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IMPAIRED ACTIVE TRANSPORTATION USERS

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16. Abstract

Researchers have determined that a significant number of pedestrian and bicycle crashes arise from intoxicated non-motorists (Hutchinson, Kloeden, and Lindsay, 2010). While driver and non-motorized fatalities have decreased significantly over several decades, the extent of alcohol involvement has declined significantly only among fatally injured drivers, despite the fact that alcohol involvement among traffic fatalities has been found to be highest among active transportation users, and recent trends show that active motorist fatalities have seen an increase as well (Holubowycs, 2015). Issues have also been found in crash report narratives, and certain environmental factors have been identified as contributing to intoxicated active transportation crashes. This project involved an in-depth evaluation of active transportation fatalities involving intoxication to create a comprehensive profile of the characteristics associated with these crashes, including personal characteristics and demographics. A policy evaluation was also included to identify how other jurisdictions are effectively addressing these crashes. The project team worked to create a more detailed profile for active transportation fatalities that involve intoxication. During the study, the group worked directly with a research team at USU to coordinate a second evaluation which examined land-use and development characteristics near crash sites. These complimentary projects will allow UDOT to better understand the circumstances surrounding active transportation fatalities that involve intoxication, which will provide insight and direction on how to best prevent such crashes from occurring.

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LIST OF ACRONYMS

ATV	All-Terrain Vehicle
BAC	Blood Alcohol Concentration
BCO	Portion of KABCO Crash Severity Scale that represents minor injury, possible injury, or no injury crashes
DPS	Department of Public Safety
EPA	Environmental Protection Agency
KA	Portion of KABCO Crash Severity Scale that represents fatal or suspected serious injury
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
SLD	Smart Location Database
SUV	Sport Utility Vehicle
UDOT	Utah Department of Transportation
UGRC	Utah Geographic Resource Center
US	United States
UTAPS-CDI	Utah Transportation and Public Safety – Crash Data Initiative

EXECUTIVE SUMMARY

Researchers have found that a significant number of pedestrian crashes arises from intoxicated pedestrians (Hutchinson et al., 2010). Over 80% of people in the United States (US) report walking at least once per week, and 92% report feeling safe while walking. Additionally, less than 3% of people report having been injured while walking in the past two years (Schroeder and Wilbur, 2013). However, 6,205 pedestrians were killed in traffic crashes nationwide in 2019 (NHTSA, 2021). While driver and pedestrian fatalities have decreased significantly over the last several decades, the extent of alcohol involvement has declined significantly only among fatally injured drivers, and recent trends have found that active transportation facilities have increased in the last decade. Research comparisons of the extent of alcohol involvement among fatally injured pedestrians, drivers, passengers, and motorcycle riders showed that alcohol involvement, particularly at the higher levels of blood alcohol concentration, was most prevalent among pedestrians (Holubowycs, 1995). Prior Utah Department of Transportation (UDOT) research has shown that pedestrian crashes are most likely to be fatal when occurring at night or during the dark hours in the evening and early morning (Burbidge, 2016). Other environmental factors such as infrastructure, lighting, and vehicle speeds may also contribute to pedestrian crashes.

The primary objective of this project will be to conduct an in-depth evaluation of active transportation fatalities involving intoxication. This evaluation will be used to create a comprehensive profile of the characteristics associated with these crashes, including personal characteristics and demographics. In order to create this profile, crashes from 2010 through 2021 were filtered for impaired pedestrians and bicyclists with severity level of fatal or suspected serious injury. This study included various secondary sources such as Utah crash data provided by Numetric, the Environmental Protection Agency Smart Location Database, US Census data, and shapefiles from the Utah Geographic Resource Center (UGRC) and the Utah Department of Transportation (UDOT) for assembling data and spatial processing to link these to individual crashes. The assembled data was then used to conduct descriptive analyses, comparative analyses, statistical tests, etc.

Comparative analysis of different groups of bicyclist/pedestrian crashes shows that impaired bicyclists/pedestrians involved in a crash tended to be older than non-impaired bicyclists/pedestrians (38 vs. 31 years old, on average). Active mode user impairment is more likely to be reported for crashes in neighborhoods with smaller average household sizes and fewer workers per household, in rural areas, in places with lower intersection density, and in areas with more facilities that sell liquor products at present. Furthermore, these crashes are more likely to be reported on weekends (vs. weekdays) and overnight (vs. in the evening, morning, or afternoon).

Of the total 299 impaired bicycle/pedestrian crashes, 181 were alcohol related. Overall results tended to match those for alcohol impairment specifically. Investigation of demographics and neighborhood social and built environment characteristics revealed that for alcohol-impaired bicycle crashes (unlike for overall impairment), roadway geometry and posted speed were not significant; but distance to the nearest crosswalk had a significant positive association with alcohol impairment status. Alcohol-impaired pedestrian crashes were higher in areas with high numbers of jobs within a 45-minute commute by transit. For drug-impaired crashes, this study found no associations with liquor facilities. However, crashes involving bicyclists were more likely to report drug impairment in areas with more food banks.

Lastly, comparison of severe vs. non-severe impaired active mode user crashes showed that for severe crashes, active mode user impairment was more likely to be reported in places with more nearby grocery stores. Crash severity tends to decrease as distance from grocery and/or convenience stores increases.

1.0 INTRODUCTION

1.1 Problem Statement

Researchers have found that a substantial portion of active transportation crashes involve intoxicated pedestrians (Hutchinson, Kloeden, and Lindsay, 2010). While driver and pedestrian fatalities have decreased significantly over the past several decades, the extent of alcohol involvement has declined significantly only among fatally injured drivers, and active transportation fatalities have increased in the last decade. Research comparisons of the extent of alcohol involvement among fatally injured pedestrians, drivers, passengers, and motorcycle riders showed that alcohol involvement, particularly at the higher levels of blood alcohol concentration, was most prevalent among pedestrians (Holubowycs, 1995). Prior UDOT research has shown that pedestrian crashes are most likely to be fatal when occurring at night or during the dark hours in the evening and early morning. A recent study of pedestrians struck by vehicles in Los Angeles County found that those struck during late hours are commonly intoxicated (Knight, Li, and Dhillon, 2020). Another major drawback of researching crashes involving an intoxicated pedestrian results from a lack of detail in the narrative. Often, once the responding law enforcement officer determines that the pedestrian was intoxicated, the investigation ends there due to an assumption (perhaps incorrect) that the individual's blood alcohol level was the sole cause of the crash. These common issues may inhibit better understanding of intoxicated pedestrian crashes.

1.2 Objectives

The primary objective of this project was to conduct an in-depth evaluation of active transportation fatalities involving intoxication. This evaluation was used to create a comprehensive profile of the characteristics associated with these crashes, including personal characteristics and demographics. A policy evaluation was also included to identify how other jurisdictions are effectively addressing these crashes. A comprehensive database of intoxicated pedestrian crashes in Utah over the last decade was compiled. The database includes site characteristics (neighborhood demographics, surrounding land-use, number of lanes, speed limit, etc.) and crash characteristics.

1.3 Scope

The project team will identify a more detailed profile for pedestrian fatalities that involve intoxication. The project team will work directly with a research team at USU to coordinate a second evaluation, which will evaluate land-use and development characteristics near crash sites. This comprehensive project will allow UDOT to better understand the circumstances surrounding pedestrian and bicycle fatalities that involve intoxication, which will provide more detailed insight.

1.4 Outline of Report

The report is organized into five sections, as follows: Section 2 provides a brief literature review of intoxicated pedestrian fatalities and their characteristics, along with a review of previously used mitigation strategies. Section 2 also includes a description of the study methods and justifications. Section 3 presents the data collection methods and provides summary characteristics of collected data on intoxicated pedestrian fatalities and associated crashes. Section 4 presents a qualitative and quantitative analysis of the crash data to create a comprehensive data evaluation. Section 5 provides conclusions based on the data analysis and evaluation. Section 6 details recommendations and an implementation plan developed with UDOT based on study findings.

2.0 RESEARCH METHODS

2.1 Overview

A thorough literature review was conducted regarding intoxicated pedestrian fatalities and their characteristics. Additionally, the research methodologies utilized and basic mitigation strategies suggested in previous studies were reviewed.

2.2 Introduction

Researchers have found that a substantial number of active transportation crashes arise from intoxicated pedestrians (Hutchinson et al., 2010). While driver and pedestrian fatalities have decreased significantly over several decades, the extent of alcohol involvement has declined significantly only among fatally injured drivers while active transportation fatalities have increased somewhat in the last decade (Holubowycz, 1995). Significant research has been performed examining the effect of intoxicated drivers on automobile crashes, but significantly less research has been conducted on the effect of pedestrian impairment on pedestrian crashes and fatalities. This is despite several past studies finding that the number of fatally injured pedestrians that were under the influence of alcohol or other substances has ranged from roughly 34% to nearly 50% (Das et al., 2020; Hezaveh and Cherry, 2018; and Pawlowski et al., 2019).

Studies have also found that pedestrians have the highest prevalence of higher blood alcohol levels among fatally injured pedestrians, drivers, passengers, and motorcycle riders (Holubowycz, 1995). Additionally, the effects of factors such as the built environment and pedestrian infrastructure on fatalities involving impaired pedestrians are also not as well understood. This in part results from a lack of detail in crash narratives. After a fatal pedestrian crash, if responding law enforcement determines that the pedestrian was intoxicated, the investigation will typically end there, assuming, perhaps incorrectly, that the individual's blood alcohol level was the sole cause of the crash.

A comprehensive review by the National Cooperative Highway Research Program (NCHRP) identified five key factors that contribute to a higher risk of a pedestrian being involved in a collision resulting in severe injuries or death (NHTSA, 2021). They include:

- Excessive motor vehicle speed - Vehicles driving faster than the posted speed limit or too fast for existing roadway conditions increase their risk of hitting a pedestrian or pedalcyclist.

- Conflicts at crossing locations - When a crossing location does not adequately accommodate pedestrians, they are more likely to be hit.

- Inadequate conspicuity - When pedestrians and cyclists are not visible due to time of day (light or dark conditions, sun reflectivity, etc.) or wear dark clothing, it is difficult for drivers to see them and stop in time to avoid a collision.

- Poor compliance with traffic laws and facilities - Drivers and pedestrians who do not comply with traffic laws put themselves and others at risk. Often poor compliance is the result of misunderstanding traffic control devices, or inadequate/poorly designed facilities.

- Inadequate separation - When pedestrians or cyclists do not have a dedicated travel space that is sufficiently separated from higher speed vehicular traffic, they may not be seen by drivers.

Pedestrian and driver travel behaviors play a critical role in determining if and when a fatal crash occurs. However, there is limited data available to the Utah Department of Transportation (UDOT) and other agencies relating to traveler decision-making and behavior, and contextual factors leading up to a crash, particularly regarding pedestrians and the effects of intoxication. Intoxication may play a role in increasing the risks posed by the above factors through the effects of making pedestrian behavior more erratic and unpredictable while reducing their ability to utilize proper judgment around traffic. This research will add to existing knowledge by examining the characteristics of fatal impaired pedestrian crashes in Utah and the factors that may influence the crash. This will help increase understanding of how impairment due to alcohol or other factors influences the behavior of pedestrians involved in fatal crashes.

2.3 Characteristics of Impaired Pedestrian Fatalities

Over 80% of people in the US report walking at least once per week, and 92% report feeling safe while walking. Additionally, less than 3% of people report having been injured while walking in the past two years (Schroeder and Wilbur, 2013). However, in 2019, 6,205 pedestrians were killed in traffic crashes nationwide (NHTSA, 2021). Several common characteristics can be identified within these pedestrian crashes. UDOT research examining pedestrian fatalities found that fatal crashes are most likely to occur in the early spring or late fall in lower light conditions when visibility is increasingly limited, and often in bad weather when a wide road is wet or icy. These crashes often involve a pedestrian who may be impaired, participating in illegal and unpredictable behaviors (such as improper crossing of the street), or wearing clothing that is not visible (Burbidge, 2016). Of these fatal pedestrian crashes, the number of involved pedestrians that are impaired is significant. Multiple studies have found that over 30% of pedestrian fatalities had a Blood Alcohol Concentration (BAC) of greater than 0.08g/dL, the legal limit for vehicle operation in most states (Das et al., 2020 and Hutchinson et al., 2010). National Highway Traffic Safety Administration (NHTSA) research estimates that 46% of all fatal pedestrian crashes of any kind involved either the driver and/or pedestrian having a BAC of at least .01 g/dL (2021). Impairment due to alcohol or other influences is a common occurrence in pedestrian fatalities.

2.3.1 Impairment

While alcohol is commonly thought of as the source of intoxication in pedestrian-impaired crashes, the influence of drugs is also a major source of impairment. However, the relationship between drugs and pedestrian fatalities is not as well understood and significantly less research exists on the subject. Limitations exist in how pedestrians may be tested for drug use after a crash. A 2014 NHTSA report acknowledged that processes for drug-testing drivers involved in crashes are limited and that no standard exists for drug-testing practices. Practices for drug-testing pedestrians involved in crashes are potentially even more limited (2014). It should also be noted that some drugs, while showing in the person’s system, do not cause impairment. These include some prescription drugs and even ibuprofen and acetaminophen.

Knowing the impact of drug use on a pedestrian fatality is also limited in that the presence of drugs does not always result in impairment. In addition, if alcohol impairment is detected at the scene of a crash, tests may not be administered to measure the potential influence of drugs. Despite data deficiencies in the influence of drug impairment, data estimates that roughly 18% of pedestrian fatalities in persons over the age of 18 involve drug use (Retting et al., 2019).

Risk of injury or death in a crash increases for impaired pedestrians through influence on pedestrian behavior. Consumption of alcohol and other forms of impairment have been found to interfere with pedestrian judgments on factors such as vehicle speeds, proximity of approaching vehicles to street crossings, and general decision-making (Hezaveh and Cherry, 2018). Previous study has found that impaired pedestrians are more likely to walk into the path of oncoming vehicles, be slower in avoiding vehicles, or potentially fall asleep on or near the roadway (Struik et al., 1988). Research has also found that pedestrians with a higher BAC level (0.07-0.10 g/dL) often show lack of awareness of their impairment and subsequent poor judgment, increasing the chance that they will make risky decisions on streets (Das et al., 2020). In addition, a study utilizing logistic regression models suggested that alcohol impairment can make a pedestrian four to five times more likely to be killed in a collision with a vehicle (Miles-Doan, 1996). Generally, impairment has been found to severely inhibit the judgment of pedestrians as they walk on or across streets, and by extension, magnify the risks that already exist on roadways for pedestrians.

2.3.2 Lighting and Visibility

Lighting and visibility have a significant influence on chances of a fatal pedestrian crash and, by extension, a fatal pedestrian crash where impairment is present. Nationally, a vast majority of pedestrian fatalities occur in hours of low light and low visibility. Over 70% of pedestrian fatalities occurred from the hours of 6 PM to 6 AM, with most occurring from 6 PM to midnight (NHTSA, 2021). Impairment from alcohol and other influences has been linked to these characteristics as well. Alcohol-related pedestrian fatalities have been found to often occur in areas with low visibility particularly during nighttime hours (Hezaveh and Cherry, 2018). The association with low visibility and late-night hours has also been found to be spatially associated with bars and alcohol vendors (Levine, 2017).

2.3.3 Location

Actual location on the street plays a significant role in fatality rates in crashes where the pedestrian was impaired. Data shows that 72 percent of pedestrian fatalities occur at non-intersection locations (NHTSA, 2021). Fatal crashes involving impaired pedestrians are also most likely to occur away from crossing locations and intersections. In one case, it was found that the frequency of fatal mid-block crashes was higher for impaired pedestrians than non-impaired pedestrians (Hezaveh and Cherry, 2018). Another study found that impaired pedestrian fatalities were more likely to occur on major arterial roadways in addition to midblock areas (Das et al., 2020).

2.3.4 Demographics

In reviewing the demographics of impaired pedestrian fatalities, several common trends can be identified. Numerous studies in the US have found that males are three times more likely than females to be involved in fatal crashes where pedestrian impairment is present. (Das et al., 2020; Hezevah and Cherry, 2018). Research abroad has found similar results. A European study found that higher concentrations of alcohol were found in male pedestrian fatalities (Pawlowski et al., 2019). Regardless of gender, younger ages are typically correlated with higher instances of impairment and fatalities, with people under the age of 34 being the most likely age group to be involved in a fatal drug or alcohol-related crash.

2.3.5 Common Characteristics

Studies have determined that numerous variables have influence on the chances of an impaired pedestrian fatality. One study identified the most common characteristics associated with severe and fatal crashes where the pedestrian was impaired (Das et al., 2020):

The most common “risk clusters” and variables associated with the most severe and fatal crashes include:

- Intersection crashes at business/industrial locations
- Midblock crashes on undivided roadways at residential and business/residential locations
- Segment-related crashes associated with a pedestrian standing in the road
- Open-area rural crashes with no lighting at night
- Pedestrian violation-related crashes on divided roadways
- Dark with no street lighting
- Open country roadways
- Non-intersection locations

These situations pose some of the greatest risks to impaired pedestrians and their chances of being involved in a fatal crash. Understanding how to best mitigate these risks and increase safety for pedestrians in these situations will be important in reducing impaired pedestrian fatalities.

2.4 Environmental Contributions to Fatal Crashes

2.4.1 Urban vs. Rural

Numerous environmental factors contribute to impaired pedestrian fatalities. Studies of pedestrian fatalities at the local level have determined that the number of pedestrian crashes (per population) is four times higher in large urban areas, and twice as high in small or midsize urban areas when compared to rural areas (USDOT, 2015). However, chances of death in a given crash are greater in rural areas, particularly for impaired pedestrians, as they are two times more likely to be killed in any given crash than in urban areas (Das et al., 2020). The location of businesses that sell alcohol, particularly in urban areas, have an impact on impaired pedestrian fatalities. One study found that significant numbers of impaired pedestrian crashes occur in close proximity to the locations where the pedestrian became intoxicated (Hutchinson et al., 2010).

2.4.2 Lighting and Visibility

As discussed previously, light and visibility play a critical role in the occurrence of pedestrian fatalities, as data shows fatalities are more likely to occur at night. One study found that in the US, pedestrian fatalities increased by 45.5% from 2009 to 2017, and more than 85% of those additional fatalities occurred during nighttime hours. These nighttime fatalities are most likely to occur in urban areas on arterial streets with poor lighting away from intersections (Ferenchak and Abadi, 2021). Night conditions are correlated to an increase in crash severity; crashes at unlit intersections have an 83% greater chance of being fatal at night, with non-intersection areas holding a 75% greater chance of fatality (Siddiqui, 2006). This severity is reflected in the large numbers of pedestrian fatalities at night (NHTSA, 2021).

These risks are compounded for impaired pedestrians; research has found that impaired pedestrians will often attempt to cross streets at night in front of oncoming traffic when they are less visible (Hutchinson et al., 2010). The environmental hazards of nighttime hours can be reduced through effective street lighting; data shows that street lighting can reduce the chances of fatal night crashes for pedestrians by roughly 30% (Siddiqui, 2006). More effective lighting increases visibility and reduces some of the hazards created in low-light conditions, although nighttime remains significantly more dangerous for pedestrians.

2.4.3 Alcohol Availability

Availability of alcohol relates to pedestrian-impaired crashes. Nighttime pedestrian-impaired crashes are connected with bars and alcohol vendors. Multiple studies have found that a greater concentration of bars leads to greater likelihood of alcohol-related crashes (Das et al., 2020; and Levine, 2017). Areas with significant nightlife venues and alcohol-related activities are likely to see more crashes involving impaired pedestrians, and by extension, fatal pedestrian crashes.

2.4.4 Infrastructure

In addition to the effects of area type and time of day, the built environment and infrastructure play an important role in pedestrian fatalities. Previous research has found that an increased severity of pedestrian crashes is associated with numerous factors, including:

- Lack of sidewalks
- Lack of buffers between pedestrians and the road (bike lanes, sidewalk buffer, etc.)
- Higher-speed roads
- Multiple lane roads
- Lack of or insufficient street lighting (Hanson et al., 2013).

Sidewalks greatly increase pedestrian safety, but nearly a third of pedestrians surveyed said there are no sidewalks in their neighborhood, and almost half report there are limited numbers of sidewalks in areas nearby (Schroeder and Wilbur, 2013). As discussed previously, many fatalities occur at non-intersection locations, particularly as pedestrians attempt to cross the street and behaviors become unpredictable for drivers to judge (Burbidge, 2016). This trend is also found among impaired pedestrians, as research has shown that a majority of pedestrian fatalities occur at midblock locations away from intersections and crossings.

2.4.5 Vehicle Speeds

Vehicle speeds are a very significant factor in fatal pedestrian crashes. Ninety percent of pedestrians will survive being hit by a car traveling at roughly 25 miles per hour, but only 25% of pedestrians will survive being hit by a vehicle traveling 50 miles per hour (Tefft, 2012). Higher-speed roads have been linked to greater chances of death for impaired pedestrians (Das et al., 2020). A 2010 study found that lower speed limits for vehicles, particularly in conjunction with other improvements in street lighting and infrastructure, can greatly reduce the chances of death for impaired pedestrians, and other pedestrians as well (Hutchinson et al., 2010).

2.5 Preventing Impaired Pedestrian Crashes

While impairment can lead to unpredictable behaviors and concomitant difficulty in mitigation, previous research has suggested that improving safety for impaired pedestrians will likely involve making overall environments safer for all pedestrians regardless of their current physical and mental state. Previous study has suggested the use of fencing on roadways, shorter cycle times at signalized crossings, and pedestrian infrastructure with greater safety measures and separation from traffic (Hutchinson et al., 2010). As reports of pedestrian-impaired crashes are often incomplete and omit important information, better design and training on filing reports can provide more complete data for research on how to reduce pedestrian fatalities (Hezevah and Cherry, 2018).

In addition to creating safer pedestrian infrastructure, education and outreach may help make the public aware of the dangers of walking while impaired. Previous research has recommended increasing public awareness of the risks of pedestrian impairment, in particular targeting male audiences about these risks (Eichelberger et al., 2018). Educational programs aimed at the public may be effective at reaching large numbers of people very quickly. However, they are limited in their actual influence to reduce impairment among pedestrians. Further types of mitigation are possible. One study has listed several suggested or existing initiatives, including (Hutchinson et al., 2010):

- Limits on the level of BAC allowed in public
- Police intervention in public intoxication or impairment
- Illegality of serving alcohol to already intoxicated persons
- Public transport for impaired persons leaving facilities or venues where alcohol is present
- Public messaging to drivers about the risk of impaired pedestrians

Implementation of these initiatives and other similar measures vary in their feasibility. However, they illustrate that there are numerous possibilities for the reduction of impairment among pedestrians. Improvements to pedestrian infrastructure and increased controls on traffic (traffic calming, lower speed limits, etc.) will make conditions safer for all pedestrians, including those that are impaired. These improvements and initiatives will work to decrease the number of pedestrian-impaired fatalities.

2.6 Summary

A significant number of pedestrian fatalities involve impairment by alcohol or other substances. Impairment among pedestrians is not as well understood as impairment in drivers. An impaired state may contribute to unpredictable pedestrian behavior and reduce the ability of pedestrians to make safe decisions. Impairment may also inhibit comprehensive report narratives in the aftermath of crashes, as it may be listed as the sole cause for a crash, discouraging further investigation. This could prevent a greater understanding of the environmental and infrastructural influences that may contribute to a non-motorist crash. More research and study will assist in developing greater understanding of impaired pedestrian traffic fatalities and help agencies take steps toward developing effective mitigation of such crashes.

3.0 DATA COLLECTION

3.1 Overview

This chapter explains the overall data collection and assembly process. Data for this study were divided into five major categories. The first category illustrates the data collection and assembly process related to crash details. The description of people involved in a crash is explained in the second category. Similarly, the third category interprets vehicles involved in a crash and their characteristics. The fourth category describes transportation infrastructure in the vicinity of the crash location, and the fifth category describes the built and social environments of the crash location. The final category then discusses crash narratives that are followed on reports filled out at the scene of a crash and how these relate to the study.

Before collecting data in each of these categories, target crashes were first selected using criteria based on the scope of this research project: people walking or bicycling who were seriously injured or killed and for whom some intoxication was suspected. To start, crash datasets were obtained from the Utah Department of Transportation (UDOT) through AASHTOWare Safety, powered by Numetric, which is populated by the Utah Transportation and Public Safety – Crash Data Initiative (UTAPS-CDI). Data represented 9,266 pedestrian-involved and 7,389 bicycle-involved crashes with motor vehicles that were reported on Utah roadways for a 12-year period from 2010 through 2021. These crash data were organized into three tables (*Crashes*, *People*, *Vehicles*), based on the information about crashes, people involved, and vehicles involved.

Next, subject crashes were extracted by filtering the datasets on multiple criteria; the *People* tables were most relevant. First, the *People* tables were filtered for person type "Pedalcyclist" (for bicycle crashes) or "Pedestrian" (for pedestrian crashes). Second, the resulting datasets were further filtered using injury severity levels of "Fatal" or "Suspected Serious Injury." Third, the resulting datasets were additionally filtered for suspected intoxication, as measured by suspected or reported drug and alcohol presence: "Y" (Yes) in the fields "Alcohol.Suspected" and "Drugs.Suspected" or one of {"Alcohol-Pos", "Drugs-Pos", "Both-

Pos"} in the field "Alcohol.Drug.Test.Result." It should be noted that these fields are undefined for many crashes and were subject to the circumstances of the crash and the person reporting (often law enforcement); thus, they may miss many intoxicated pedestrians/cyclists, or the suspicions of intoxication may not have been warranted.

Lastly, the unique Crash IDs representing people involved in crashes were extracted as the list of crashes to investigate further. After this filtering process, there were 109 intoxicated pedestrian and 17 intoxicated bicyclist fatal/serious injury crashes. The open source statistical and programming software R was used to assemble all datasets for this study. Subsequent statistical analysis was conducted using IBM's SPSS software.

3.2 Crash Details

Crash details include data describing characteristics of crashes such as crash identification number, date/time and location of crash occurrence, severity level, and environmental conditions during crash occurrence. This study used crash data from Numetric (the *Crashes* table) to collect crash details. The following subsections further describe the crash details data collection and assembly processes.

3.2.1 Crash ID

The Crash identification number or Crash ID is a unique number assigned to each crash. As mentioned above, Crash IDs for bicyclists and pedestrians who experienced a fatal or suspected serious injury and who were suspected to have drug or alcohol consumption involved were assembled by filtering the datasets. Crash ID was the key element to link three datasets containing information about crashes, people, and vehicles.

3.2.2 Crash Date/Time

Crash date and time contain the information about the year, month, day of the week (weekday vs. weekend), and time of the crash occurrence.

3.2.3 Crash Location

Latitude, longitude, type of route, and mile point data are collected under the category of crash location. Route is classified as federal, state, or local.

3.2.4 Crash Severity

Crash severity is commonly measured using the KABCO scale (see Table 3-1). Information regarding crash severity was collected and assembled from the crash datasets provided by Numetric for both bicyclist- and pedestrian-involved crashes. Based on the scope of study, all crashes were filtered to retain bicyclists and pedestrians with K (fatal, killed) and A (suspected serious injury) types. In addition, the number of fatalities and various injury levels were also extracted from the *Crashes* table.

Table 3-1 Definition of KABCO scale corresponding to crash injury severity

Scale	Definition of scale
K	Fatal injury (killed)
A	Incapacitating or serious or major injury, prevents some sort of activities
B	Non-incapacitating or minor injury, evident but not serious
C	Possible injury, may not be evident
O	Property-damage only (no injury)

3.2.5 Environmental Conditions

Environmental conditions contain information about the weather condition, roadway surface condition, and lighting status of the crash site during the crash occurrence. Weather conditions are categorized as blowing sand, soil, and dirt, blowing snow, clear, cloudy, fog and smog, rain, severe crosswinds, sleet and hail, snowing, and others. Roadway surface conditions are categorized as roadway with sand, dirt, gravel, ice/frost, slush, snow, wet, and others. Lighting status is classified as dark-lighted, dark not lighted, dark unknown lighting, dawn, daylight, dusk, and others. Information regarding environmental conditions was collected and assembled from Numetric's *Crashes* table.

3.3 People Involved

The “people involved” category includes data describing demographics of pedestrians and bicyclists, categories of road users based on the vehicle usage status during the crash, DUI test results, and crash contributing circumstances. This study used crash data from Numetric (the *People* table) to collect details about people involved. Because there may have been multiple pedestrians, cyclists, and/or drivers involved in each crash, this people information was collected for all participants, as appropriate. For pedestrian crashes, there were up to 8 drivers and 4 pedestrians involved. For bicycle crashes, there were up to 4 drivers and 4 bicyclists involved. Information was obtained for each party in all of these crashes. The following subsections further describe data collection and assembly processes for people involved in crashes.

3.3.1 Demographics

Demographic data contain information about the age and gender of the people involved in crashes. Age is measured by years and gender is categorized as male or female.

3.3.2 Crash Contributing Circumstances

Crash contributing circumstances contains information about the circumstances of each driver and non-motorist involved in a crash: each driver’s first and second contributing circumstances, each non-motorist’s contributing circumstance and location during crash, and any safety equipment used and the restrained status of all road users during the crash. Crash contributing circumstances includes information such as hit and run, reckless/aggressive, disregard traffic signals, failed to keep in proper lane, failed to yield right of way, followed closely, improper passing, etc. Similarly, location of the crash describes crash spot such as island, roadside, intersection-marked crosswalk, shoulders/roadside travel lane, etc. This information regarding crash contributing circumstances was collected and assembled from the *People* table in Numetric.

3.4 Vehicles Involved

The "vehicles involved” category includes data describing characteristics of vehicles involved in crashes, which includes the number and types of vehicles, estimated vehicle speeds, and pre- and post-crash vehicle movements. This study used vehicle data from Numetric (the *Vehicles* table) to collect details about vehicles involved. The following subsections further describe the "involved vehicles" data collection and assembly processes.

3.4.1 Types of Vehicles

Information about the types of vehicles involved in each crash is recorded based on vehicle size. Examples include commercial motor vehicles, heavy motor vehicles, motorcycles, trains, and other transit vehicles. The vehicle type field contains various categories such as bus/motor coach, motorcycle, off-road vehicles, passenger car (4 door), single-unit truck, station wagon, van or minivan, street-legal all-terrain vehicle (ATV), sport utility vehicle (SUV), etc. Other vehicle involvement fields are classified as "Y" for yes and "N" for no.

3.4.2 Estimated Vehicle Speeds

This information reports the estimated travel speeds of vehicles involved in each crash. Information regarding speeds was collected and assembled from the *Vehicles* table provided by Numetric.

3.4.3 Pre-Crash Vehicle Movements

Pre-crash vehicle movement contains information about vehicle maneuvers prior to the crash. It also includes status of motor vehicles making right turns, left turns, or U turns prior to the crash. Pre-crash maneuvers include various categories such as: backing, changing lanes, entering traffic lane, leaving traffic lane, making U turn, merging, negotiating a curve, overtaking/passing, parked, parking maneuvers, slowing in traffic lane, starting to move in traffic, stopped in traffic lane, straight ahead, turning left, turning right, unknown, and others. The turning status of motor vehicle is classified as "Y" for yes and "N" for no.

3.4.4 Post-Crash Vehicle Status

Post-crash vehicle status contains information about vehicle overturning or rolling status after the crash, classified as "Y" for yes and "N" for no.

3.5 Transportation Infrastructure

Transportation infrastructure includes information describing types of roadways, types of intersections, roadway geometric characteristics, and characteristics of other facilities at the crash location. This study used crash data from Numetric (the *Crashes* and *People* tables) as well as shapefiles provided through UDOT's Open Data Portal and the Utah Geospatial Resource Center (UGRC) to collect transportation infrastructure details. The following subsections further describe the data collection and assembly processes for transportation infrastructure at crash sites.

3.5.1 Type of Roadways

"Types of roadways" contains information about roadway description and functional class for crash sites. Roadway description gives information about whether the roadway is one-way or two-way, parking lot aisle/stall or quasi-public road or parking lot way, divided or not-divided or not-divided with continuous left-turn lane, positive median barrier or unprotected median, etc. Functional class is subcategorized as interstate, local, major collector, minor arterial, minor collector, freeways/expressway, principal arterial, etc. Information regarding roadway types was collected and assembled from the *Crashes* table provided by Numetric for both bicycle and pedestrian-related crashes.

3.5.2 Intersection Information

Intersection information contains data about roadway junction type, signal and traffic control device description, the number of intersections within 400 meters (0.25 miles) of the crash site, the distance to the nearest intersection, the number of legs of the nearest intersection to the crash location, and the distance to the nearest traffic control device. Roadway junction type is subcategorized as 4-legged intersection, 5-legged or more intersection, alley, bridge (overpass/underpass), business drive, crossover in median, farm/residential drive, multi-use path/trail intersection, no special feature/junction, off-ramp, deceleration lane, on-ramp, acceleration lane, railroad crossing, ramp intersection with crossroad, roundabouts, T-intersection, Y-intersection, unknown, and others.

Signal and traffic control device description provides information about the presence of various types of traffic control devices such as flashing traffic control signal, person (including flagger, officer, crossing guard, etc.), railroad crossing – no signal, railroad crossing – signal/gate, school zone – active, school zone – inactive, stop signs, traffic control signal, warning signs, yield signs, unknown, none, and others. Information regarding roadway junction type, and signal and control device description was collected and assembled from the *Crashes* table from Numetric.

To count the number of intersections within 400 meters of each crash site, the distance to the nearest intersection, the number of legs of the nearest intersection from the crash location, the distance to the nearest traffic control device, and the location and characteristics of intersections were obtained from UDOT's Open Data Portal. Note that this only gives the information about intersections located on state highways. Next, a 400-meter circular buffer was created around each crash location, after which the number of intersections located within each buffer was counted. This generated the number of intersections within 400 meters. Similarly, distances to the nearest intersection and traffic control device were calculated, and the number of legs of the nearest intersection were obtained.

3.5.3 Roadway Geometry

Information about the horizontal alignment, vertical alignment, and roadway cross-section were collected under roadway geometry. Vertical alignment was categorized as downhill, hill crest, level, other, retired (grade), sag (bottom), uphill, and unknown. Similarly, horizontal alignment was categorized as curved, curve left, curve right, straight, and unknown. This information regarding roadway geometry and alignments was collected and assembled from the *Crashes* table provided by Numetric.

Alternatively, data for lanes, shoulders, driveways, and medians were assembled using segment shapefiles available on UDOT's Open Data Portal. A 25-meter circular buffer was created around each crash location for assembling segment data. Data such as the number of lanes, number of thru lanes, width of thru lanes, number of two-way left-turn lanes, presence of HOV lanes, number of left-turn lanes, number of right-turn lanes, presence of shoulders, width of shoulders, number of driveways, width of driveways, number of major driveways, number of minor driveways, number of commercial driveways, number of industrial/institutional driveways, number of residential driveways, status for presence of median, status for presence of median with island, and width of median inside the 25-meter buffer were then collected.

If there were multiple matches for each variable inside the 25-meter buffer, various conditions were used to filter them. To assemble the presence of medians, driveways, and shoulders, their presence inside the 25-meter buffer was created as a dummy variable and presence was detected using conditions. Driveways, major driveways, minor driveways, commercial driveways, industrial/institutional driveways, residential driveways, lanes, thru lanes, two-way left-turn lane, left-turn lane, and right-turn lane inside the 25-meter buffers were counted. For lane, median, and shoulder widths, the maximum values of all those matching segments were used.

3.5.4 Other Facilities

Other facility data includes information about speed limits, transit stops/stations, on-street bike facilities, pedestrian crosswalks, and curb ramps. Speed limit data was obtained from the *Crashes* table from Numetric. Data for transit facilities and on-street bike facilities were obtained from shapefiles from the UGRC. Data on crosswalks and pedestrian curb ramps were assembled from shapefiles on UDOT's Open Data Portal.

A 400-meter circular buffer was created for all the crash sites to assemble the number of transit stations, number of bus stops, number of light rail stations, number of commuter rail stations, number of crosswalks, and nearest crosswalk distance from each crash location. Similarly, 75-meter and 25-meter circular buffers were used to assemble on-street bike facilities (left and right sides) and number of pedestrian curb ramps, respectively. To assemble types of on-street bike facilities if multiple matches differed, a hierarchy was created and types with the highest ranks were adopted, as shown in Table 3-2.

Table 3-2 Hierarchy for On-Street Bike Facility Type

On-street bicycle facility type (Original)	On-street bicycle facility type (Revised)	Hierarchy
Parallel Bike Path, Paved Parallel Bike Path, Unpaved	Parallel paths	4
Cycle track, at-grade, protected with parking Cycle track, protected with barrier Cycle track, raised and curb separated Cycle track, unspecified	Cycle tracks	3
Buffered bike lane Bike lane Bike lane, unspecified	Bike lane	2
Shoulder bikeway Marked shared roadway Signed shared roadway Other bike route, unspecified	Other bike ways	1

3.6 Built and Social Environments

The built and social environments include data about the surrounding land use, built environment, neighborhood demographics, and nearby destinations. This study used data from Numetric (the *Crashes* table), UGRC, the US Environmental Protection Agency (EPA) Smart Location Database (SLD), and US Census to collect built and social environment details for both pedestrian- and bicycle-related crashes. The following subsections further describe the data collection and assembly processes for built and social environment data.

3.6.1 Destinations

Destination information contains data about community services, health care facilities, liquor stores, schools and libraries, community centers, grocery and food stores, and retail centers. These data were obtained from shapefiles on the UGRC website. Community services were classified as government service, food bank service, human services, and work force service. Health care facilities were classified as home/living medical facility, general medical facility, special medical facility, and other medical facility. Liquor facilities were classified as liquor store and packaging agency. Community centers were classified as recreation center and library. Utah grocery and food stores were classified as convenience store, supermarket, grocery store, other grocery, and food stores. Destination information also gives data about near-school crashes, which were obtained from Numetric.

A 400-meter buffer was created for all the crash sites, and the number of each type of community services, health care facilities, liquor stores, schools and libraries, community centers, grocery and food stores, and retail centers within the 400-meter buffer was counted.

3.6.2 Demographics

To assemble demographic data about neighborhoods, information related to households, children, income, median income, total employment, labor force employment, total population, vehicle ownership, all races, race non-Hispanic, White alone, and tenure (owner-occupied versus renter-occupied) were collected from the US Census Bureau for all Census block groups in Utah. The collected information was further processed to calculate average household size (total population / households), average number of children per household (children / households), average number of workers per household (labor force employment / households), average number of vehicles per household (vehicle ownership / households), mean income per household (income / households), unemployment rate (100 * (1 - (labor force employment / total employment))), non-white or Hispanic race per ethnicity (100 * (1 - (race non-Hispanic White alone / total race))) and rental rate (100 * (Renters occupied / Tenure Total)).

Data were summarized by polygons representing US Census block groups (roughly small neighborhood zones). To extract information from this polygonal data, a circular buffer of 400 meters was created for each crash site. After that, the area-weighted average value for each category based on Census block groups within the 400-meter buffer was calculated.

3.6.3 Built Environment

Built environment characteristics contain information about neighborhood type, residential and employment density, land-use diversity, design of the built environment, access to destination, and distance to transit. Urbanization status information was collected using crash data from Numetric. Residential and employment densities represent information about gross residential density (housing units per acre), gross population density (people per acre), and gross employment density (jobs per acre). Similarly, jobs per household was selected to measure land-use diversity. To assemble design of the built environment, information about total road network density and street intersection density was also collected. Access to destinations was characterized by jobs within 45 minutes of auto travel time and transit travel time. Distance from the population-weighted centroid to nearest transit stop (meters) and aggregate frequency of transit service per square mile were assembled to describe distance to transit.

All these built environment variables were assembled from the EPA SLD, updated in 2021. This data is formed of polygons representing US Census block groups. To extract information from this polygonal data, a circular buffer of 400 meters was created for each crash site. After that, the area-weighted average value for each category based on Census block groups within the 400-meter buffer was calculated.

3.7 Crash Narratives

The UTAPS-CDI Database collects data from traffic crash reports. These reports are completed by law enforcement officers who investigate crash scenes on public roads. Information is collected when a crash involves injuries, deaths, or at least $1,500 property damage. The research team collected redacted crash narratives for study crashes from the UDOT Division of Traffic and Safety. The redacted crash narratives had all personally identifiable information removed from them including names of people involved, names of witnesses, and license plate numbers. 154 crashes which involved a pedestrian and also intoxication were ultimately found. The research team then analyzed the crash narratives to answer the following questions:

- Can it be confirmed that the pedestrian or bicyclist involved in the crash was indeed intoxicated?
- Can it be confirmed that the crash was likely caused by an intoxicated pedestrian or bicyclist?
- Are there other contributing factors to the crash?

Based on this investigation, the research team was able to identify the following information from the redacted crash narratives:

Confirmed Pedestrian Intoxication: This was a Yes/No field to determine how many crashes had a confirmed case of an intoxicated pedestrian. Out of 154 crashes, five could be confirmed from the narrative to have an intoxicated pedestrian involved in the crash.

Possible Pedestrian Intoxication: This was a Yes/No field to indicate how many crashes were suspected to have an intoxicated pedestrian involved. Out of 154 crashes, one was identified as a case of possible pedestrian intoxication.

Confirmed Driver Intoxication: This was a Yes/No field to determine how many crashes had a confirmed case of an intoxicated driver. Out of 154 crashes, 20 could be confirmed from the narrative to have an intoxicated driver involved in the crash.

Possible Driver Intoxication: This was a Yes/No field to indicate how many crashes were suspected to have an intoxicated driver being involved. Out of 154 crashes, 22 were identified as a case of possible driver intoxication.

Other contributing factors: This was a text field to document if any other contributing circumstances were present during the crash event. Other than intoxication, no other contributing factors were extracted from the narratives.

The distribution is shown in Table 3-3.

Table 3-3 Intoxication Information from Crash Narratives

Intoxication Information	Number of Crashes (%)
Confirmed Ped Intoxication	5 (3.2%)
Possible Ped Intoxication	1 (0.6%)
Confirmed Driver Intoxication	20 (13%)
Possible Driver Intoxication	22 (14%)
No Intoxication Information	106 (69%)

The 20 confirmed driver intoxication crashes were removed from further analysis, as this analysis was focused on intoxicated pedestrians.

3.8 Summary

This chapter explained the strategy used for data collection and assembly in our study area based on the scope of the study. Crashes from 2010 through 2021 were filtered for pedestrians and bicyclists with severity level of fatal or suspected serious injury and who were indicated as impaired in the crash report database. This study then used various secondary sources such as Utah crash data provided by Numetric, UTAPS-CDI, the EPA SLD, US Census data, and shapefiles from UGRC and UDOT for assembling data and spatial processing to link these data types to individual crashes. The next step is to use these assembled data to conduct analyses of the data, potentially including descriptive analyses, comparative analyses, statistical tests, etc. That next step is discussed in Chapter 4.

4.0 DATA EVALUATION

4.1 Overview

This chapter presents the descriptive and analytical findings from an exploration of impairment status and severity of crashes involving active mode users. The second section of the chapter illustrates the methods used to analyze datasets assembled for this study. Results from the data analysis of independent variables versus active mode user impairment status are explained in subsequent subsections. The third section interprets results of independent variables versus active mode user impairment status, followed by sections reporting differences when focusing on alcohol-impaired and drug-impaired active mode users. Next are sections discussing differences when focusing on crashes with KA severity (fatal or suspected serious injury) and BCO crash severity (minor injury, possible injury, or no injury). The eighth section describes results of independent variables that are associated with injury severity overall, and when looking only at crashes with impaired and non-impaired active mode users. This chapter ends with a summary of key findings.

4.2 Analysis Methods

Given the exploratory nature of this analysis in association with impairment status and crash severity level for active mode crashes, a simple bivariate analysis between impairment status and severity level (dependent variable) and other independent variables of interest (demographics, temporal conditions, roadway geometry, neighborhood environment, destinations) was used. Given the dichotomous nature of the dependent variable (i.e., true vs. false, impaired vs. non-impaired), a different analysis was used when the independent variable was categorical or continuous.

For a categorical independent variable, this study used Pearson's Chi-Squared Tests of independence and calculated (as well as visualized) the share of impaired active mode users and severely injured active mode users for each category. For a continuous independent variable, this study used a test of the point-biserial correlation and calculated (and visualized) the mean value of the independent variable for impaired and non-impaired active mode crashes and for crashes involving active motorists with KA and BCO severity level. Through hypothesis testing and visualizations, these bivariate analyses identified factors having a significant association or difference ($p<0.10$) with impairment status and crash severity level; in other words, characteristics, conditions, or locations for which suspected impairment and severe crash of an active mode road user was more or less likely.

4.2.1 Chi-Square Test

A Pearson's Chi-Square Test is used on categorical data to compare an observed distribution to a theoretical one (measuring goodness of fit) for one or more categories. The events included must be mutually exclusive (e.g., weather cannot be clear and raining at the same time) and have a total probability of 1 (Greene, 2018).

Model:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

where

- χ^2 is the chi-square value
- Σ is the summation sign
- O is the observed frequency
- E is the expected frequency

4.2.2 Bivariate Analysis

Bivariate analysis is a statistical method that involves the analysis of two variables (denoted as *X*, *Y*), for the purpose of determining the relationship between them. Based on the occurrence of an independent variable *X*, the analysis identifies an outcome or dependent variable, *Y*. When taken comprehensively, this analysis can help researchers predict an outcome based on a measurement for any independent variable. The most common form of bivariate analysis is linear regression.

4.2.3 Point-Biserial Correlation

The point-biserial correlation, r_{pb}, is the value of Pearson's product moment correlation when one of the variables is dichotomous, taking on only two possible values coded 0 and 1, and the other variable as metric (interval or ratio). Values range from +1, a perfect positive relation; through zero, no association at all; to −1, a perfect negative correlation. The square of this correlation, r_{pb}^2, is a measure of effect size in terms of the proportion of variability accounted for by the relation between the two variables (Kornbrot, 2014).

4.3 Results for All Impairment Statuses, All Bicycle/Pedestrian Crashes

Figure 4.1 and Figure 4.3 show the percent impaired for bicycle and pedestrian crashes, by significant categorical variables. Figure 4.2 and Figure 4.4show mean values of significant continuous variables by impairment status for bicycle and pedestrian crashes. Later in this chapter, Table 4-1 displays the results of point-biserial correlation coefficient (r_{pb}) tests and chi-squared (χ^2) tests of independence for continuous and categorical independent variables versus all active mode user impairment statuses (i.e., both alcohol and drugs).

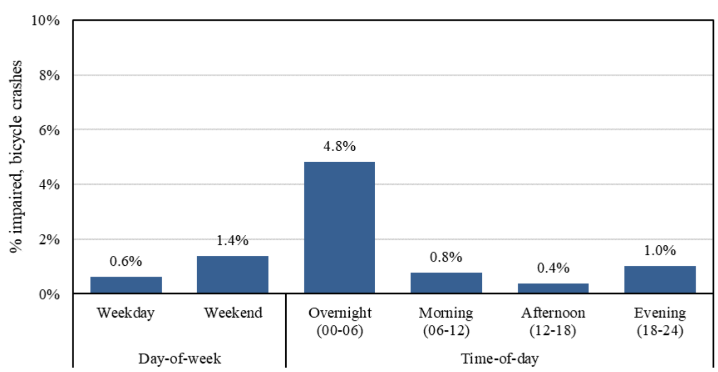

Figure 4.1 Percent Impaired for Bicycle Crashes by Significant Categorical Variables

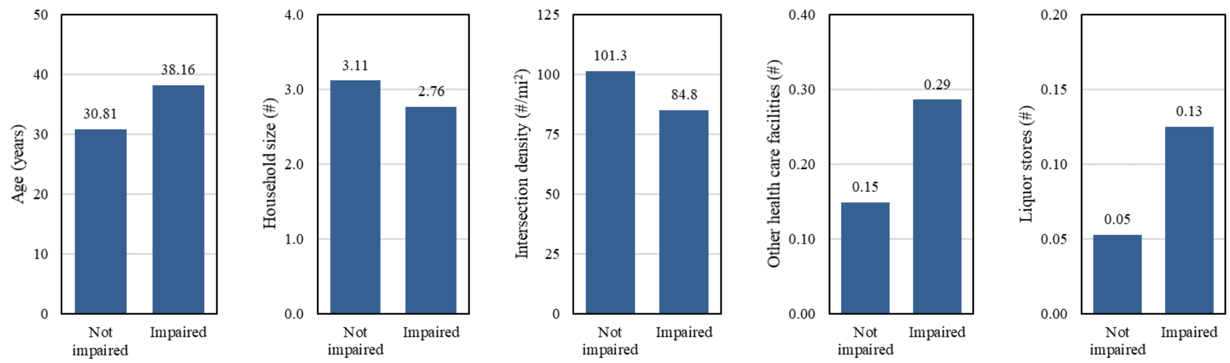

Figure 4.2 Mean Values of Significant Continuous Variables by Impaired Status for Bicycle Crashes

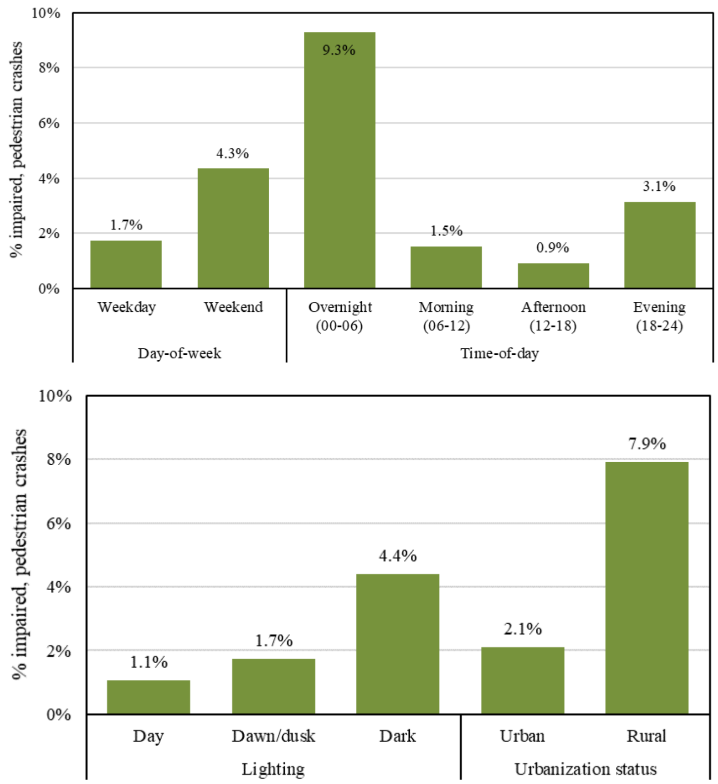

Figure 4.3 Percent Impaired for Pedestrian Crashes by Significant Categorical Variables

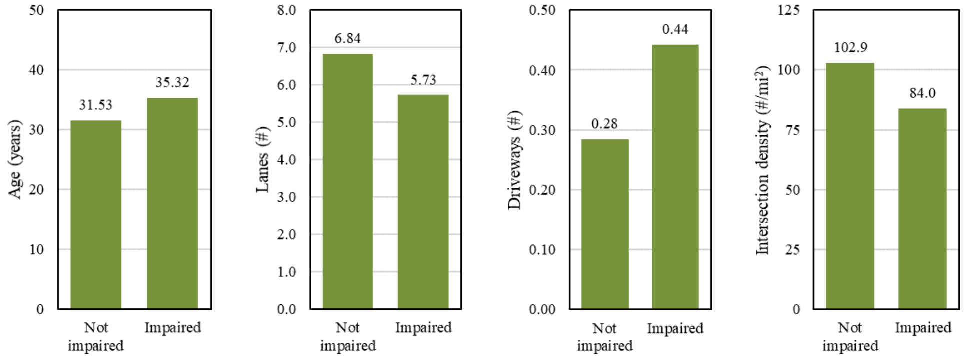

Figure 4.4 Mean Values of Significant Continuous Variables by Impairment Status for Pedestrian Crashes

4.3.1 Active Mode User Demographics

For bicycle-involved crashes, there was a significant correlation between impairment status and age, but no significant association with gender. Impaired bicyclists involved in a crash were slightly but significantly older than non-impaired bicyclists (38 vs. 31 years old, on average).

A significant positive association was also identified for impaired pedestrians with age, although the difference was not as large as for bicyclists: Average ages were 35 for impaired pedestrians and 32 for non-impaired pedestrians. A Chi-Squared Test revealed a marginally significant relationship between impairment status and gender: Male pedestrians were slightly more likely to be suspected to be impaired than female pedestrians.

4.3.2 Crash Temporal Conditions

Investigation of crash temporal conditions revealed day of week, time of day, and lighting condition to have significant associations with bicyclists' impairment status. A relatively greater proportion of bicyclists involved in crashes on weekends (1.4%) were suspected to be impaired, compared to weekdays (0.6%). Crashes involving impaired bicyclists were much more likely overnight (4.8%) than in the evening (1.0%), morning (0.8%), or afternoon (0.4%).

The study also observed similar associations with temporal conditions—day of week, time of day, and lighting condition—for crashes involving impaired pedestrians. A greater share of pedestrian crashes on weekends (4.3%) reported a suspected intoxicated pedestrian than on weekdays (1.7%). Overnight crashes involving pedestrians were much more likely to suspect impairment (9.3%) than crashes during evening (3.1%), morning (1.5%), and afternoon (0.9%). Similarly, impaired pedestrian crashes were more common during dark (4.4%) conditions than during dawn/dusk (1.7%) and day (1.1%).

4.3.3 Roadway Geometry

For bicycle-involved crashes, the only significant bivariate association with impairment status was for the posted speed limit: Impairment was more likely to be reported for bicycle crashes on higher-speed roadways. Other roadway geometry characteristics did not appear to have impairment-specific associations for bicycle crashes.

On the other hand, numerous roadway geometry characteristics were significantly associated with suspected impairment status for pedestrian-involved crashes in the bivariate analyses: route type, posted speed, distance to nearest crosswalk, traffic control devices, number of lanes, presence of shoulder, and number of driveways. Specifically, pedestrian crashes were more likely to involve suspected impairment on higher-speed roads, with fewer lanes, with more driveways, at uncontrolled intersections, and in places further from the nearest crosswalk.

4.3.4 Neighborhood Social Environment

For bicycle crashes, the correlation tests found significant negative associations between impairment status and both average household size and the average number of workers per household.

In bivariate analysis, impairment status for pedestrian crashes was found to be negatively associated with average household size, average number of workers per household, and the average rental housing rate. A positive correlation between suspected impairment and unemployment rate was observed for pedestrian crashes.

4.3.5 Neighborhood Built Environment

Several variables related to a neighborhood's built environment were found to be associated with impairment status for bicycle crashes. In the bivariate analysis, impairment was more likely to be suspected in rural areas. Significant negative correlations were observed between impairment and intersection density and impairment and population density.

Many of the same built environment factors were also significantly associated with pedestrian impairment. More pedestrian crashes in rural areas (7.9%) reported suspected impairment than those in urban areas (2.1%). As with bicycle crashes, impairment was less likely in areas with greater intersection density. Similarly, both residential density and population density were found to have significant negative association with suspected impairment of pedestrians.

4.3.6 Nearby Destinations

Only a few types of destinations were significantly associated with impairment status for bicycle-involved crashes. There were positive correlations between impairment and both liquor stores (and all liquor facilities) as well as with the number of other health care facilities. Other health care facilities include those not included as home living medical, general medical, and special medical facilities. Liquor stores and liquor facilities include bars and establishments that sell alcohol to customers.

Different but related destinations were significantly associated with impairment status for pedestrian crashes in the bivariate analysis. Specifically, impairment was less likely to be reported in areas with more workforce service and health care facilities. Pedestrian crashes were less likely to involve impairment if they occurred near health care facilities in general, as well as near the specific categories of home living medical and special medical services. Also, a positive correlation of pedestrian impairment was revealed with the number of overall liquor facilities and liquor package agencies.

Table 4-1 Bivariate associations with active mode user impairment status

	All Bicycle Crashes (n=7389)				*All Pedestrian Crashes (n=9000)*			
	Impaired (n=56) vs Non-Impaired (n=7333)				Impaired (n=201) vs Non-Impaired (n=8799)			
Variable	df	r_{pb}	χ^2	p	df	r_{pb}	χ^2	p
Active mode user demographics								
Age (years)	**7111**	**0.0370**		**0.0018**	**8148**	**0.0295**		**0.0077**
Gender (male, female)	1		0.0027	0.9583	**1**		**3.2436**	**0.0717**
Distraction	**1**		**9.4398**	**0.0021**	**1**		**2.7389**	**0.0979**
Crash temporal conditions								
Year	7387	-0.0096		0.4099	8998	-0.0038		0.7159
Season (winter, spring, summer, fall)	3		4.7908	0.1878	3		4.5528	0.2076
Day of week (weekday, weekend)	**1**		**8.3611**	**0.0038**	**1**		**43.4080**	**0.0000**
Time of day (00-06, 06-12, 12-18, 18-24)	**3**		**49.5260**	**0.0000**	**3**		**153.9100**	**0.0000**
Weather (clear, other)	1		1.8022	0.1794	1		0.5075	0.4762
Lighting (day, dawn/dusk, dark)	**2**		**25.0710**	**0.0000**	**2**		**98.7440**	**0.0000**
Roadway geometry								
Route type (federal, state, local)	2		3.3544	0.1869	**2**		**6.0650**	**0.0482**
Functional class (freeway, arterial, collector, local)	3		0.7089	0.8711	2		3.9871	0.1362
Posted speed (mph)	**4718**	**0.0357**		**0.0142**	**4981**	**0.0381**		**0.0071**
Intersections (#)	7387	0.0045		0.7016	8998	-0.0150		0.1553
Distance to nearest intersection (m)	7387	-0.0021		0.8568	8998	0.0150		0.1543
Distance to nearest crosswalk (m)	7387	0.0154		0.1842	**8998**	**0.0376**		**0.0004**
Traffic control (active control, passive control, uncontrolled)	2		1.6765	0.4325	**2**		**12.1530**	**0.0023**
Lanes (#)	3394	-0.0018		0.9171	**4034**	**-0.0726**		**0.0000**
Median (present, absent)	1		0.3808	0.5372	1		0.4867	0.4854
Shoulder (present, absent)	1		0.0231	0.8791	**1**		**2.7537**	**0.0970**
Pedestrian curb ramps (#)	7387	0.0001		0.9952	8998	-0.0103		0.3292
Driveways (#)	7387	0.0119		0.3065	**8998**	**0.0307**		**0.0036**
Horizontal alignment (level, curve)	2		0.7368	0.6919	2		0.1452	0.9300
Vertical alignment (level, grade)	2		0.3920	0.8220	2		1.0527	0.5908
Transit stations (#)	7387	-0.0026		0.8200	8998	-0.0108		0.3038
Bus stops (#)	7387	-0.0021		0.8550	8998	-0.0124		0.2376
Commuter rail stations (#)	7387	-0.0075		0.5193	8998	0.0086		0.4166
Light rail stations (#)	7387	-0.0053		0.6516	8998	0.0121		0.2518
Neighborhood social environment								
Household size (#)	**7370**	**-0.0227**		**0.0515**	**8970**	**-0.0201**		**0.0563**
Children per household (#)	7383	-0.0156		0.1810	8975	0.0017		0.8717

Workers per household (#)	**7383**	**-0.0204**		**0.0799**	**8975**	**-0.0263**		**0.0128**
Vehicles per household (#)	7286	-0.0057		0.6243	8823	-0.0085		0.4259
Household income ($), mean	7370	0.0000		0.9938	8970	0.0087		0.4095
Household income ($), median	7375	0.0030		0.7997	8974	0.0152		0.1512
Unemployment rate (%)	7383	0.0084		0.4683	**8975**	**0.0181**		**0.0859**
Non-white or Hispanic race/ethnicity (%)	7383	-0.0067		0.5648	8975	0.0054		0.6072
Rental housing rate (%)	7383	-0.0105		0.3659	**8975**	**-0.0243**		**0.0213**
Neighborhood built environment								
Urbanization status (urban, rural)	**1**		**8.9337**	**0.0028**	**1**		**32.4730**	**0.0000**
Residential density (housing units/acre)	7387	-0.0145		0.2121	**8998**	**-0.0277**		**0.0085**
Population density (people/acre)	**7387**	**-0.0243**		**0.0370**	**8998**	**-0.0391**		**0.0002**
Employment density (jobs/acre)	7387	-0.0013		0.9142	8998	0.0028		0.7884
Jobs per household (#/#)	7387	0.0026		0.8246	8998	0.0006		0.9570
Intersection density (#/mi^2)	**7387**	**-0.0266**		**0.0225**	**8998**	**-0.0521**		**0.0000**
Jobs (#) within 45 minutes auto travel time	7387	-0.0014		0.9070	8998	-0.0131		0.2137
Jobs (#) within 45-minute transit commute	5177	0.0069		0.6219	6594	0.0191		0.1201
Average distance (m) to nearest transit stop	4725	0.0000		0.9994	6071	-0.0105		0.4127
Aggregate transit service frequency (#/mi^2)	5548	-0.0095		0.4793	7065	-0.0134		0.2615
Nearby destinations (#)								
Community services	7387	0.0002		0.9860	8998	-0.0059		0.5754
Government services	7387	-0.0018		0.8768	8998	-0.0013		0.9021
Food banks	7387	0.0051		0.6630	8998	-0.0093		0.3779
Human services	7387	0.0049		0.6718	8998	0.0020		0.8532
Workforce services	7387	-0.0014		0.9073	**8998**	**-0.0187**		**0.0767**
Health care facilities	7387	0.0067		0.5636	**8998**	**-0.0199**		**0.0593**
Home living medical facilities	7387	-0.0039		0.7380	**8998**	**-0.0213**		**0.0430**
General medical facilities	7387	-0.0004		0.9709	8998	-0.0173		0.1003
Special medical facilities	7387	-0.0008		0.9456	**8998**	**-0.0215**		**0.0419**
Other health care facilities	**7387**	**0.0256**		**0.0278**	8998	0.0075		0.4786
Liquor facilities	**7387**	**0.0299**		**0.0102**	**8998**	**0.0194**		**0.0661**
Liquor stores	**7387**	**0.0280**		**0.0162**	8998	0.0064		0.5456
Liquor package agency	7387	0.0168		0.1481	**8998**	**0.0251**		**0.0173**
Schools	7387	-0.0040		0.7337	8998	-0.0081		0.4444
Community centers	7387	-0.0007		0.9507	8998	-0.0017		0.8738
Recreation centers	7387	-0.0017		0.8837	8998	0.0049		0.6417
Libraries	7387	0.0005		0.9683	8998	-0.0067		0.5279
Grocery and food stores	7387	-0.0102		0.3793	8998	0.0000		0.9996
Convenience grocery stores	7387	0.0003		0.9769	8998	-0.0010		0.9262
Supermarkets	7387	-0.0071		0.5436	8998	-0.0071		0.5034
Grocery stores	7387	-0.0094		0.4196	8998	0.0093		0.3761

Other grocery and food stores	7387	-0.0127	0.2745	8998	-0.0012	0.9125
Retail centers	7387	-0.0024	0.8342	8998	0.0111	0.2941

Notes: **Bold text** indicates a significant independent variable (p<0.10). df = degrees of freedom, r_{pb} = point-biserial correlation coefficient, χ^2 = Chi-Squared Test statistic, p = p-value.

4.4 Results for Alcohol Impairment Status, All Bicycle/Pedestrian Crashes

Table 4-2 displays the results of point-biserial correlation coefficient (r_{pb}) tests and Chi-Squared (χ^2) tests of independence for continuous and categorical independent variables versus alcohol impairment status for crashes involving active mode uses. Figure 4.5 and Figure 4.7 show the alcohol-impaired percentage for bicycle and pedestrian crashes by significant categorical variables. Figure 4.6 and Figure 4.8 show mean values of significant continuous variables by alcohol impairment status for bicycle and pedestrian crashes.

4.4.1. Alcohol Impairment vs. Overall Impairment Among Bicyclists

In comparing crashes involving bicyclists and pedestrians, some variables were revealed to have significant associations with alcohol impairment status that were different from those associations with overall impairment. The following list highlights notable differences between alcohol impairment vs. overall impairment when comparing significance of variables among bicyclists.

- Demographics
    - Only a marginally significant positive association was observed for alcohol impairment with age.
- Crash Temporal Conditions
    - Marginally significant seasonal differences:
        - Crashes involving alcohol-impaired bicyclists were found slightly more often in spring (0.7%) than in summer (0.6%), fall (0.2%), or winter (0.1%).
    - Similar significance of time of day, day of week, and lighting variables between alcohol impairment and overall impairment
- Roadway Geometry
    - Posted speed was not found to be significant for alcohol impairment among cyclists.
    - Distance to the nearest crosswalk had a significant positive association with alcohol impairment status.

- Neighborhood Social Environment
    - Alcohol impairment was significantly less likely to be reported for bicycle crashes in areas with more average children per household.
- Neighborhood Built Environment
    - Only marginally significant negative relationship between alcohol impairment for bicyclists and intersection density
- Nearby Destinations
    - Alcohol impairment and overall impairment have similar significance among variables associated with nearby destinations

4.4.2. Alcohol Impairment vs. Overall Impairment Among Pedestrians

Results were also slightly different regarding alcohol impairment compared to overall impairment for crashes involving pedestrians as well. See the following list for notable differences:

- Demographics
    - Gender not significantly associated with alcohol impairment
    - Distraction was not significantly associated with alcohol impairment
    - Only marginally significant positive association with pedestrian's age
- Crash Temporal Conditions
    - Similar significance between alcohol vs. overall impairment
- Roadway Geometry
    - Route type not statistically significant
    - Presence of shoulder not statistically significant
    - Only marginally significant associations between alcohol impairment and posted speed and number of driveways
- Neighborhood Social Environment
    - Negative association with rental housing rate not significantly associated with alcohol impairment
- Neighborhood Built Environment

- Marginally significant positive association between alcohol impairment status of a pedestrian and the number of jobs within a 45-minute commute by transit.

- Nearby Destinations
  - Number of workforce services not significantly associated with alcohol impairment
  - Stronger positive associations between alcohol impairment and the number of liquor facilities and liquor package agencies

Table 4-2 Bivariate associations with active mode user alcohol impairment status

	All Bicycle Crashes (n=7389)				*All Pedestrian Crashes (n=9000)*			
	Alcohol-Impaired (n=35) vs Non-Alcohol-Impaired (n=7354)				Alcohol-Impaired (n=146) vs Non-Alcohol-Impaired (n=8854)			
Variable	*df*	r_{pb}	χ^2	*P*	*df*	r_{pb}	χ^2	*p*
Active mode user demographics								
Age (years)	**7111**	**0.0214**		**0.0717**	**8148**	**0.0186**		**0.0923**
Gender (male, female)	1		0.4115	0.5212	1		1.4769	0.2243
Distraction	**1**		**4.4543**	**0.0348**	1		0.4743	0.4910
Crash temporal conditions								
Year	7387	-0.0107		0.3577	8998	-0.0071		0.5017
Season (winter, spring, summer, fall)	**3**		**6.9565**	**0.0733**	3		2.5577	0.4650
Day of week (weekday, weekend)	**1**		**9.3810**	**0.0022**	**1**		**57.9810**	**0.0000**
Time of day (00-06, 06-12, 12-18, 18-24)	**3**		**65.5940**	**0.0000**	**3**		**151.1100**	**0.0000**
Weather (clear, other)	1		0.0157	0.9004	1		2.1764	0.1401
Lighting (day, dawn/dusk, dark)	**2**		**24.0180**	**0.0000**	**2**		**114.5100**	**0.0000**
Roadway geometry								
Route type (federal, state, local)	2		1.5940	0.4507	2		4.3343	0.1145
Functional class (freeway, arterial, collector, local)	3		0.8154	0.8458	2		1.0518	0.5910
Posted speed (mph)	4612	0.0202		0.1700	**5480**	**0.0236**		**0.0809**
Intersections (#)	7387	0.0044		0.7037	8998	-0.0103		0.3308
Distance to nearest intersection (m)	7387	0.0023		0.8432	8998	0.0167		0.1139
Distance to nearest crosswalk (m)	**7387**	**0.0231**		**0.0470**	**8998**	**0.0288**		**0.0063**
Traffic control (active control, passive control, uncontrolled)	2		3.7803	0.1511	**2**		**13.1860**	**0.0014**
Lanes (#)	3394	0.0044		0.7971	**4034**	**-0.0668**		**0.0000**
Median (present, absent)	1		0.5910	0.4420	1		0.6524	0.4193
Shoulder (present, absent)	1	0.1281		0.7205	1		2.4054	0.1209
Pedestrian curb ramps (#)	7387	-0.0017		0.8828	8998	-0.0173		0.1000
Driveways (#)	7387	-0.0016		0.8874	**8998**	**0.0184**		**0.0810**
Horizontal alignment (level, curve)	2		0.7027	0.7037	2		0.1579	0.9241
Vertical alignment (level, grade)	2		0.6823	0.7110	2		2.1795	0.3363
Transit stations (#)	7387	0.0068		0.5582	8998	-0.0121		0.2507
Bus stops (#)	7387	0.0067		0.5628	8998	-0.0137		0.1953
Commuter rail stations (#)	7387	-0.0059		0.6109	8998	0.0056		0.5921
Light rail stations (#)	7387	0.0045		0.7001	8998	0.0118		0.2645
Neighborhood social environment								
Household size (#)	**7370**	**-0.0232**		**0.0462**	**8970**	**-0.0226**		**0.0320**
Children per household (#)	**7383**	**-0.0245**		**0.0352**	8975	-0.0074		0.4844

Workers per household (#)	**7383**	**-0.0196**		**0.0926**	**8975**	**-0.0281**		**0.0079**
Vehicles per household (#)	7286	-0.0123		0.2957	8823	-0.0171		0.1080
Household income ($), mean	7370	0.0030		0.7949	8970	0.0058		0.5799
Household income ($), median	7375	0.0001		0.9901	8974	0.0102		0.3322
Unemployment rate (%)	7383	0.0121		0.2983	**8975**	**0.0209**		**0.0479**
Non-white or Hispanic race/ethnicity (%)	7383	-0.0072		0.5351	8975	-0.0036		0.7309
Rental housing rate (%)	7383	-0.0001		0.9903	8975	-0.0142		0.1773
Neighborhood built environment								
Urbanization status (urban, rural)	**1**		**18.9790**	**0.0000**	**1**		**27.0160**	**0.0000**
Residential density (housing units/acre)	7387	-0.0120		0.3035	**8998**	**-0.0253**		**0.0163**
Population density (people/acre)	**7387**	**-0.0251**		**0.0311**	**8998**	**-0.0400**		**0.0001**
Employment density (jobs/acre)	7387	0.0047		0.6851	8998	0.0145		0.1693
Jobs per household (#/#)	7387	0.0040		0.7327	8998	0.0014		0.8973
Intersection density (#/mi^2)	**7387**	**-0.0220**		**0.0592**	**8998**	**-0.0505**		**0.0000**
Jobs (#) within 45 minutes auto travel time	7387	0.0057		0.6213	8998	-0.0149		0.1575
Jobs (#) within 45-minute transit commute	5177	0.0140		0.3148	**6594**	**0.0229**		**0.0633**
Average distance (m) to nearest transit stop	4725	-0.0014		0.9230	6071	-0.0052		0.6848
Aggregate transit service frequency (#/mi^2)	5548	-0.0042		0.7550	7065	-0.0038		0.7480
Nearby destinations (#)								
Community services	7387	0.0008		0.9448	8998	0.0030		0.7789
Government services	7387	0.0007		0.9551	8998	0.0072		0.4939
Food banks	7387	-0.0002		0.9870	8998	-0.0053		0.6123
Human services	7387	0.0128		0.2699	8998	0.0058		0.5804
Workforce services	7387	-0.0099		0.3966	8998	-0.0143		0.1746
Health care facilities	7387	0.0064		0.5820	**8998**	**-0.0184**		**0.0812**
Home living medical facilities	7387	0.0007		0.9509	**8998**	**-0.0236**		**0.0250**
General medical facilities	7387	-0.0133		0.2544	8998	-0.0138		0.1896
Special medical facilities	7387	0.0019		0.8735	**8998**	**-0.0187**		**0.0756**
Other health care facilities	**7387**	**0.0287**		**0.0137**	8998	0.0084		0.4279
Liquor facilities	**7387**	**0.0284**		**0.0146**	**8998**	**0.0247**		**0.0190**
Liquor stores	**7387**	**0.0276**		**0.0178**	8998	0.0048		0.6499
Liquor package agency	7387	0.0147		0.2052	**8998**	**0.0361**		**0.0006**
Schools	7387	0.0013		0.9103	8998	-0.0075		0.4771
Community centers	7387	0.0050		0.6658	8998	0.0014		0.8979
Recreation centers	7387	0.0020		0.8625	8998	0.0106		0.3144
Libraries	7387	0.0057		0.6267	8998	-0.0072		0.4929
Grocery and food stores	7387	-0.0096		0.4094	8998	-0.0083		0.4330
Convenience grocery stores	7387	0.0020		0.8667	8998	-0.0088		0.4019
Supermarkets	7387	-0.0024		0.8368	8998	-0.0136		0.1958
Grocery stores	7387	-0.0089		0.4448	8998	0.0045		0.6723

Other grocery and food stores	7387	-0.0164	0.1579	8998	-0.0050	0.6386
Retail centers	7387	-0.0024	0.8342	8998	0.0111	0.2941

Notes: **Bold text** indicates a significant independent variable (p<0.10). df = degrees of freedom, r_{pb} = point-biserial correlation coefficient, χ^2 = Chi-Squared Test statistic, p = p-value.

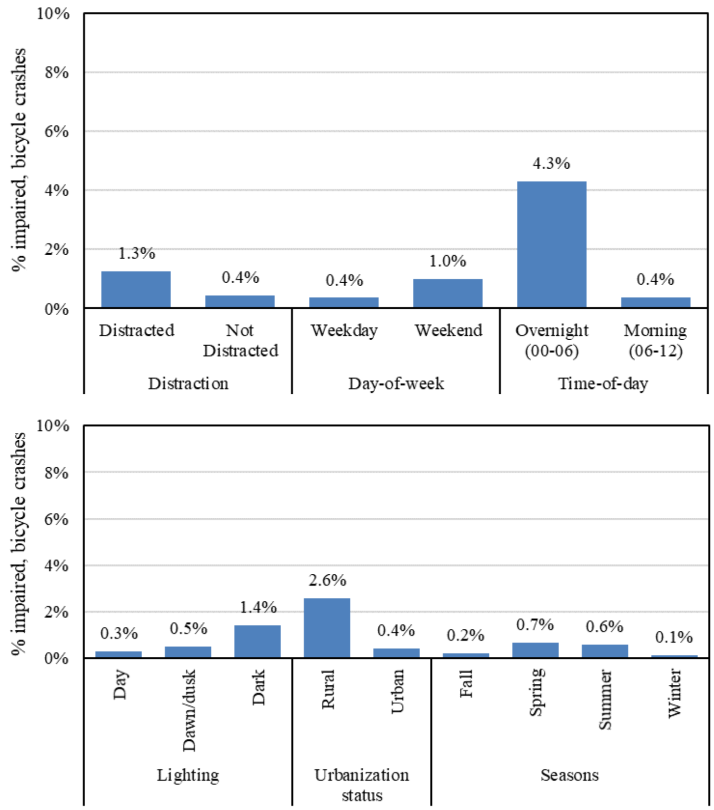

Figure 4.5. Percent Alcohol-Impaired for Bicycle Crashes by Significant Categorical Variable

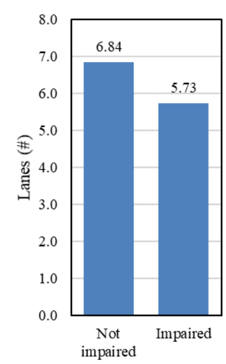

Figure 4.6. Mean Values of Significant Variables by Alcohol Impairment Status for Bicycle Crashes

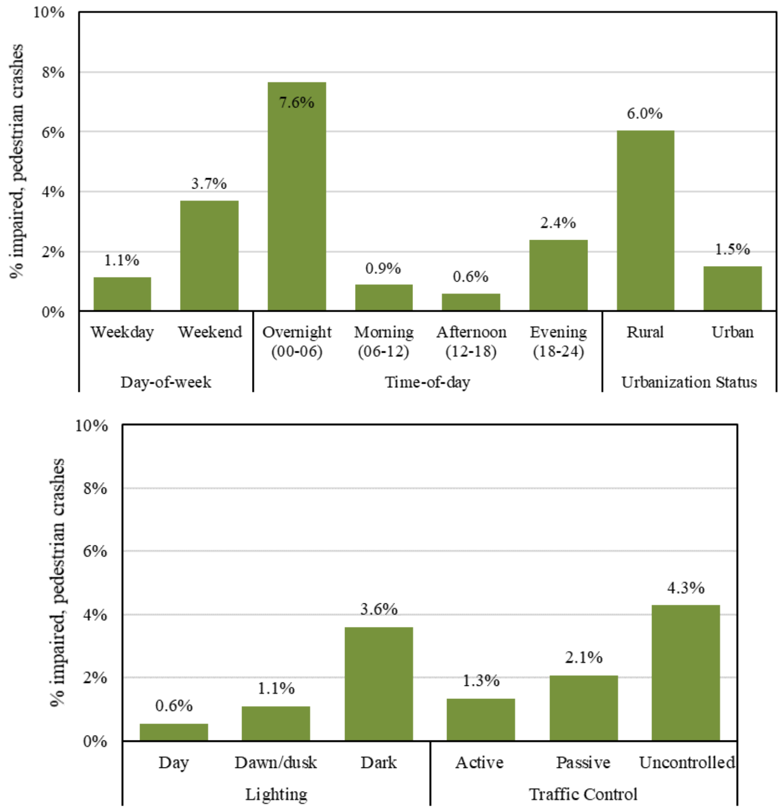

Figure 4.7. Percent Alcohol-Impaired for Pedestrian Crashes by Significant Categorical Variables

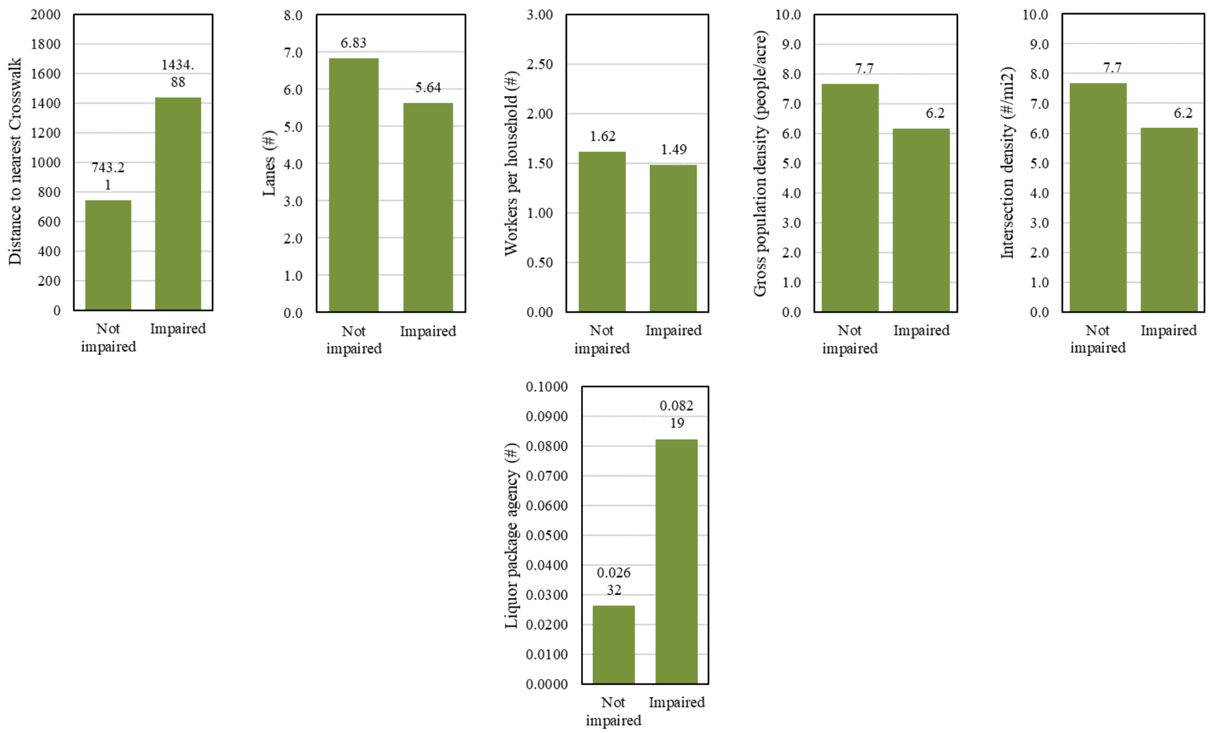

Figure 4.8. Mean Values of Significant Variables by Alcohol Impairment Status for Pedestrian Crashes

4.5 Results for Drug Impairment Status, All Bicycle/Pedestrian Crashes

Table 4-3 Bivariate associations with active mode user drugs impairment status displays the results of point-biserial correlation coefficient (r_{pb}) tests and Chi-Squared (χ^2) tests of independence for continuous and categorical independent variables versus drug impairment status for crashes involving active mode users. Figure 4.9 and Figure 4.11 show the percent drug-impaired for bicycle and pedestrian crashes by significant categorical variables. Figure 4.10 and Figure 4.12 show mean values of significant continuous variables by drug impairment status for bicycle and pedestrian crashes.

4.5.1. Drug Impairment vs. Overall Impairment Among Bicyclists

For crashes involving bicyclists, some differences in association were observed for drug impairment status compared to overall impairment:

- Demographics
  - No significant difference between drug impairment vs. overall impairment
- Crash Temporal Conditions
  - Lighting condition no longer significant
  - Less significant day-of-week and time-of-day differences
    - Drug impairment is somewhat higher on weekends (0.6%) than on weekdays (0.3%).
- Roadway Geometry
  - No significant difference between drug impairment vs. overall impairment
- Neighborhood Social Environment
  - No significant difference between drug impairment in social environment
- Neighborhood Built Environment
  - Urbanization status not found to be significant
  - Population density not found to be significant
  - Only marginally significant negative association with intersection density
- Nearby Destinations
  - Associations with other health care facilities, liquor facilities, and liquor stores were found to not be significant

- Significant positive association with number of food banks
    - Crashes involving bicyclists were more likely to report drug impairment in areas with more food banks.

4.5.2. Drug Impairment vs. Overall Impairment Among Pedestrians

Results were also slightly different regarding alcohol impairment compared to overall impairment for crashes involving pedestrians as well. See the following list for notable differences:

- Demographics
  - Distraction found to have a significant association with drug impairment:
    - Drug impairment was more likely for pedestrian crashes reporting distraction (1.8%) compared to crashes that had other contributing circumstances besides distraction (0.9%).
- Crash Temporal Conditions
  - Day of week found to not be significant
- Roadway Geometry
  - Presence of a shoulder not found to be significant
  - but with regard to roadway functional class, a relatively larger proportion of drug impairment was found on arterial roads (1.4%) when compared to local (0.7%) and collector (0.6%) roads
- Neighborhood Social Environment
  - Drug impairment found to be negatively associated with rental housing rate
  - Household size, workers per household, and unemployment rate found to not be significant
- Neighborhood Built Environment
  - Negative associations with residential density and population density found not to be significant,
  - Aggregate transit frequency found to be marginally significant

        - Pedestrian crashes were more likely to have suspected drug impairment in areas with lower transit service frequency

- Nearby Destinations
    - Workforce service, health care facilities, home living medical facilities, liquor facilities and liquor package agencies found to not be significant
    - Negative association with the number of special medical facilities was found for drug impairment

Table 4-3 Bivariate associations with active mode user drugs impairment status

	All Bicycle Crashes (n=7389)				*All Pedestrian Crashes (n=9000)*			
	Drug-Impaired (n=27) vs Non-Drug-Impaired (n=7362)				Drug-Impaired (n=91) vs Non-Drug-Impaired (n=8909)			
Variable	*df*	r_{pb}	χ^2	*p*	*df*	r_{pb}	χ^2	*p*
Active mode user demographics								
Age (years)	**7111**	**0.0363**		**0.0022**	**8148**	**0.0284**		**0.0104**
Gender (male, female)	1		1.6455	0.1996	**1**		**3.1903**	**0.0741**
Distraction	**1**		**13.5600**	**0.0002**	**1**		**4.4458**	**0.0350**
Crash temporal conditions								
Year	7387	0.0067		0.5676	8998	0.0053		0.6163
Season (winter, spring, summer, fall)	3		3.5538	0.3139	3		4.6107	0.2026
Day of week (weekday, weekend)	**1**		**2.7543**	**0.0970**	1		1.4600	0.2269
Time of day (00-06, 06-12, 12-18, 18-24)	**3**		**8.7675**	**0.0326**	**3**		**26.0180**	**0.0000**
Weather (clear, other)	1		2.5131	0.1129	1		0.1715	0.6788
Lighting (day, dawn/dusk, dark)	1		4.1503	0.1255	**1**		**21.4710**	**0.0000**
Roadway geometry								
Route type (federal, state, local)	2		3.3634	0.1861	**2**		**7.3534**	**0.0253**
Functional class (freeway, arterial, collector, local)	3		2.7278	0.4355	**2**		**11.8020**	**0.0027**
Posted speed (mph)	**4612**	**0.0375**		**0.0100**	**5480**	**0.0283**		**0.0359**
Intersections (#)	7387	0.0060		0.6068	8998	-0.0048		0.6495
Distance to nearest intersection (m)	7387	-0.0118		0.3110	8998	0.0068		0.5194
Distance to nearest crosswalk (m)	7387	0.0124		0.2855	**8998**	**0.0250**		**0.0175**
Traffic control (active control, passive control, uncontrolled)	2		0.4278	0.8074	**2**		**8.1631**	**0.0169**
Lanes (#)	3394	0.0038		0.8268	**4034**	**-0.0466**		**0.0031**
Median (present, absent)	1		0.3858	0.5345	1		0.2189	0.6399
Shoulder (present, absent)	1		0.6700	0.4131	1		0.4219	0.5160
Pedestrian curb ramps (#)	7387	0.0074		0.5268	8998	0.0037		0.7287
Driveways (#)	7387	0.0137		0.2379	**8998**	**0.0537**		**0.0000**
Horizontal alignment (level, curve)	2		3.9194	0.1409	2		0.9347	0.6266
Vertical alignment (level, grade)	2		2.7790	0.2492	2		0.0558	0.9725
Transit stations (#)	7387	-0.0136		0.2431	8998	-0.0020		0.8520
Bus stops (#)	7387	-0.0125		0.2838	8998	-0.0021		0.8423
Commuter rail stations (#)	7387	-0.0052		0.6552	8998	0.0016		0.8783
Light rail stations (#)	7387	-0.0163		0.1621	8998	0.0004		0.9672
Neighborhood social environment								
Household size (#)	7370	-0.0099		0.3950	8970	-0.0059		0.5759
Children per household (#)	7383	0.0019		0.8695	8975	0.0110		0.2954

Workers per household (#)	7383	-0.0084		0.4679	8975	-0.0107		0.3092
Vehicles per household (#)	7286	-0.0007		0.9493	8823	0.0088		0.4092
Household income ($), mean	7370	-0.0086		0.4593	8970	0.0037		0.7271
Household income ($), median	7375	0.0010		0.9324	8974	0.0101		0.3395
Unemployment rate (%)	7383	-0.0040		0.7311	8975	0.0115		0.2776
Non-white or Hispanic race/ethnicity (%)	7383	0.0015		0.9000	8975	0.0086		0.4134
Rental housing rate (%)	7383	-0.0153		0.1882	**8975**	**-0.0247**		**0.0194**
Neighborhood built environment								
Urbanization status (urban, rural)	1		0.1308	0.7176	**1**	**6.9693**		**0.0083**
Residential density (housing units/acre)	7387	-0.0146		0.2106	8998	-0.0170		0.1067
Population density (people/acre)	7387	-0.0142		0.2221	8998	-0.0173		0.1016
Employment density (jobs/acre)	7387	-0.0078		0.5051	8998	-0.0097		0.3558
Jobs per household (#/#)	7387	-0.0003		0.9791	8998	0.0016		0.8814
Intersection density (#/mi^2)	**7387**	**-0.0204**		**0.0796**	**8998**	**-0.0252**		**0.0169**
Jobs (#) within 45 minutes auto travel time	7387	-0.0001		0.9935	8998	-0.0048		0.6458
Jobs (#) within 45-minute transit commute	5177	-0.0004		0.9799	6594	0.0041		0.7383
Average distance (m) to nearest transit stop	4725	0.0091		0.5318	6071	-0.0017		0.8970
Aggregate transit service frequency (#/mi^2)	5548	-0.0102		0.4472	**7065**	**-0.0196**		**0.0993**
Nearby destinations (#)								
Community services	7387	0.0067		0.5626	8998	-0.0167		0.1127
Government services	7387	0.0011		0.9236	8998	-0.0154		0.1447
Food banks	**7387**	**0.0233**		**0.0454**	8998	-0.0085		0.4185
Human services	7387	-0.0097		0.4059	8998	-0.0054		0.6072
Workforce services	7387	0.0074		0.5275	8998	-0.0086		0.4158
Health care facilities	7387	0.0009		0.9382	8998	-0.0121		0.2512
Home living medical facilities	7387	-0.0115		0.3218	8998	-0.0109		0.3030
General medical facilities	7387	0.0102		0.3801	8998	-0.0117		0.2664
Special medical facilities	7387	-0.0022		0.8471	**8998**	**-0.0180**		**0.0872**
Other health care facilities	7387	0.0095		0.4160	8998	0.0078		0.4585
Liquor facilities	7387	0.0147		0.2074	8998	0.0003		0.9764
Liquor stores	7387	0.0156		0.1791	8998	0.0027		0.7998
Liquor package agency	7387	0.0057		0.6215	8998	-0.0027		0.7972
Schools	7387	0.0018		0.8754	8998	0.0049		0.6412
Community centers	7387	-0.0067		0.5648	8998	-0.0097		0.3593
Recreation centers	7387	-0.0006		0.9566	8998	-0.0100		0.3411
Libraries	7387	-0.0094		0.4196	8998	-0.0052		0.6199
Grocery and food stores	7387	0.0011		0.9261	8998	0.0112		0.2881
Convenience grocery stores	7387	0.0030		0.7945	8998	0.0151		0.1514
Supermarkets	7387	-0.0040		0.7287	8998	0.0033		0.7517
Grocery stores	7387	0.0053		0.6514	8998	0.0159		0.1314

Other grocery and food stores	7387	-0.0018	0.8794	8998	-0.0022	0.8365
Retail centers	7387	-0.0110	0.3437	8998	-0.0077	0.4631

Notes: **Bold text** indicates a significant independent variable ($p<0.10$). df = degrees of freedom, r_{pb} = point-biserial correlation coefficient, χ^2 = Chi-Squared Test statistic, p = p-value.

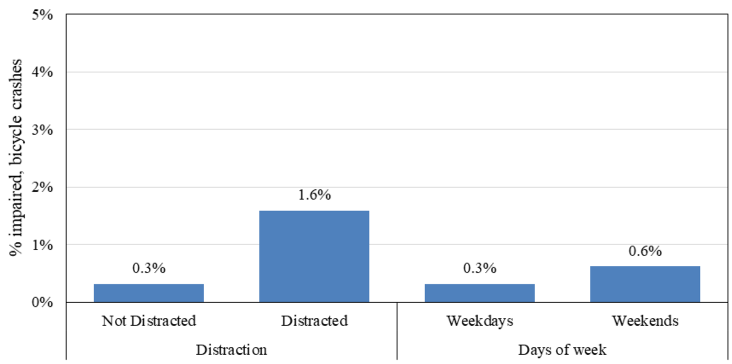

Figure 4.9. Percent Drug-Impaired for Bicycle Crashes by Significant Categorical Variables

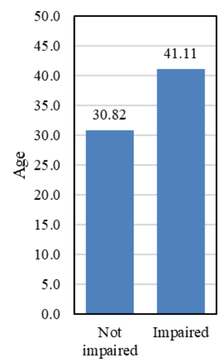

Figure 4.10. Mean Values of Significant Continuous Variable by Drug Impairment Status for Bicycle Crashes

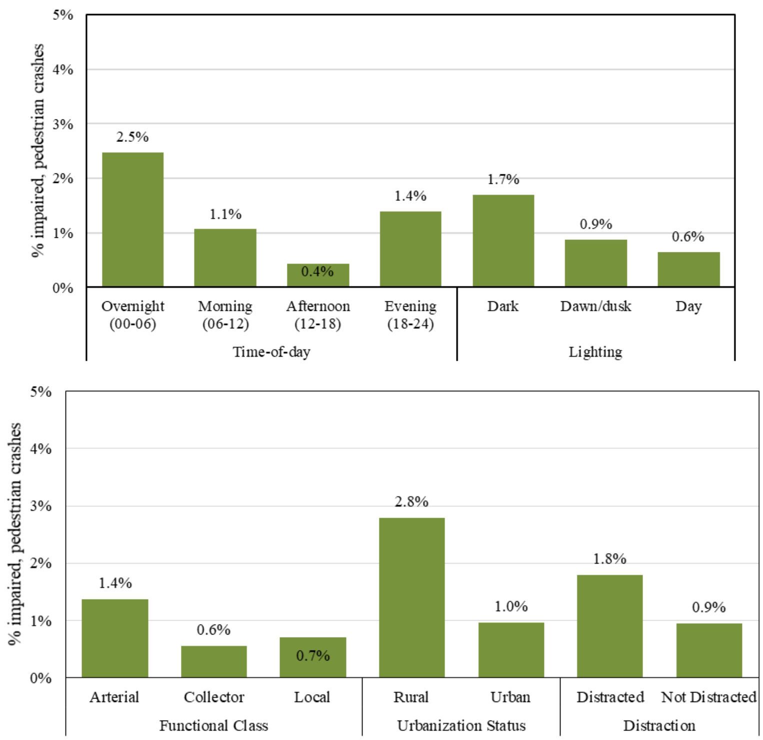

Figure 4.11. Percent Drug-Impaired for Pedestrian Crashes by Significant Categorical Variables

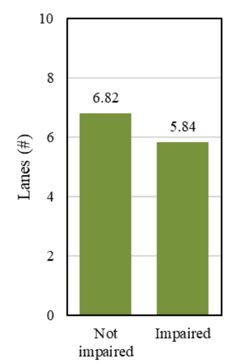

Figure 4.12. Mean Values of Significant Continuous Variables by Drug Impairment Status for Pedestrian Crashes

4.6 Results for Impairment Status, Fatal and Serious Injury Bicycle/Pedestrian Crashes

Table 4-4 displays the bivariate analysis results for independent variables versus active mode user impairment status for crashes with KA severity (fatal or suspected serious injury). Figure 4.13 and Figure 4.14 show significant differences for bicycle crashes, while Figure 4.15 and Figure *4.16* show key results for pedestrian crashes. To avoid repetition, only results that differ from those reported in Section 4.3 (for crashes of all severity levels) are discussed.

4.6.1. KA Impairment vs. Overall Impairment Among Bicyclists

For KA severity crashes involving bicyclists, fewer and some different variables were significantly associated with impairment status

- Demographics
    - No significant difference between KA impairment vs. overall impairment
- Crash Temporal Conditions
    - Time of day had a marginally significant association with impairment: Bicycle impairment for KA crashes were found comparatively more frequently overnight (9.1%) than in the morning (2.7%), evening (2.2%), or afternoon (1.6%).
- Roadway Geometry
    - Speed was not significant, but traffic control device type was: A greater proportion of bicyclists involved in KA crashes at uncontrolled intersections (10.5%) were suspected to be impaired when compared to active traffic control (2.1%) and passive control (1.8%) intersections
- Neighborhood Social Environment
    - No significant difference between KA impairment vs. overall impairment
- Neighborhood Built Environment
    - No significant difference between KA impairment vs. overall impairment
- Nearby Destinations
    - Results for the number of liquor stores and the number of liquor facilities were similarly significant (or marginally significant) with stronger positive associations for KA crashes than overall. While the association with other

health care facilities was no longer significant, there was a significant association with grocery stores: Crashes involving bicyclists with KA severity were more likely to report impairment in areas with more grocery stores.

4.6.2. KA Impairment vs. Overall Impairment Among Pedestrians

A number of variables were found to be different for KA crashes compared to overall crashes among pedestrians. See the following list for notable differences:

- Demographics
  - No demographic characteristics found to be significant
- Roadway Geometry
  - Several roadway geometry variables that showed statistical significance for overall pedestrian crashes were not found to be significantly associated with impairment for KA severity crashes, including:
    - Route type
    - Posted speed
    - Distance to nearest crosswalk
    - Traffic control device
    - Presence of a shoulder
  - Number of lanes (negative association) and number of driveways (positive association) were found to be significant.
- Neighborhood Social Environment
  - Household size and the number of workers per household are similarly significant (or marginally significant) with a stronger negative correlation
  - Unemployment rate and rental housing found to not be significant in comparison to crashes of all severity levels
- Neighborhood Built Environment
  - Urbanization status, residential density, and population density not found to be significant

- Number of jobs within a 45-minute transit commute was found to be significant:
  - Impairment was significantly less likely to be suspected among pedestrians with KA crash severity in areas with less transit accessibility.
- Nearby Destinations
  - Associations with the following variables were found to not be significant:
    - Number of workforce services
    - Health care facilities
    - Home living medical facilities
    - Liquor facilities
    - Liquor package agencies
  - Significant positive associations with the following variables were identified:
    - Convenience grocery stores
    - Grocery stores
    - Other grocery and food stores
      - Crashes involving bicyclists with KA severity were more likely to report impairment in areas with more grocery and food stores, convenience grocery stores, and grocery stores.

Table 4-4 Bivariate associations with impaired active mode user with KA crash severity

	KA Bicycle Crashes (n=718)				*KA Pedestrian Crashes (n=1707)*			
	Impaired (n=17) vs Non-Impaired (n=701)				Impaired (n=97) vs Non-Impaired (n=1610)			
Variable	*df*	r_{pb}	χ^2	*P*	*df*	r_{pb}	χ^2	*p*
Active mode user demographics								
Age (years)	700	-0.0087		0.8180	1613	0.0208		0.4033
Gender (male, female)	1		0.5919	0.4417	1		1.3596	0.2436
Distraction	1		1.3595	0.2436	1		0.2946	0.5873
Crash temporal conditions								
Year	716	-0.0254		0.4966	1705	0.0353		0.1444
Season (winter, spring, summer, fall)	3		2.7380	0.4338	3		5.5445	0.1360
Day of week (weekday, weekend)	1		0.0282	0.8667	**1**		**14.5800**	**0.0001**
Time of day (00-06, 06-12, 12-18, 18-24)	**3**		**7.3553**	**0.0614**	**3**		**30.4890**	**0.0000**
Weather (clear, other)	1		1.3618	0.2432	1		0.0521	0.8194
Lighting (day, dawn/dusk, dark)	2		4.2606	0.1188	**2**		**8.7986**	**0.0123**
Roadway geometry								
Route type (federal, state, local)	2		0.8603	0.6504	2		0.9683	0.6162
Functional class (freeway, arterial, collector, local)	3		1.2899	0.7315	2		2.2975	0.3170
Posted speed (mph)	472	0.0678		0.1403	1129	0.0242		0.4159
Intersections (#)	716	0.0153		0.6822	1705	-0.0069		0.7750
Distance to nearest intersection (m)	716	-0.0085		0.8201	1705	0.0066		0.7855
Distance to nearest crosswalk (m)	716	-0.0215		0.5652	1705	0.0020		0.9355
Traffic control (active control, passive control, uncontrolled)	**2**		**6.2522**	**0.0439**	2		1.7810	0.4104
Lanes (#)	316	0.0347		0.5372	**845**	**-0.0980**		**0.0043**
Median (present, absent)	1		0.0585	0.8089	1		0.2114	0.6457
Shoulder (present, absent)	1		1.5489	0.2133	1		0.7826	0.3763
Pedestrian curb ramps (#)	716	0.0220		0.5559	1705	0.0063		0.7948
Driveways (#)	716	0.0402		0.2825	**1705**	**0.0499**		**0.0393**
Horizontal alignment (level, curve)	2		0.7361	0.6921	2		2.4982	0.2868
Vertical alignment (level, grade)	2		0.2880	0.8659	2		1.1857	0.5528
Transit stations (#)	716	-0.0285		0.4451	1705	-0.0188		0.4367
Bus stops (#)	716	-0.0288		0.4404	1705	-0.0220		0.3626
Commuter rail stations (#)	716	-0.0117		0.7552	1705	0.0096		0.6908
Light rail stations (#)	716	-0.0028		0.9403	1705	0.0341		0.1593
Neighborhood social environment								
Household size (#)	715	-0.0216		0.5630	**1703**	**-0.0500**		**0.0391**
Children per household (#)	716	0.0025		0.9461	1703	-0.0218		0.3693

Workers per household (#)	716	-0.0221		0.5540	**1703**	**-0.0465**		**0.0551**
Vehicles per household (#)	703	0.0255		0.4985	1663	-0.0347		0.1567
Household income ($), mean	715	0.0057		0.8794	1703	-0.0080		0.7402
Household income ($), median	714	0.0110		0.7690	1702	0.0004		0.9860
Unemployment rate (%)	716	-0.0009		0.9818	1703	0.0071		0.7691
Non-white or Hispanic race/ethnicity (%)	716	-0.0201		0.5908	1703	0.0295		0.2235
Rental housing rate (%)	716	-0.0318		0.3951	1703	-0.0057		0.8156
Neighborhood built environment								
Urbanization status (urban, rural)	1		0.0393	0.8428	1		0.1086	0.7418
Residential density (housing units/acre)	716	-0.0221		0.5536	1705	-0.0185		0.4455
Population density (people/acre)	716	-0.0173		0.6442	1705	-0.0373		0.1232
Employment density (jobs/acre)	716	0.0000		0.9996	1705	0.0356		0.1417
Jobs per household (#/#)	716	-0.0092		0.8046	1705	0.0091		0.7074
Intersection density (#/mi^2)	716	-0.0126		0.7359	**1705**	**-0.0498**		**0.0397**
Jobs (#) within 45 minutes auto travel time	716	0.0541		0.1479	1705	0.0073		0.7640
Jobs (#) within 45-minute transit commute	454	0.0320		0.4955	**1191**	**0.0743**		**0.0103**
Average distance (m) to nearest transit stop	409	0.0150		0.7624	1094	0.0105		0.7295
Aggregate transit service frequency (#/mi^2)	493	-0.0300		0.5053	1281	0.0012		0.9652
Nearby destinations (#)								
Community services	716	-0.0071		0.8503	1705	-0.0249		0.3033
Government services	716	0.0071		0.8484	1705	-0.0204		0.4002
Food banks	716	-0.0074		0.8431	1705	-0.0330		0.1729
Human services	716	-0.0211		0.5716	1705	0.0275		0.2559
Workforce services	716	-0.0211		0.5716	1705	-0.0127		0.6004
Health care facilities	716	0.0293		0.4326	1705	-0.0135		0.5786
Home living medical facilities	716	-0.0083		0.8244	1705	-0.0089		0.7130
General medical facilities	716	0.0411		0.2716	1705	-0.0115		0.6342
Special medical facilities	716	0.0264		0.4804	1705	-0.0421		0.0818
Other health care facilities	716	0.0320		0.3919	1705	0.0207		0.3917
Liquor facilities	716	0.0729		0.0507	1705	0.0269		0.2673
Liquor stores	**716**	**0.1021**		**0.0062**	1705	0.0235		0.3313
Liquor package agency	716	-0.0194		0.6033	1705	0.0177		0.4640
Schools	716	0.0566		0.1294	1705	-0.0199		0.4106
Community centers	716	0.0186		0.6197	1705	0.0133		0.5834
Recreation centers	716	-0.0039		0.9165	1705	0.0197		0.4157
Libraries	716	0.0324		0.3863	1705	0.0010		0.9656
Grocery and food stores	716	0.0280		0.4535	**1705**	**0.0534**		**0.0273**
Convenience grocery stores	716	-0.0095		0.7999	**1705**	**0.0581**		**0.0164**
Supermarkets	716	0.0534		0.1529	1705	0.0017		0.9437
Grocery stores	**716**	**0.0868**		**0.0200**	**1705**	**0.0439**		**0.0698**

Other grocery and food stores	716	-0.0077	0.8372	1705	0.0351	0.1476
Retail centers	716	0.0203	0.5872	1705	0.0177	0.4644

Notes: **Bold text** indicates a significant independent variable ($p<0.10$). *df* = degrees of freedom, r_{pb} = point-biserial correlation coefficient, χ^2 = Chi-Squared Test statistic, *p* = p-value.

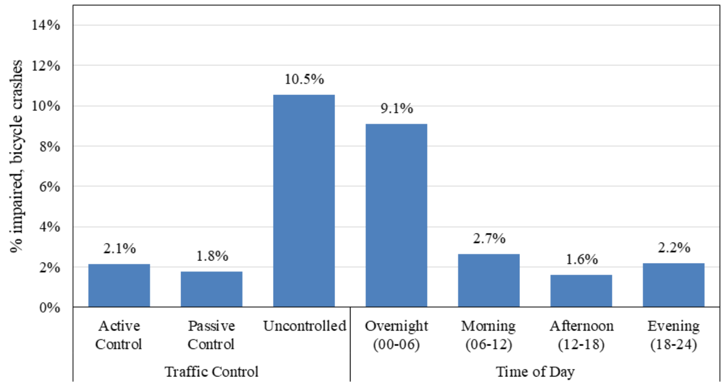

Figure 4.13. Percent Impaired for KA Bicycle Crashes by Significant Categorical Variables

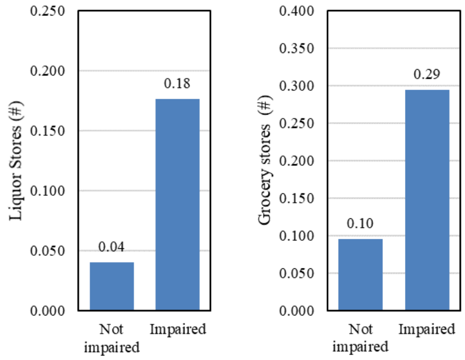

Figure 4.14. Mean Values of Significant Continuous Variables by Impaired Status for KA Bicycle Crashes

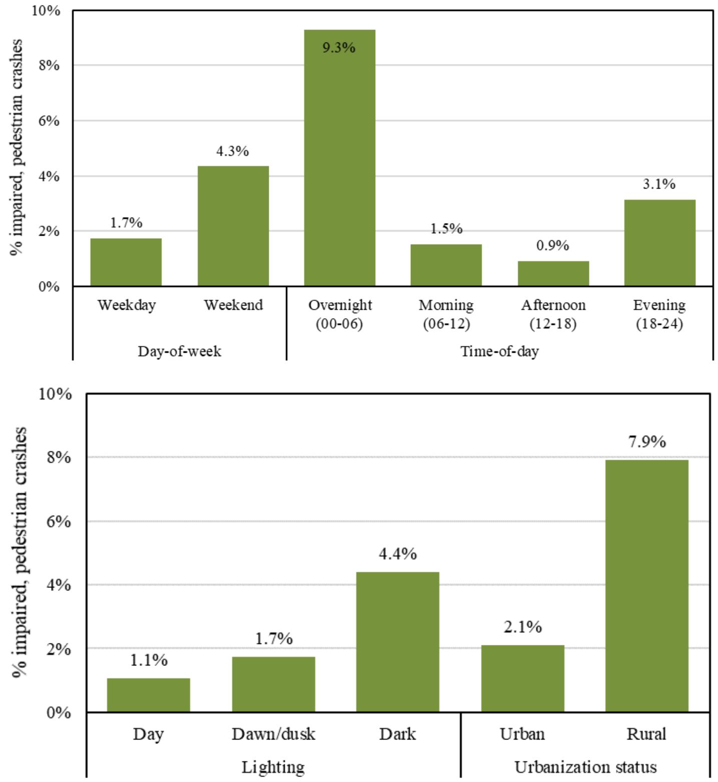

Figure 4.15. Percent Impaired for KA Pedestrian crashes by Significant Categorical Variables

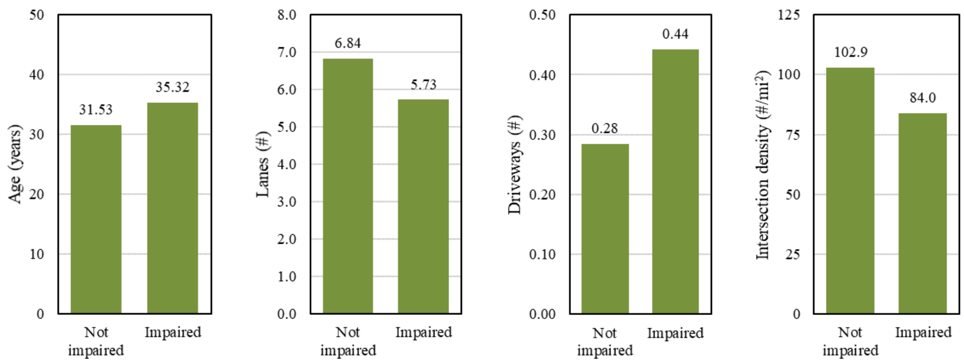

Figure 4.16. Mean Values of Significant Continuous Variables by Impairment Status for KA Pedestrian Crashes

4.7 Results for Impairment Status, Non-Fatal/Serious Injury Bicycle/Pedestrian Crashes

Table 4-5 displays the results of point-biserial correlation coefficient (r_{pb}) tests and Chi-Squared (χ^2) tests of independence for continuous and categorical independent variables versus impaired active mode users with BCO crash severity, i.e., non-severe (minor injury, possible injury, or no injury). Figure 4.17 and Figure 4.19 show the percent impaired for bicycle and pedestrian crashes with BCO severity by significant categorical variables. Figure 4.18 and Figure 4.20 show mean values of significant continuous variables by impairment status for bicycle and pedestrian crashes with BCO severity.

<u>4.7.1. BCO Crash Severity vs. Overall Crash Severity Among Bicyclists</u>

For BCO severity crashes involving bicyclists, many results were similar to those for all-severity-level crashes, but a few different variables were significantly associated with impairment status.

- Demographics
    - For demographics, crash temporal conditions, and roadway geometry variables, results were quite similar for BCO and all crashes. One slight difference was a decrease in the significance of the positive association between impairment and speed. Also, impairment among non-severe bicycle crashes was found to increase correspondingly with an increase in distance to the nearest crosswalk.
- Neighborhood Social Environment
    - Household size found to have a stronger negative association for BCO crashes
    - BCO bicycle crashes were more likely to report impairment in areas with fewer children per household.
- Nearby Destinations
    - Number of liquor stores not found to be significant
    - Liquor package agencies found to have a significant positive association for BCO crashes.

    - Crashes involving bicyclists with BCO severity were more likely to report impairment in areas with fewer grocery stores.

4.7.2. BCO Crash Severity vs. Overall Crash Severity Among Pedestrians

For BCO severity crashes among pedestrians, a number of differences were seen as opposed to all-severity-level crashes.

- Demographics
    - Gender and age found not to be significant
    - Distraction found to be significant
        - Distraction significantly more likely (2.6%) than for crashes with contributing circumstances besides distraction (1.3%).
- Crash Temporal Conditions
    - Year was found to have a stronger negative association with impairment for BCO crashes than overall:
        - Significant decrease over time in the reporting of impaired pedestrians in non-severe crashes.
- Roadway Geometry
    - No significant association with route type, speed limit, presence of a shoulder, and number of driveways
    - Only marginally significant association with traffic control device type
- Neighborhood Social Environment
    - Results for household size and the number of workers per household were no longer significant for BCO pedestrian crashes compared to overall
    - Marginally significant positive association for median household income
- Nearby Destinations
    - Associations with special medical facilities and liquor facilities were found to not be significant,
    - Significant negative association with convenience grocery stores

- Crashes involving pedestrians with BCO severity were more likely to report impairment in areas with fewer convenience grocery stores.

Table 4-5 Bivariate associations with impaired active mode user with BCO crash severity

	BCO Bicycle Crashes (n=66070)				*BCO Pedestrian Crashes (n=7292)*			
	Impaired (n=39) vs Non-Impaired (n=6631)				Impaired (n=104) vs Non-Impaired (n=7188)			
Variable	*df*	r_{pb}	χ^2	*p*	*df*	r_{pb}	χ^2	*p*
Active mode user demographics								
Age (years)	**6408**	**0.0431**		**0.0006**	6533	0.0141		0.2561
Gender (male, female)	1		0.1972	0.6570	1		0.9973	0.3180
Distraction	**1**		**7.5073**	**0.0061**	**1**		**5.2607**	**0.0218**
Crash temporal conditions								
Year	6668	-0.0082		0.5031	**7290**	**-0.0260**		**0.0267**
Season (winter, spring, summer, fall)	3		3.5434	0.3152	3		3.0465	0.3845
Day of week (weekday, weekend)	**1**		**9.8810**	**0.0017**	**1**		**22.9130**	**0.0000**
Time of day (00-06, 06-12, 12-18, 18-24)	**3**		**38.1720**	**0.0000**	**3**		**108.0400**	**0.0000**
Weather (clear, other)	1		0.8712	0.3506	1		0.3467	0.5560
Lighting (day, dawn/dusk, dark)	**2**		**20.2630**	**0.0000**	**2**		**74.6640**	**0.0000**
Roadway geometry								
Route type (federal, state, local)	2		1.0333	0.5965	2		3.6784	0.1589
Functional class (freeway, arterial, collector, local)	3		0.4158	0.9370	2		1.3461	0.5101
Posted speed (mph)	**4149**	**0.0283**		**0.0679**	4348	0.0205		0.1773
Intersections (#)	6668	0.0061		0.6178	7290	-0.0171		0.1432
Distance to nearest intersection (m)	6668	-0.0057		0.6442	7290	0.0178		0.1293
Distance to nearest crosswalk (m)	6668	0.0208		0.0889	**7290**	**0.0559**		**0.0000**
Traffic control (active control, passive control, uncontrolled)	2		0.9672	0.6166	**2**	**5.3962**		**0.0673**
Lanes (#)	3075	-0.0051		0.7757	**3186**	**-0.0429**		**0.0153**
Median (present, absent)	1		0.2798	0.5968	1		0.0096	0.9221
Shoulder (present, absent)	1		0.8525	0.3558	1		1.0378	0.3083
Pedestrian curb ramps (#)	6668	-0.0015		0.9020	7290	-0.0162		0.1655
Driveways (#)	6668	0.0076		0.5365	7290	0.0077		0.5103
Horizontal alignment (level, curve)	2		0.4449	0.8005	2		1.5104	0.4699
Vertical alignment (level, grade)	2		1.0333	0.5965	2		1.3431	0.5109
Transit stations (#)	6668	0.0081		0.5086	7290	-0.0019		0.8684
Bus stops (#)	6668	0.0088		0.4743	7290	-0.0034		0.7739
Commuter rail stations (#)	6668	-0.0067		0.5863	7290	0.0111		0.3415
Light rail stations (#)	6668	-0.0040		0.7459	7290	0.0116		0.3225
Neighborhood social environment								
Household size (#)	**6652**	**-0.0248**		**0.0429**	7264	-0.0095		0.4178
Children per household (#)	**6664**	**-0.0225**		**0.0658**	7269	0.0088		0.4511
Workers per household (#)	**6664**	**-0.0211**		**0.0843**	7269	-0.0192		0.1011

Vehicles per household (#)	6580	-0.0170		0.1684	7157	-0.0007		0.9538
Household income ($), mean	6652	-0.0074		0.5458	7264	0.0146		0.2141
Household income ($), median	6658	-0.0049		0.6903	**7269**	**0.0201**		**0.0868**
Unemployment rate (%)	6664	0.0109		0.3726	**7269**	**0.0239**		**0.0417**
Non-white or Hispanic race/ethnicity (%)	6664	-0.0015		0.9027	7269	-0.0029		0.8056
Rental housing rate (%)	6664	-0.0019		0.8798	**7269**	**-0.0304**		**0.0096**
Neighborhood built environment								
Urbanization status (urban, rural)	**1**		**12.5690**	**0.0004**	**1**		**50.8440**	**0.0000**
Residential density (housing units/acre)	6668	-0.0099		0.4198	**7290**	**-0.0246**		**0.0354**
Population density (people/acre)	6668	-0.0233		0.0569	**7290**	**-0.0330**		**0.0048**
Employment density (jobs/acre)	6668	0.0016		0.8959	7290	-0.0054		0.6462
Jobs per household (#/#)	6668	0.0061		0.6176	7290	-0.0021		0.8557
Intersection density (#/mi^2)	**6668**	**-0.0257**		**0.0357**	**7290**	**-0.0442**		**0.0002**
Jobs (#) within 45 minutes auto travel time	6668	-0.0098		0.4240	7290	-0.0160		0.1726
Jobs (#) within 45-minute transit commute	4720	0.0038		0.7960	5400	-0.0007		0.9594
Average distance (m) to nearest transit stop	4313	-0.0032		0.8318	4974	-0.0188		0.1840
Aggregate transit service frequency (#/mi^2)	5052	-0.0044		0.7525	5781	-0.0156		0.2341
Nearby destinations (#)								
Community services	6668	0.0029		0.8133	7290	0.0062		0.5973
Government services	6668	-0.0017		0.8889	7290	0.0104		0.3739
Food banks	6668	0.0068		0.5800	7290	0.0009		0.9388
Human services	6668	0.0109		0.3721	7290	-0.0033		0.7749
Workforce services	6668	0.0029		0.8102	**7290**	**-0.0193**		**0.0992**
Health care facilities	6668	0.0024		0.8440	**7290**	**-0.0201**		**0.0862**
Home living medical facilities	6668	-0.0025		0.8389	**7290**	**-0.0254**		**0.0302**
General medical facilities	6668	-0.0074		0.5446	7290	-0.0179		0.1258
Special medical facilities	6668	-0.0080		0.5132	7290	-0.0131		0.2645
Other health care facilities	**6668**	**0.0259**		**0.0342**	7290	0.0048		0.6847
Liquor facilities	**6668**	**0.0256**		**0.0367**	7290	0.0174		0.1376
Liquor stores	6668	0.0163		0.1819	7290	-0.0010		0.9322
Liquor package agency	**6668**	**0.0245**		**0.0458**	**7290**	**0.0306**		**0.0090**
Schools	6668	-0.0128		0.2953	7290	0.0050		0.6719
Community centers	6668	-0.0023		0.8504	7290	-0.0031		0.7896
Recreation centers	6668	-0.0004		0.9749	7290	0.0003		0.9814
Libraries	6668	-0.0031		0.8013	7290	-0.0047		0.6875
Grocery and food stores	6668	-0.0137		0.2637	7290	-0.0190		0.1055
Convenience grocery stores	6668	0.0048		0.6925	**7290**	**-0.0213**		**0.0693**
Supermarkets	6668	-0.0154		0.2091	7290	-0.0075		0.5221
Grocery stores	**6668**	**-0.0203**		**0.0977**	7290	-0.0060		0.6089
Other grocery and food stores	6668	-0.0118		0.3370	7290	-0.0139		0.2362

Retail centers	6668	-0.0116		0.3427	7290	0.0097		0.4056

Notes: **Bold text** indicates a significant independent variable (p<0.10). df = degrees of freedom, r_{pb} = point-biserial correlation coefficient, χ^2 = Chi-Squared Test statistic, p = p-value.

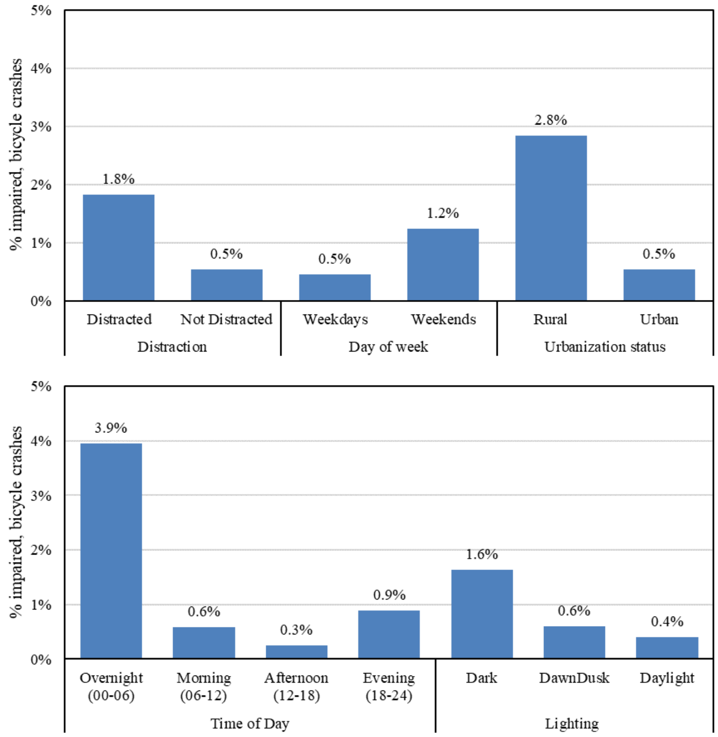

Figure 4.17. Percent Impaired for BCO Bicycle Crashes by Significant Categorical Variables

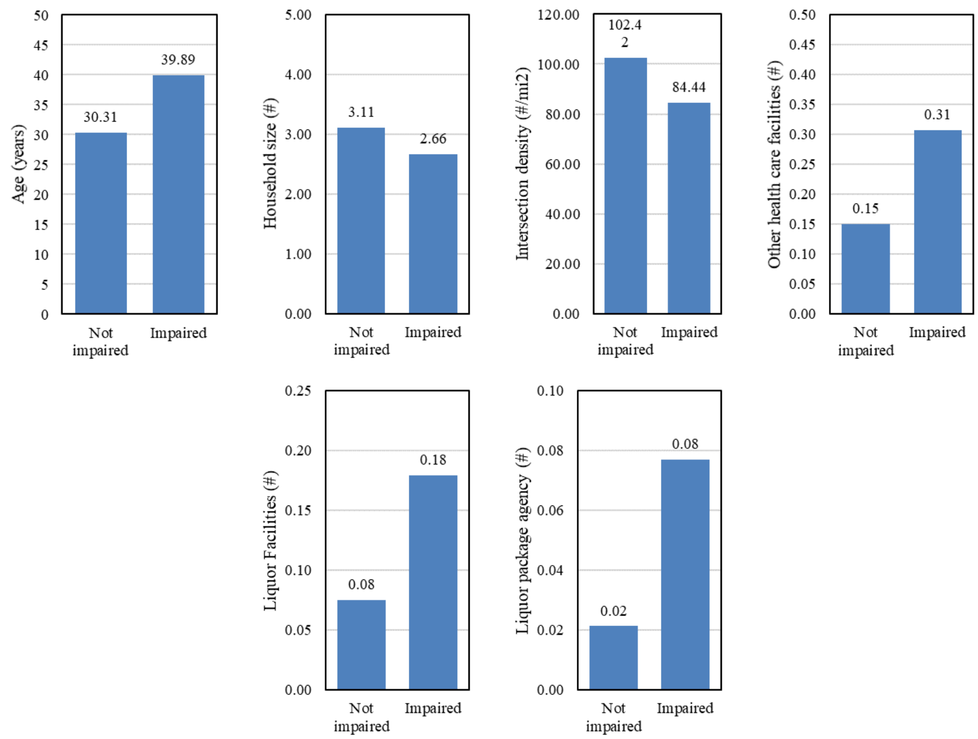

Figure 4.18. Mean Values of Significant Continuous Variables by Impairment Status for BCO Bicycle Crashes

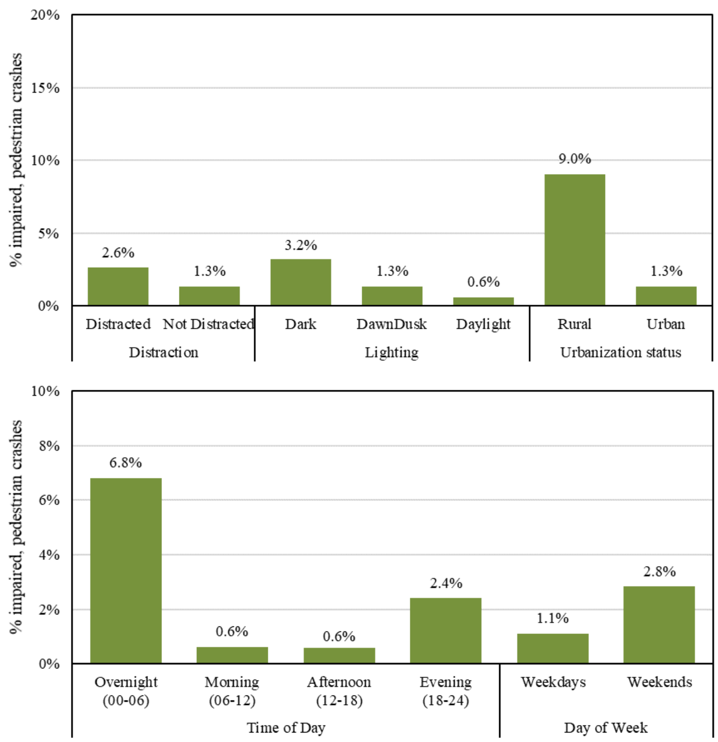

Figure 4.19. Percent Impaired for BCO Pedestrian Crashes by Significant Categorical Variables

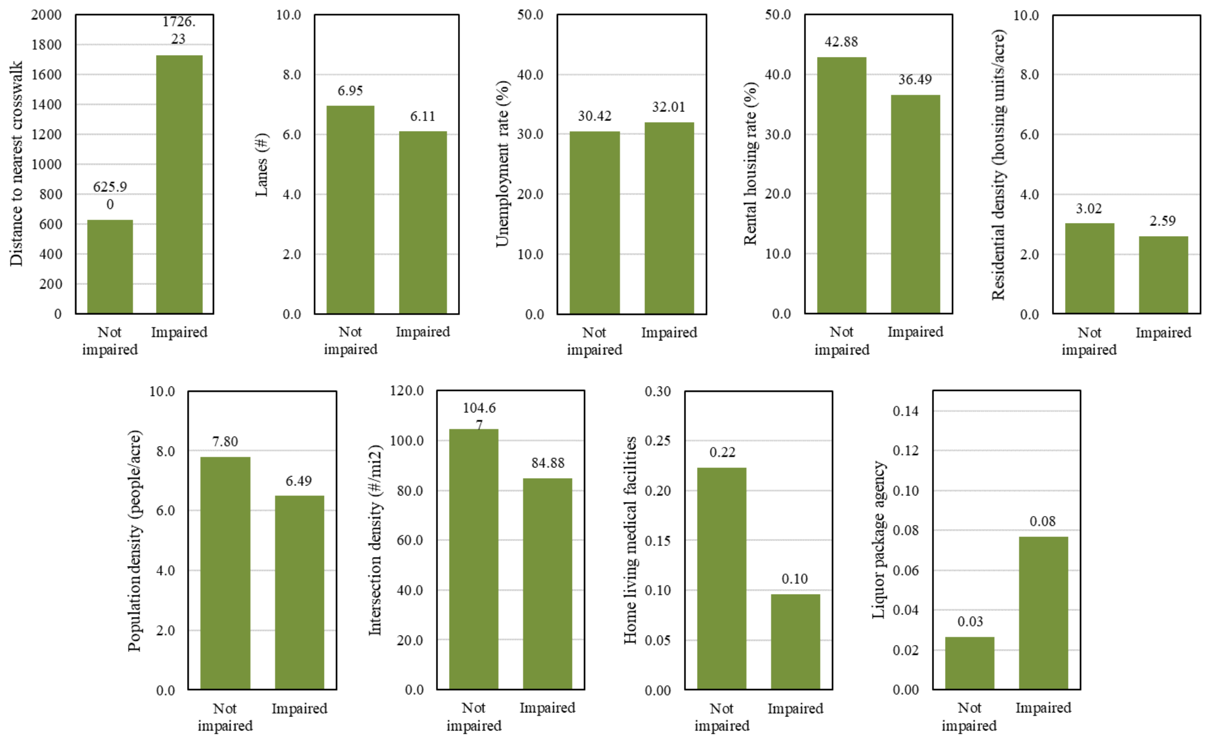

Figure 4.20. Mean Values of Significant Continuous Variables by Impairment Status for BCO Pedestrian Crashes

4.8 Results for Injury Severity, All Bicycle/Pedestrian Crashes, Impaired Bicycle/Pedestrian Crashes, and Non-Impaired Bicycle/Pedestrian Crashes

Table 4-6, Table 4-7, and Table 4-8 display the results of point-biserial correlation coefficient (rpb) tests and Chi-Squared ($\chi 2$) tests of independence for continuous and categorical independent variables versus active mode users' severity level: severe vs. non-severe (KA vs. BCO) for all crashes and for impaired crashes and non-impaired crashes, respectively.

4.8.1 Active Mode User Demographics

For bicycle-involved crashes, age had a significant bivariate association with crash severity for non-impaired crashes. Severely injured bicyclists were significantly older than bicyclists involved in non-severe crashes, but there was no significant difference for impaired crashes. There were no other significant associations with demographic characteristics except for a marginally significant association between severity and distraction overall, although this was not significant when looking only at impaired or non-impaired bicyclists.

There was a significant positive association between severely injured pedestrians and their age: On average, older pedestrians were more likely to be severely injured when compared to younger ones. A similar association was also observed for crashes involving impaired pedestrians, where severely injured pedestrians tended to be older than less-severely injured pedestrians (38 vs. 33 years old, on average). While for overall pedestrian crashes as mentioned in Section 4.3 (and for non-impaired pedestrians), males were slightly more likely to be severely injured than females, and a severe crash was more likely to involve distracted pedestrians over crashes that had contributing circumstances besides distraction. There were no significant associations of severity with gender or distraction for impaired pedestrians.

4.8.2 Crash Temporal Conditions

Investigation of crash temporal conditions revealed that year, day of week, time of day, and lighting condition were significantly associated with bicyclists' and pedestrians' severity levels, ignoring impairment status. More severe active mode user injuries were more likely to occur in more recent years, on weekends (compared to weekdays), and overnight (than evening, morning, or afternoon). Regarding lighting condition, severe pedestrian crashes were more likely during dark conditions (vs. dawn/dusk or day), while severe bicycle crashes were more likely during dawn/dusk (vs. dark or day). However, most of these trends were present for non-impaired crashes only. In fact, no temporal conditions were significantly associated with severity for impaired bicycle crashes. Alternatively, year was positively associated with severity only for impaired (and not for non-impaired) pedestrian crashes. This implies an increase in more severe impaired pedestrian crashes in recent years.

4.8.3 Roadway Geometry

Several variables related to roadways were found to be associated with bicycle crash severity. Less severe bicycle crashes happened in places with more transit stations and bus stops, and severity increased with posted speed and at uncontrolled intersections, for both impaired and non-impaired bicyclists. Other factors were only associated with severity for non-impaired bicyclists: negatively (less severe) for the number of intersections, number of lanes, and number of light rail stations, and positively (more severe) for distance to the nearest intersection and crosswalk, and roadways with curves and grades.

Several roadway geometry characteristics were significantly associated with crash severity for pedestrian-involved crashes in the bivariate analyses. Only a few trends were common to both impaired and non-impaired pedestrians: Crash severity was worse on arterials vs. collector and local roads (55% vs. 44% and 38%) and in places with higher speeds and more driveways. The other results were only significant for non-impaired pedestrians. Specifically, pedestrian crashes were more likely to be severe on state roads, locations with greater distance to the nearest crosswalk, at uncontrolled intersections, with fewer lanes, no medians, roads with shoulders, graded roadways, and lower numbers of transit stations, bus stops and light rail stations.

4.8.4 Neighborhood Social Environment

Investigation of neighborhood social environment characteristics revealed that the average number of children per household, average number of vehicles per household, average household income, and median household income had significant positive associations with bicyclist injury severity. Similarly, bicycle crashes were more likely to be severe in areas with a lower percentage of non-white or Hispanic race per ethnicity and lower rental housing rates. However, most of these findings were only significant for non-impaired bicyclists. For crashes involving impaired bicyclists, the only (marginally) significant association was for vehicle ownership: Impaired bicycle crashes were more likely to be of KA severity in areas with a higher number of vehicles per household.

For pedestrian-involved crashes, all associations with severity were for non-impaired pedestrians only: Positive association with the average number of children and vehicles per household, and with mean and median household income, but a negative association with the rental housing rate. No factors were significantly associated with severity for impaired pedestrians.

4.8.5 Neighborhood Built Environment

Overall, both bicycle and pedestrian crashes were more severe in rural places and in neighborhoods that had lower levels of residential density, population density, employment density, intersection density, number of jobs within 45 minutes of auto travel time, and aggregate transit service frequency. Almost all of these relationships held only for non-impaired active mode users. The only difference for crashes with impaired active mode users was a marginally significant positive association between crash severity among impaired pedestrians and the number of jobs within a 45-minute transit commute.

4.8.6 Nearby Destinations

Bicycle crashes involving non-impaired bicyclists tended to be less severe in locations with more of several kinds of destinations: schools, community centers, libraries, grocery and food stores (including convenience grocery stores, supermarkets, grocery stores, and other grocery and food stores), and retail centers. There was only one (marginally) significant association for impaired bicyclists: Impaired bicycle crashes tended to be more severe in areas with more grocery stores.

Similar to bicycle crashes, pedestrian crashes involving non-impaired pedestrians were less severe generally in areas with more destinations: community services, government services, human services, workforce services, healthcare facilities (home living, general medical, and overall), schools, community centers, libraries, grocery and food stores (overall, convenience grocery stores, supermarkets, and others), and retail centers. For impaired pedestrian crashes, severity was similarly lower in places with more community services, government services, and schools. On the other hand, impaired pedestrian crashes were more likely to be severe in areas with more grocery and food stores and conventional grocery stores, unlike the relationship for non-impaired pedestrians.

Table 4-6 Bivariate associations with active mode user crash severity

	All Bicycle Crashes (n=7388)				*All Pedestrian Crashes (n=8999)*			
	KA (n=718) vs BCO (n=6670)				KA (n=1707) vs BCO (n=7292)			
Variable	*df*	r_{pb}	χ^2	*p*	*df*	r_{pb}	χ^2	*p*
Active mode user demographics								
Age (years)	**7110**	**0.0859**		**0.0000**	**8148**	**0.1184**		**0.0000**
Gender (male, female)	1		0.0064	0.9361	**1**		**6.3248**	**0.0119**
Distraction	**1**		**2.7286**	**0.0986**	**1**		**17.9340**	**0.0000**
Crash temporal conditions								
Year	**7386**	**0.0234**		**0.0441**	**8997**	**0.0220**		**0.0365**
Season (winter, spring, summer, fall)	3		1.7093	0.6349	3		4.9354	0.1766
Day of week (weekday, weekend)	**1**		**10.4950**	**0.0012**	**1**		**14.1050**	**0.0002**
Time of day (00-06, 06-12, 12-18, 18-24)	**3**		**15.4790**	**0.0015**	**3**		**176.6800**	**0.0000**
Weather (clear, other)	1		0.8547	0.3552	1		1.3682	0.2421
Lighting (day, dawn/dusk, dark)	**2**		**14.9900**	**0.0006**	**2**		**247.1000**	**0.0000**
Roadway geometry								
Route type (federal, state, local)	2		0.3861	0.8244	**2**		**48.4780**	**0.0000**
Functional class (freeway, arterial, collector, local)	3		5.0334	0.1694	**2**		**45.3430**	**0.0000**
Posted speed (mph)	**4718**	**0.0982**		**0.0000**	**5479**	**0.1555**		**0.0000**
Intersections (#)	**7386**	**-0.0474**		**0.0000**	8997	-0.0153		0.1479
Distance to nearest intersection (m)	**7386**	**0.0670**		**0.0000**	8997	0.0129		0.2214
Distance to nearest crosswalk (m)	**7386**	**0.0722**		**0.0000**	**8997**	**0.0769**		**0.0000**
Traffic control (active control, passive control, uncontrolled)	**2**		**15.5770**	**0.0004**	**2**		**67.6410**	**0.0000**
Lanes (#)	**3393**	**-0.0616**		**0.0003**	**4033**	**-0.1110**		**0.0000**
Median (present, absent)	1		0.3650	0.5458	**1**		**14.7770**	**0.0001**
Shoulder (present, absent)	1		0.3924	0.5311	**1**		**7.8657**	**0.0050**
Pedestrian curb ramps (#)	**7386**	**-0.0368**		**0.0015**	8997	-0.0138		0.1894
Driveways (#)	7386	-0.0114		0.3276	**8997**	**0.0726**		**0.0000**
Horizontal alignment (level, curve)	**2**		**38.3400**	**0.0000**	2		4.0161	0.1342
Vertical alignment (level, grade)	**2**		**70.8840**	**0.0000**	**2**		**50.5840**	**0.0000**
Transit stations (#)	**7386**	**-0.0723**		**0.0000**	**8997**	**-0.0366**		**0.0005**
Bus stops (#)	**7386**	**-0.0718**		**0.0000**	**8997**	**-0.0340**		**0.0013**
Commuter rail stations (#)	7386	-0.0067		0.5651	8997	-0.0121		0.2518
Light rail stations (#)	**7386**	**-0.0267**		**0.0219**	**8997**	**-0.0363**		**0.0006**
Neighborhood social environment								
Household size (#)	7369	0.0095		0.4161	8969	0.0121		0.2502
Children per household (#)	**7382**	**0.0290**		**0.0128**	**8974**	**0.0208**		**0.0491**
Workers per household (#)	7382	0.0007		0.9489	8974	0.0050		0.6343

Vehicles per household (#)	**7285**	**0.0599**		**0.0000**	**8822**	**0.0205**		**0.0541**
Household income ($), mean	**7369**	**0.0732**		**0.0000**	8969	0.0166		0.1157
Household income ($), median	**7374**	**0.0740**		**0.0000**	**8973**	**0.0179**		**0.0907**
Unemployment rate (%)	7382	0.0002		0.9889	8974	0.0047		0.6557
Non-white or Hispanic race/ethnicity (%)	**7382**	**-0.0360**		**0.0020**	8974	-0.0127		0.2305
Rental housing rate (%)	**7382**	**-0.0579**		**0.0000**	**8974**	**-0.0257**		**0.0148**
Neighborhood built environment								
Urbanization status (urban, rural)	**1**		**63.7430**	**0.0000**	**1**		**84.5270**	**0.0000**
Residential density (housing units/acre)	**7386**	**-0.0469**		**0.0001**	**8997**	**-0.0552**		**0.0000**
Population density (people/acre)	**7386**	**-0.0458**		**0.0001**	**8997**	**-0.0561**		**0.0000**
Employment density (jobs/acre)	**7386**	**-0.0414**		**0.0004**	**8997**	**-0.0339**		**0.0013**
Jobs per household (#/#)	7386	-0.0067		0.5659	8997	-0.0060		0.5690
Intersection density (#/mi^2)	**7386**	**-0.0662**		**0.0000**	**8997**	**-0.0745**		**0.0000**
Jobs (#) within 45 minutes auto travel time	**7386**	**-0.0451**		**0.0001**	**8997**	**-0.0447**		**0.0000**
Jobs (#) within 45-minute transit commute	5176	-0.0204		0.1423	6593	-0.0097		0.4305
Average distance (m) to nearest transit stop	4724	0.0013		0.9311	6070	-0.0074		0.5624
Aggregate transit service frequency (#/mi^2)	**5547**	**-0.0228**		**0.0891**	**7064**	**-0.0292**		**0.0142**
Nearby destinations (#)								
Community services	7386	-0.0181		0.1207	**8997**	**-0.0286**		**0.0066**
Government services	**7386**	**-0.0228**		**0.0501**	**8997**	**-0.0252**		**0.0168**
Food banks	7386	0.0185		0.1124	8997	-0.0006		0.9546
Human services	7386	-0.0165		0.1574	**8997**	**-0.0223**		**0.0343**
Workforce services	7386	-0.0045		0.6982	**8997**	**-0.0225**		**0.0332**
Health care facilities	7386	-0.0083		0.4769	**8997**	**-0.0259**		**0.0142**
Home living medical facilities	7386	-0.0084		0.4698	**8997**	**-0.0185**		**0.0794**
General medical facilities	7386	-0.0142		0.2235	**8997**	**-0.0208**		**0.0488**
Special medical facilities	7386	0.0083		0.4773	8997	-0.0163		0.1216
Other health care facilities	7386	-0.0082		0.4787	8997	-0.0137		0.1937
Liquor facilities	7386	-0.0168		0.1478	8997	-0.0003		0.9783
Liquor stores	7386	-0.0146		0.2081	8997	0.0002		0.9875
Liquor package agency	7386	-0.0110		0.3459	8997	-0.0007		0.9481
Schools	**7386**	**-0.0343**		**0.0032**	**8997**	**-0.0528**		**0.0000**
Community centers	**7386**	**-0.0248**		**0.0332**	**8997**	**-0.0276**		**0.0088**
Recreation centers	7386	-0.0131		0.2611	8997	-0.0073		0.4890
Libraries	**7386**	**-0.0251**		**0.0312**	**8997**	**-0.0335**		**0.0015**
Grocery and food stores	**7386**	**-0.0570**		**0.0000**	**8997**	**-0.0274**		**0.0093**
Convenience grocery stores	**7386**	**-0.0312**		**0.0072**	**8997**	**-0.0333**		**0.0016**
Supermarkets	**7386**	**-0.0424**		**0.0003**	**8997**	**-0.0233**		**0.0271**
Grocery stores	**7386**	**-0.0513**		**0.0000**	8997	0.0010		0.9213
Other grocery and food stores	**7386**	**-0.0346**		**0.0029**	8997	-0.0168		0.1121

Retail centers	**7386**	**-0.0426**		**0.0002**	**8997**	**-0.0254**		**0.0159**

Table 4-7 Bivariate associations with impaired active mode user crash severity

	Impaired Bicycle Crashes (n=56)				*Impaired Pedestrian Crashes (n=201)*			
	KA (n=17) vs BCO (n=39)				KA (n=97) vs BCO (n=104)			
Variable	*df*	r_{pb}	χ^2	*p*	*df*	r_{pb}	χ^2	*p*
Active mode user demographics								
Age (years)	53	-0.1461		0.2871	**194**	**0.1624**		**0.0230**
Gender (male, female)	1		0.7420	0.3890	1		0.3693	0.5434
Distraction	1		0.0121	0.9125	1		0.9701	0.3247
Crash temporal conditions								
Year	54	0.0067		0.9609	**199**	**0.2050**		**0.0035**
Season (winter, spring, summer, fall)	3		1.7277	0.6308	3		1.7178	0.6330
Day of week (weekday, weekend)	1		0.8303	0.3622	1		0.0553	0.8140
Time of day (00-06, 06-12, 12-18, 18-24)	3		1.2825	0.7333	3		5.8730	0.1180
Weather (clear, other)	1		0.0640	0.8003	1		0.0009	0.9758
Lighting (day, dawn/dusk, dark)	2		1.0417	0.5940	2		1.0744	0.5844
Roadway geometry								
Route type (federal, state, local)	2		0.2365	0.8885	2		2.7557	0.2521
Functional class (freeway, arterial, collector, local)	2		0.6232	0.7323	**2**		**4.8548**	**0.0883**
Posted speed (mph)	**37**	**0.2694**		**0.0973**	**129**	**0.1591**		**0.0695**
Intersections (#)	54	-0.0646		0.6365	199	0.0391		0.5814
Distance to nearest intersection (m)	54	0.1017		0.4558	199	-0.0448		0.5273
Distance to nearest crosswalk (m)	54	-0.0653		0.6328	199	-0.0503		0.4786
Traffic control (active control, passive control, uncontrolled)	**2**		**5.0901**	**0.0785**	2		0.5905	1.0536
Lanes (#)	28	0.0314		0.8694	93	-0.1525		0.1402
Median (present, absent)	1		0.0000	1.0000	1		1.2329	0.2668
Shoulder (present, absent)	1		2.0779	0.1494	1		0.1383	0.7100
Pedestrian curb ramps (#)	54	0.0130		0.9242	199	0.0590		0.4058
Driveways (#)	54	0.0412		0.7630	**199**	**0.1351**		**0.0559**
Horizontal alignment (level, curve)	2		2.4099	0.2997	2		2.4361	0.2958
Vertical alignment (level, grade)	2		1.6407	0.4403	2		0.0870	0.9574
Transit stations (#)	**54**	**-0.2351**		**0.0812**	199	-0.0707		0.3186
Bus stops (#)	**54**	**-0.2368**		**0.0789**	199	-0.0696		0.3260
Commuter rail stations (#)	54	NA		NA	199	-0.0368		0.6043
Light rail stations (#)	54	-0.0261		0.8488	199	-0.0308		0.6644
Neighborhood social environment								

Household size (#)	53	0.2367		0.0819	199	-0.0796		0.2613
Children per household (#)	54	0.2214		0.1010	199	-0.0494		0.4864
Workers per household (#)	54	0.1602		0.2381	199	-0.0250		0.7248
Vehicles per household (#)	**53**	**0.2384**		**0.0796**	190	-0.0388		0.5934
Household income ($), mean	53	0.1910		0.1624	199	-0.0579		0.4142
Household income ($), median	53	0.1992		0.1448	198	-0.0598		0.4000
Unemployment rate (%)	54	-0.0633		0.6428	199	-0.0728		0.3046
Non-white or Hispanic race/ethnicity (%)	54	-0.1043		0.4441	199	0.0532		0.4528
Rental housing rate (%)	54	-0.1972		0.1451	199	0.0848		0.2315
Neighborhood built environment								
Urbanization status (urban, rural)	1		0.2786	0.5976	1		1.2501	0.2635
Residential density (housing units/acre)	54	-0.0971		0.4766	199	-0.0060		0.9325
Population density (people/acre)	54	0.0201		0.8831	199	-0.0166		0.8151
Employment density (jobs/acre)	54	-0.0814		0.5511	199	0.0396		0.5765
Jobs per household (#/#)	54	-0.1045		0.4434	199	0.0212		0.7651
Intersection density (#/mi^2)	54	0.0132		0.9229	199	-0.0183		0.7966
Jobs (#) within 45 minutes auto travel time	54	0.1351		0.3209	199	0.0217		0.7600
Jobs (#) within 45-minute transit commute	35	0.0460		0.7868	**129**	**0.1519**		**0.0832**
Average distance (m) to nearest transit stop	32	0.0726		0.6831	122	0.0921		0.3090
Aggregate transit service frequency (#/mi^2)	40	-0.1402		0.3759	142	0.0439		0.6010
Nearby destinations (#)								
Community services	54	-0.0845		0.5360	**199**	**-0.1172**		**0.0976**
Government services	54	-0.0147		0.9145	**199**	**-0.1169**		**0.0984**
Food banks	54	-0.0323		0.8131	199	-0.0760		0.2836
Human services	54	-0.1271		0.3507	199	0.0338		0.6341
Workforce services	54	-0.0890		0.5141	199	0.0732		0.3016
Health care facilities	54	0.0596		0.6628	199	0.0380		0.5918
Home living medical facilities	54	-0.0240		0.8605	199	0.1001		0.1576
General medical facilities	54	0.1274		0.3496	199	0.0448		0.5273
Special medical facilities	54	0.1713		0.2070	199	-0.0760		0.2836
Other health care facilities	54	-0.0476		0.7278	199	0.0027		0.9700
Liquor facilities	54	-0.0028		0.9839	199	-0.0128		0.8573
Liquor stores	54	0.1028		0.4511	199	0.0486		0.4928
Liquor package agency	54	-0.1203		0.3771	199	-0.0576		0.4169
Schools	54	0.1485		0.2748	**199**	**-0.1226**		**0.0830**
Community centers	54	0.0229		0.8669	199	0.0023		0.9746
Recreation centers	54	-0.0323		0.8131	199	0.0268		0.7061
Libraries	54	0.0547		0.6887	199	-0.0214		0.7634
Grocery and food stores	54	0.0784		0.5657	**199**	**0.1307**		**0.0644**
Convenience grocery stores	54	-0.1187		0.3836	**199**	**0.1550**		**0.0280**

Supermarkets	54	0.1786		0.1878	199	0.0051		0.9430
Grocery stores	**54**	**0.2400**		**0.0749**	199	0.0985		0.1642
Other grocery and food stores	54	-0.0032		0.9810	199	0.0901		0.2034
Retail centers	54	0.0558		0.6829	199	-0.0350		0.6219

Table 4-8 Bivariate associations with non-impaired active mode user crash severity

	Not-Impaired Bicycle Crashes (n=7332)				*Not-Impaired Pedestrian Crashes (n=8798)*			
	KA (n=701) vs BCO (n=6631)				KA (n=1610) vs BCO (n=7188)			
Variable	*df*	r_{pb}	χ^2	*p*	*df*	r_{pb}	χ^2	*p*
Active mode user demographics								
Age (years)	**7055**	**0.0868**		**0.0000**	**7952**	**0.1148**		**0.0000**
Gender (male, female)	1		0.0410	0.8396	**1**		**5.0564**	**0.0245**
Distraction	1		2.2999	0.1294	**1**		**19.3120**	**0.0000**
Crash temporal conditions								
Year	**7330**	**0.0243**		**0.0375**	8796	0.0172		0.1073
Season (winter, spring, summer, fall)	3		2.1356	0.5447	**3**		**6.9517**	**0.0735**
Day of week (weekday, weekend)	**1**		**10.6200**	**0.0011**	**1**		**9.3477**	**0.0022**
Time of day (00-06, 06-12, 12-18, 18-24)	**3**		**12.8060**	**0.0051**	**3**		**160.9700**	**0.0000**
Weather (clear, other)	1		1.1212	0.2897	1		1.2576	0.2621
Lighting (day, dawn/dusk, dark)	**2**		**14.3460**	**0.0008**	**2**		**230.2000**	**0.0000**
Roadway geometry								
Route type (federal, state, local)	2		0.4382	0.8032	**2**		**44.0500**	**0.0000**
Functional class (freeway, arterial, collector, local)	3		5.5612	0.1350	**2**		**40.1130**	**0.0000**
Posted speed (mph)	**4679**	**0.0944**		**0.0000**	**5348**	**0.1529**		**0.0000**
Intersections (#)	**7330**	**-0.0476**		**0.0000**	8796	-0.0152		0.1534
Distance to nearest intersection (m)	**7330**	**0.0669**		**0.0000**	8796	0.0130		0.2236
Distance to nearest crosswalk (m)	**7330**	**0.0737**		**0.0000**	**8796**	**0.0786**		**0.0000**
Traffic control (active control, passive control, uncontrolled)	**2**		**13.7820**	**0.0010**	2		**61.7420**	**0.0000**
Lanes (#)	**3363**	**-0.0632**		**0.0002**	**3938**	**-0.1016**		**0.0000**
Median (present, absent)	1		0.3242	0.5691	**1**		**13.3050**	**0.0003**
Shoulder (present, absent)	1		0.7010	0.4025	**1**		**6.7423**	**0.0094**
Pedestrian curb ramps (#)	**7330**	**-0.0376**		**0.0013**	8796	-0.0150		0.1589
Driveways (#)	7330	-0.0129		0.2684	**8796**	**0.0669**		**0.0000**
Horizontal alignment (level, curve)	**2**		**35.9300**	**0.0000**	**2**		**5.2995**	**0.0707**
Vertical alignment (level, grade)	**2**		**70.2570**	**0.0000**	**2**		**51.5010**	**0.0000**
Transit stations (#)	**7330**	**-0.0704**		**0.0000**	**8796**	**-0.0346**		**0.0012**
Bus stops (#)	**7330**	**-0.0698**		**0.0000**	**8796**	**-0.0317**		**0.0030**

Commuter rail stations (#)	7330	-0.0063		0.5892	8796	-0.0123		0.2504
Light rail stations (#)	**7330**	**-0.0264**		**0.0236**	**8796**	**-0.0381**		**0.0003**
Neighborhood social environment								
Household size (#)	7314	0.0098		0.4028	8768	0.0164		0.1258
Children per household (#)	**7326**	**0.0281**		**0.0161**	**8773**	**0.0230**		**0.0312**
Workers per household (#)	7326	0.0012		0.9174	8773	0.0086		0.4188
Vehicles per household (#)	**7230**	**0.0580**		**0.0000**	**8630**	**0.0235**		**0.0289**
Household income ($), mean	**7314**	**0.0722**		**0.0000**	**8768**	**0.0178**		**0.0948**
Household income ($), median	**7319**	**0.0727**		**0.0000**	**8773**	**0.0185**		**0.0830**
Unemployment rate (%)	7326	0.0004		0.9694	8773	0.0050		0.6362
Non-white or Hispanic race/ethnicity (%)	**7326**	**-0.0348**		**0.0028**	8773	-0.0154		0.1485
Rental housing rate (%)	**7326**	**-0.0560**		**0.0000**	**8773**	**-0.0262**		**0.0140**
Neighborhood built environment								
Urbanization status (urban, rural)	**1**		**65.4800**	**0.0000**	**1**		**89.0660**	**0.0000**
Residential density (housing units/acre)	**7330**	**-0.0457**		**0.0001**	**8796**	**-0.0538**		**0.0000**
Population density (people/acre)	**7330**	**-0.0451**		**0.0001**	**8796**	**-0.0531**		**0.0000**
Employment density (jobs/acre)	**7330**	**-0.0410**		**0.0004**	**8796**	**-0.0372**		**0.0005**
Jobs per household (#/#)	7330	-0.0060		0.6072	8796	-0.0069		0.5202
Intersection density (#/mi^2)	**7330**	**-0.0657**		**0.0000**	**8796**	**-0.0707**		**0.0000**
Jobs (#) within 45 minutes auto travel time	**7330**	**-0.0475**		**0.0000**	**8796**	**-0.0457**		**0.0000**
Jobs (#) within 45-minute transit commute	5139	-0.0215		0.1229	6462	-0.0160		0.1990
Average distance (m) to nearest transit stop	4690	0.0005		0.9731	5946	-0.0091		0.4821
Aggregate transit service frequency (#/mi^2)	5505	-0.0214		0.1118	**6920**	**-0.0295**		**0.0142**
Nearby destinations (#)								
Community services	7330	-0.0176		0.1329	**8796**	**-0.0258**		**0.0157**
Government services	**7330**	**-0.0229**		**0.0503**	**8796**	**-0.0226**		**0.0338**
Food banks	7330	0.0189		0.1061	8796	0.0026		0.8086
Human services	7330	-0.0153		0.1898	**8796**	**-0.0243**		**0.0227**
Workforce services	7330	-0.0035		0.7652	**8796**	**-0.0219**		**0.0401**
Health care facilities	7330	-0.0096		0.4111	**8796**	**-0.0251**		**0.0183**
Home living medical facilities	7330	-0.0080		0.4921	**8796**	**-0.0186**		**0.0812**
General medical facilities	7330	-0.0159		0.1721	**8796**	**-0.0202**		**0.0578**
Special medical facilities	7330	0.0067		0.5670	8796	-0.0131		0.2178
Other health care facilities	7330	-0.0091		0.4339	8796	-0.0152		0.1539
Liquor facilities	7330	-0.0190		0.1034	8796	-0.0021		0.8441
Liquor stores	7330	-0.0185		0.1133	8796	-0.0021		0.8422
Liquor package agency	7330	-0.0098		0.4036	8796	-0.0010		0.9271
Schools	**7330**	**-0.0367**		**0.0017**	**8796**	**-0.0501**		**0.0000**
Community centers	**7330**	**-0.0254**		**0.0300**	**8796**	**-0.0285**		**0.0075**
Recreation centers	7330	-0.0128		0.2725	8796	-0.0090		0.4008

Libraries	**7330**	**-0.0262**	**0.0250**	**8796**	**-0.0333**	**0.0018**
Grocery and food stores	**7330**	**-0.0580**	**0.0000**	**8796**	**-0.0330**	**0.0020**
Convenience grocery stores	**7330**	**-0.0304**	**0.0091**	**8796**	**-0.0392**	**0.0002**
Supermarkets	**7330**	**-0.0446**	**0.0001**	**8796**	**-0.0235**	**0.0276**
Grocery stores	**7330**	**-0.0542**	**0.0000**	8796	-0.0035	0.7462
Other grocery and food stores	**7330**	**-0.0342**	**0.0034**	**8796**	**-0.0204**	**0.0557**
Retail centers	**7330**	**-0.0434**	**0.0002**	**8796**	**-0.0263**	**0.0137**

Notes: **Bold text** indicates a significant independent variable (p<0.10). df = degrees of freedom, r_{pb} = point-biserial correlation coefficient, χ^2 = Chi-Squared Test statistic, p = p-value.

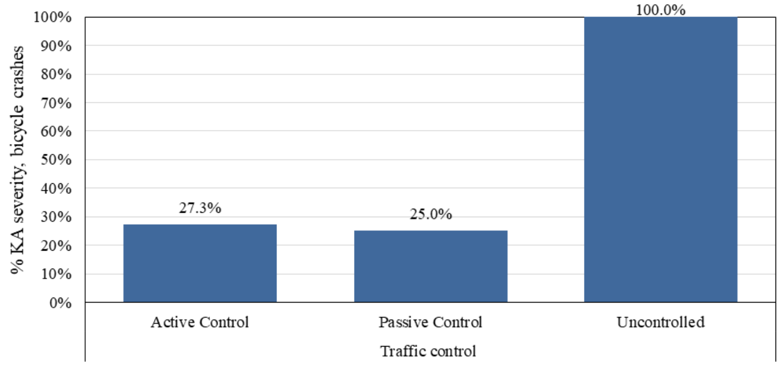

Figure 4.21. Percent Severe Bicycle Crashes for Impaired Bicyclist by Significant Categorical Variables

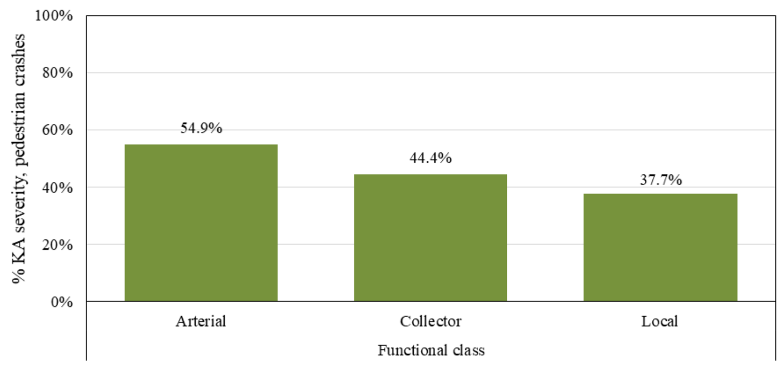

Figure 4.22. Percent Severe Pedestrian Crashes for Impaired Pedestrian by Significant Categorical Variables

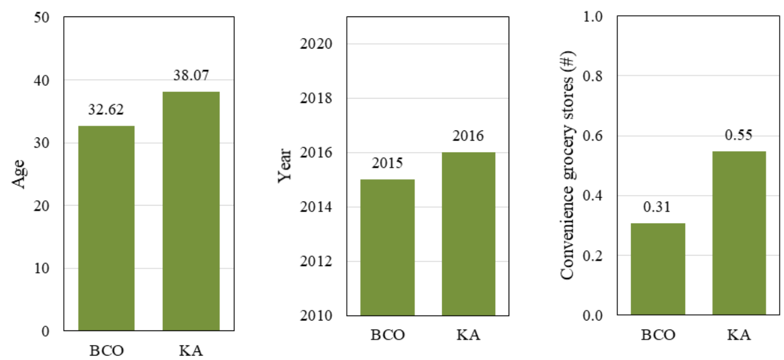

Figure 4.23. Mean Values of Significant Continuous Variables by Severity Level for Impaired Pedestrian Crashes

4.9 Key Findings

This chapter presented many findings from multiple sets of analyses regarding the relationships between active mode user impairment status, injury severity, and many other variables for bicycle and pedestrian crashes in Utah. In this section, we highlight a few key results (not comprehensive), organized into different sections.

4.9.1 Factors Associated with Impairment Status

- Impaired bicyclists/pedestrians involved in a crash tended to be older than non-impaired bicyclists/pedestrians.
- Active mode user impairment was more likely to be reported for crashes on weekends (vs. weekdays) and overnight (vs. in the evening, morning, or afternoon).
- Both bicycle and pedestrian crashes were more likely to involve suspected impairment on higher-speed roads, and impairment was more likely to be reported for pedestrian crashes in places with fewer lanes, more driveways, and uncontrolled intersections, and further from a crosswalk.
- Active mode user impairment was more likely to be reported for crashes in neighborhoods with smaller average household sizes and fewer workers per household, in rural areas, in places with lower intersection density, and in areas with more liquor facilities.

4.9.2 Differences in Factors Associated with Alcohol vs. Drug Impairment Status

- Most impaired crashes were related to alcohol impairment, so overall results (above) tended to match those for alcohol impairment specifically.
- Associations between distraction and impairment were stronger for drug-impaired active mode users than for alcohol-impaired users.
- There were no associations with liquor facilities and drug-impairment. However, crashes involving bicyclists were more likely to report drug impairment in areas with more food banks.

4.9.3 Differences in Factors Associated with Impairment for KA vs. BCO Crashes

- Most impaired crashes were of BCO severity, so overall results (above) tended to match those for BCO crashes specifically.
- The positive association between liquor stores and impairment remained for KA pedestrian crashes but not for KA bicycle crashes.
- However, for KA crashes, active mode user impairment was more likely to be reported in places with more nearby grocery stores. (For BCO crashes, the association with grocery/convenience stores was the opposite.)

4.9.4 Differences in Factors Associated with Crash Severity for Impairment Status

- Most crashes did not report involving impaired active mode users, so severity results overall tended to match those for non-impaired crashes specifically.
- Overall, and for non-impaired crashes, severity tends to decrease with increasing numbers of nearby grocery stores.
- However, crashes with impaired active mode users tend to be more severe in places with more grocery and/or convenience stores.

4.10 Summary

Based on the objective of the project, this chapter summarized the descriptive and analytical findings involving an exploration of impairment status and crash severity among crashes with active mode users in Utah. To observe the relationship of impairment status and severity level (dependent variable) with other independent variables of interest (demographics, temporal conditions, roadway geometry, neighborhood environment, destinations), this study presented results from a bivariate analysis (Pearson's Chi-Squared Tests of independence, and point-biserial correlation tests), which is a state-of-the-practice approach to exploratory study. The preceding section summarized key findings.

5.0 CONCLUSIONS

5.1 Summary

Based on the analysis provided in Chapter 4, this chapter summarizes the findings of the research. Additionally, this chapter highlights limitations and challenges that were identified as the research was undertaken.

5.2 Overview of Findings

First, the study analyzed all the impaired pedestrian/bicycle crashes against different roadway and socio-economic characteristics. Comparative analysis of different groups of bicyclists/pedestrian crashes shows that impaired bicyclists/pedestrians involved in a crash tended to be older than non-impaired bicyclists/pedestrians (38 vs. 31 years old, on average). Active mode user impairment was more likely to be reported for crashes in neighborhoods with smaller average household sizes and fewer workers per household, in rural areas, in places with lower intersection density, and in areas with more liquor facilities. Furthermore, these crashes are more likely to be reported on weekends (vs. weekdays) and overnight (vs. in the evening, morning, or afternoon).

The study then took a closer look at the crashes of different categories instead of merely analyzing all the impaired crashes as one single category. Regarding impairment type, most impaired crashes were related to alcohol impairment. 181 of the total 299 impaired bicycle/pedestrian crashes were alcohol related. Overall results tended to match those for alcohol impairment specifically. Investigation of demographics, and neighborhood social and built environment characteristics revealed that for alcohol-impaired bicycle crashes (unlike for overall impairment), roadway geometry and posted speed were not significant, but distance to the nearest crosswalk had a significant positive association with alcohol impairment status. Alcohol-impaired pedestrian crashes are higher in areas with high numbers of jobs within a 45-minute commute by transit. For drug-impaired crashes, this study found no associations with liquor facilities and drug-impairment. However, crashes involving bicyclists were more likely to report drug impairment in areas with more food banks.

Comparison of severe vs. non-severe impaired active mode user crashes showed that for severe crashes, active mode user impairment was more likely to be reported in places with more nearby grocery stores. Crash severity tends to decrease as distance from grocery and/or convenience stores increases.

5.3 Limitations and Challenges

As with any research study, datasets come with limitations and challenges. The following limitations were identified within this project:

1. A lack of impairment status reporting for active mode user crashes. While the crash database is effective at maintaining impairment information for drivers, for pedestrian and bicycle crashes, they are not always mentioned. This results in limited sample size for impaired active transportation-related crashes.

2. A lack of pedestrian and cyclist volumes for all locations. While traffic volumes in the form of AADT for each corridor and crash location were able to be gathered, accurate pedestrian and cyclist volumes were unavailable. Not having accurate volumes results in the inability to calculate crash rates for non-motorist crashes (e.g., x ped crashes per 1,000 peds).

3. A lack of pedestrian and cyclist travel behavior data. As mentioned in the literature review, understanding both driver and non-motorist travel behavior and decision making is critical to understanding why crashes occur. The dataset evaluated for this project did not include comprehensive travel behavior data. While basic travel behavior data was included (vehicle maneuver, excess speed, etc.), this does not provide adequate information on decision making. For example, why did a pedestrian choose to walk across a busy street less than 600 feet from a crosswalk? Or, why did a cyclist choose to ride along a high-volume busy roadway rather than a parallel route with lower vehicular volumes and a bike lane? This information is not easily attainable as it would require on-site interviews at the time a behavior is taking place.

6.0 RECOMMENDATIONS AND IMPLEMENTATION

6.1 Recommendations

Based on the findings presented in the prior section, the following recommendations have been identified:

- Target enforcement / prevention activities in these areas, particularly on weekend nights, in target geographic areas that may include smaller households, fewer workers per household, lower intersection density, and higher density of liquor facilities.

- Target enforcement / prevention activities for drug intoxication in areas near food banks / assistance centers, focusing on persons riding bikes.

- Work with law enforcement agencies and other partners to develop procedures to collect data on alcohol and drug impairment in more consistent and accurate ways through crash report procedures.

- Evaluate opportunities to implement additional midblock crossings in the above identified areas, as well as in areas with a higher density of convenient or grocery stores, to provide higher safe crossing densities.

6.2 Implementation Plan

1. The Department of Public Safety (DPS) will identify appropriate new enforcement and education efforts and specific target areas based on the first two recommendations above for future High Visibility Enforcement activities.

2. Integrate larger-scale educational campaigns focusing on improving safe travel for intoxicated cyclists and pedestrians (focus on options and transport decision making) within the Zero Fatalities program. UDOT will partner with DPS to create a grassroots strategy to address impairment appropriately at the local level.

3. UDOT and DPS will work with the Traffic Records Coordinating Committee to identify ways to improve data collection and reporting efficiency and accuracy.

4. As a part of the systemic analysis, UDOT will reevaluate locations where additional non-motorist infrastructure and amenities should be added, such as pedestrian fencing, grade-separated facilities, lighting, etc.

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