1
KANE	FEMALE	23169	11948	6644	0
KANE	MALE	22756	11259	5432	0
KANKAKEE	FEMALE	5876	3509	2452	0
KANKAKEE	MALE	5414	3112	1826	2
KENDALL	FEMALE	4689	2291	1085	0
KENDALL	MALE	4272	2137	871	0
KNOX	FEMALE	3367	2220	1717	0
KNOX	MALE	3138	1976	1292	1
LA SALLE	FEMALE	6408	4221	3309	0
LA SALLE	MALE	6340	3746	2449	0
LAKE	FEMALE	32883	16519	10194	0
LAKE	MALE	32883	15855	8572	0
LAWRENCE	FEMALE	885	603	506	0
LAWRENCE	MALE	838	516	348	0
LEE	FEMALE	2081	1239	892	0
LEE	MALE	1997	1146	718	0
LIVINGSTON	FEMALE	2067	1355	1186	0
LIVINGSTON	MALE	2006	1205	802	0
LOGAN	FEMALE	1612	1113	923	0
LOGAN	MALE	1520	927	648	1
MACON	FEMALE	6658	4044	3274	0
MACON	MALE	6037	3596	2423	0
MACOUPIN	FEMALE	2874	1797	1495	0
MACOUPIN	MALE	2798	1688	1140	1
MADISON	FEMALE	15106	9242	6734	0
MADISON	MALE	13684	8000	4994	0
MARION	FEMALE	2420	1617	1178	0
MARION	MALE	2264	1480	870	0
MARSHALL	FEMALE	823	523	413	0
MARSHALL	MALE	830	486	315	0

DP_COUNTY_NAME	GENDER	AGE_65_74	AGE_75_84	AGE_85	NO_ADDR
MASON	FEMALE	926	598	484	0
MASON	MALE	900	599	364	1
MASSAC	FEMALE	888	659	437	1
MASSAC	MALE	842	572	344	0
MC DONOUGH	FEMALE	1594	1007	969	0
MC DONOUGH	MALE	1554	941	640	3
MC HENRY	FEMALE	16048	8339	4107	0
MC HENRY	MALE	15610	7926	3601	0
MC LEAN	FEMALE	7913	4196	3096	0
MC LEAN	MALE	7354	3617	2220	1
MENARD	FEMALE	829	461	292	0
MENARD	MALE	746	422	235	1
MERCER	FEMALE	1027	736	535	1
MERCER	MALE	1062	694	397	1
MONROE	FEMALE	1931	1136	796	0
MONROE	MALE	1961	993	620	0
MONTGOMERY	FEMALE	1695	1166	1003	0
MONTGOMERY	MALE	1619	1000	692	0
MORGAN	FEMALE	2082	1408	1101	0
MORGAN	MALE	1910	1171	732	2
MOULTRIE	FEMALE	817	522	416	1
MOULTRIE	MALE	780	482	308	0
OGLE	FEMALE	2965	1876	1290	0
OGLE	MALE	2962	1794	1042	0
OUT OF STATE	FEMALE	271	53	13	0
OUT OF STATE	MALE	1222	378	45	1
PEORIA	FEMALE	10167	5821	4517	0
PEORIA	MALE	9295	5257	3282	0
PERRY	FEMALE	1248	805	637	0
PERRY	MALE	1189	752	444	0
PIATT	FEMALE	1020	703	536	0
PIATT	MALE	1004	603	397	0
PIKE	FEMALE	957	692	600	0
PIKE	MALE	979	622	426	0
POPE	FEMALE	304	201	102	1
POPE	MALE	325	223	132	0
PULASKI	FEMALE	380	217	186	0
PULASKI	MALE	359	216	145	3
PUTNAM	FEMALE	396	240	171	0
PUTNAM	MALE	416	257	129	0

DP_COUNTY_NAME	GENDER	AGE_65_74	AGE_75_84	AGE_85	NO_ADDR
RANDOLPH	FEMALE	1814	1244	934	0
RANDOLPH	MALE	1761	1094	638	2
RICHLAND	FEMALE	961	723	557	0
RICHLAND	MALE	914	651	399	1
ROCK ISLAND	FEMALE	8825	5337	4262	0
ROCK ISLAND	MALE	8273	4916	3089	0
SALINE	FEMALE	1557	1171	791	0
SALINE	MALE	1415	964	564	1
SANGAMON	FEMALE	12235	6617	4775	0
SANGAMON	MALE	10643	5538	3367	0
SCHUYLER	FEMALE	456	309	262	0
SCHUYLER	MALE	467	293	197	0
SCOTT	FEMALE	300	208	164	0
SCOTT	MALE	292	198	121	0
SHELBY	FEMALE	1425	925	718	1
SHELBY	MALE	1416	907	553	0
ST. CLAIR	FEMALE	13529	7550	5609	0
ST. CLAIR	MALE	12414	6339	4153	0
STARK	FEMALE	364	252	228	0
STARK	MALE	362	266	140	0
STEPHENSON	FEMALE	3007	2050	1569	0
STEPHENSON	MALE	2807	1801	1189	0
TAZEWELL	FEMALE	8116	4975	3611	1
TAZEWELL	MALE	7557	4361	2941	0
UNION	FEMALE	1119	780	485	0
UNION	MALE	1074	751	359	0
VERMILION	FEMALE	4681	3107	2338	0
VERMILION	MALE	4370	2738	1723	1
WABASH	FEMALE	735	475	412	0
WABASH	MALE	737	423	271	0
WARREN	FEMALE	1045	715	560	0
WARREN	MALE	1008	663	370	0
WASHINGTON	FEMALE	829	591	465	0
WASHINGTON	MALE	897	518	313	1
WAYNE	FEMALE	1014	788	631	0
WAYNE	MALE	958	703	448	1
WHITE	FEMALE	974	711	579	2
WHITE	MALE	900	606	427	0
WHITESIDE	FEMALE	3649	2256	1761	0
WHITESIDE	MALE	3377	2107	1315	0

DP_COUNTY_NAME	GENDER	AGE_65_74	AGE_75_84	AGE_85	NO_ADDR
WILL	FEMALE	30031	15702	8211	0
WILL	MALE	29008	14681	6923	1
WILLIAMSON	FEMALE	4118	2711	1778	1
WILLIAMSON	MALE	3750	2379	1279	0
WINNEBAGO	FEMALE	16284	9408	6624	0
WINNEBAGO	MALE	15045	8490	5057	0
WOODFORD	FEMALE	2152	1295	1137	0
WOODFORD	MALE	2168	1213	796	1

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