Analysis of Vulnerable Road User-to-Motor Vehicle Collisions in New Brunswick

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ABSTRACT

Vulnerable road users (VRU), including pedestrians, cyclists, and power-assisted bikes and scooters (PABS), are the most at risk of a fatality or serious injury when involved in a collision with a motor vehicle. This study undertook a statistical analysis of VRU-to-motor vehicle collisions in New Brunswick (NB) between 1993 and 2017. Over the 25-year period, the collision data captured a total of 3143 pedestrian collisions, 2214 cyclist collisions, and 203 PABS collisions in NB. Patterns and long-term trends were investigated to gain a better understanding of VRU safety and identify cost-effective safety countermeasures.

The study found that VRU-to-vehicle collisions have steadily decreased between 1993 and 2017 in both urban and rural NB. Further, the frequency analysis revealed five key results: VRU's under the age of 30 were significantly over-represented in the collision data, less than half of cyclists and PABS drivers were reported wearing safety equipment, the severity of a collision generally increased as the speed of the vehicle increased, a large proportion of collisions occurred during dark conditions, and the two major contributing factors were driver inattention and pedestrian error/confusion.

Based on the study findings, it is recommended that provincial and municipal road authorities consider promoting or implementing safety countermeasures including training and education initiatives, VRU-related infrastructure improvements, speed reduction measures, strategic lighting improvements, and autonomous emergency braking systems (AEB) that detect VRUs.

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AEB	Autonomous Emergency Braking
CMF	Collision Modification Factor
DTI	Department of Transportation and Infrastructure
EPP	Exclusive Pedestrian Phase
GNB	Government of New Brunswick
LPI	Leading Pedestrian Interval
MCF	Major Contributing Factor
MDC	Motor Driven Cycle
NB	New Brunswick
NBDTI	New Brunswick Department of Transportation and Infrastructure
PABS	Power-Assisted Bike and Scooter
VRU	Vulnerable Road User

1. INTRODUCTION

In recent years, there has been a major push to promote active transportation in countless communities through various plans and strategies. Despite active transportation plans being accompanied by health, environmental, economic, and social benefits, there has been some concern that the increase in activity has contributed to an increase in collisions involving a vulnerable road user (VRU).

With an increase in active transportation comes an increase in VRU movement, which includes walking, running, cycling, and motorized cycling. Based on Transport Canada's collision statistics, approximately 20% of all traffic-related fatalities in 2018 involved a pedestrian or cyclist (Transport Canada 2020). Further, the same percentage can be seen of all traffic-related serious injuries in 2018 involving pedestrians or cyclists (Transport Canada 2020). Since VRUs are considered most at risk when travelling in traffic areas, collision severity is generally greater for these road users. Currently, most roads are designed in favor of motor vehicle use and therefore, VRUs have increased exposure to the risk of a collision with limited protection. By identifying recurring factors in these types of collisions there is potential to improve VRU infrastructure and safety. Examples of infrastructure include pedestrian crosswalks, sidewalks, multi-use trails, cyclist lanes, pedestrian signals, etc.

The focus of this research was to identify and investigate the major patterns and trends that influence collisions between motor vehicles and pedestrians, cyclists, and motor driven cyclists. It should be noted that the Government of New Brunswick (GNB) defines a motor driven cycle (MDC) as a vehicle with a motor that displaces less than 50ccs or

500 watts, which includes electric or motorized scooters (i.e. vespa and mobility scooters), electric bikes, and mopeds (Department of Public Safety, 2011). For this report, the term used to define MDCs is power-assisted bikes and scooters (PABS). The dataset used for analysis included both urban and rural New Brunswick (NB) collisions reported between 1993 and 2017. Since nearly half of NB residents live in urban areas and the other half in rural areas, it was beneficial to analyze collision data in both areas separately. Numerous collision characteristics were explored in the study, including but not limited to environmental, behavioral, collision, and demographic characteristics.

1.1 Problem Statement

This study conducted multiple data analyses of VRU-related collisions in NB and suggested recommended cost-effective safety countermeasures based on the analysis results. The central problem addressed by this research was that the primary factors influencing collisions involving VRUs have never been sufficiently identified and analyzed in both urban and rural areas of NB. Currently, the studies conducted on VRU related collisions in NB are limited in scope and outdated. To conduct a more comprehensive study, this project examined three types of VRUs (pedestrians, cyclists, and PABSs) involved in collisions with a motor vehicle and analyzed all relevant collision attributes. Further, a long collision history (1993-2017) was exploited to identify any evolving trends over the 25-year period. Finally, the study looked at the collisions in a rural and urban context separately to develop the most appropriate safety recommendations for either environment.

1.2 Research Goals and Objectives

The primary goal of this project was to identify and analyze patterns and long-term trends of VRU-to-vehicle collisions in both rural and urban NB. Based upon the results of the study, several countermeasures were recommended to improve VRU safety.

The three main objectives that were required to achieve the goal of this project were:

1. To develop a dataset of all motor vehicle collisions involving pedestrians, cyclists, and PABS drivers in NB between 1993 and 2017.
2. To identify and analyze patterns and long-term trends of collision attributes in urban and rural areas of NB separately over the 25-year period.
3. To recommend cost-effective safety countermeasures that municipal and provincial road authorities can implement to reduce VRU collisions in NB.

1.3 Expected Outcomes

A thorough review and analysis of VRU-to-vehicle collisions provides a better understanding of the extent of VRU safety in NB. Additionally, it could aid the province as well as major cities of NB in identifying how to improve VRU infrastructure in both urban and rural areas. Currently, there is limited research on this topic with only one study that analyzed pedestrian-related collisions in rural NB between 2001 and 2012 (Scott 2016).

The greatest benefit of this research is the potential to improve VRU safety in NB through an extensive analysis of VRU-related collisions. Additionally, the results of this research will be helpful for the New Brunswick Department of Transportation and Infrastructure (NBDTI) and municipalities looking to improve VRU infrastructure in both urban and rural areas of NB.

1.4 Research Scope and Limitations

The extent of this research project was a statistical analysis of collisions involving pedestrians, cyclists or PABS drivers and a motor vehicle in NB as well as the development of safety countermeasures to improve VRU safety and infrastructure.

This project was limited to analyzing cyclist and PABS collision data provided by NBDTI from 1993 to 2017 and pedestrian collision data from 1995 to 2016. Unfortunately, collision data from 2013 was not recorded by the department and was not included in the dataset or analysis. Additionally, the study was restricted on the number of collision attributes received by DTI for the purpose of confidentiality. Another limitation was that not all minor collisions are reported and therefore, the dataset provided by the provincial government does not reflect the true extent of all collisions or incidents. Finally, due to time constraints, this research project required no further data collection in the field as it was deemed not necessary.

1.5 Report Organization

The report is organized into five primary chapters following the introduction chapter, which describes the purpose, scope, and goals and objectives of this research. The remaining chapters are briefly described below:

- Chapter 2 provides a review of similar research in the form of a literature review. This chapter looks at the similarities between publications as well as gaps within the literature.

- Chapter 3 contains the methodology which follows the steps and methods used to conduct the analysis. The section includes data collection methods, data organization methods, and analysis procedures.
- Chapter 4 presents the results of the analysis that was conducted based on NB collision data. Frequency analysis was utilized to determine the collision patterns and trend analysis was used to present long-term collision trends over the 25-year period.
- Chapter 5 provides a discussion of the results. Specifically, the section will evaluate the results and how it relates to the literature review. In addition, the discussion will consider safety countermeasures to implement based on the results.
- Chapter 6 presents the overall conclusions that were drawn from the research and further included in this chapter are recommendations for future research.

2. LITERATURE REVIEW

This section includes a review of literature pertaining to the patterns and characteristics of VRU-to-vehicle collisions. Moreover, it highlights recommended safety countermeasures based on the results of the studies. This chapter is divided into four main sections: common VRU collision patterns, trends of collision attributes, recommendations for countermeasures to improve VRU safety, and gaps within the sources reviewed.

2.1 Common Collision Patterns

Most recent studies have primarily been focused on collision patterns and characteristics involving pedestrians or cyclists and motor vehicles (Scott 2016, Miles and Verzosa 2016, Chong *et al.* 2018, Senserrick *et al.* 2014, Beck *et al.* 2016, Boufous *et al.* 2012). Of these publications, frequency analysis was continually utilized to determine the patterns and characteristics of the collision attributes. Throughout the research, several common characteristics and recurring patterns were recognized relating to road user, environmental, collision, and behavioral characteristics. It should be noted that nearly all papers explored for the literature review were conducted in countries other than Canada, including the United States and Australia, which may have produced results dissimilar to those in NB given the differences in climate, population distributions, demographics, road characteristics, travel patterns and behavior, etc.

2.1.1 Road User Characteristics

In all studies explored, common pedestrian and cyclist characteristics, including gender, age, and injury severity were investigated. It is interesting to note that males accounted for the majority of pedestrians and cyclists injured or fatally injured in collisions in each study. Specifically, two studies were conducted in two Australian cities which looked at various characteristics of cyclist collisions (Beck *et al.* 2016, Boufous *et al.* 2012). The results revealed that males accounted for 81.0% and 76.6% of cyclists involved in a collision with a motor vehicle in Melbourne and Victoria, respectively (Beck *et al.* 2016, Boufous *et al.* 2012). Likewise, a report focused on pedestrian-vehicle collisions in rural NB found that male pedestrians accounted for 64.1% of collisions resulting in injuries and 79.7% of collisions resulting in a fatality (Scott 2016).

Regarding the age of pedestrians and cyclists, certain studies provided a percentage per age group while others provided a median age. Despite no particular age of VRU's accounting for the majority of collisions throughout the literature, an overarching theme in all studies was the fatality rate was higher in elderly people aged 85+ whereas the injury rate was higher for younger VRU's (Scott 2016, Jiménez-Mejías *et al.* 2016, Chong *et al.* 2018)

Further, driver characteristics such as gender and age were briefly explored in the literature. A pedestrian-vehicle collision study conducted in Spain found that younger drivers and senior pedestrians are at a higher risk of being involved in a collision and that nearly 60.0% of collisions involved male drivers (Jiménez-Mejías *et al.* 2016). Several publications lacked an analysis of driver characteristics which could be beneficial when determining how to improve VRU safety (Scott 2016, Miles and Verzosa 2016, Chong *et al.* 2018, Beck *et al.* 2016, Boufous *et al.* 2012).

Additionally, the use of helmets worn by cyclists was investigated and compared to crash severity. Two studies in Australia, the first in Melbourne found that helmets were worn in 97.0% of cases and the second in Victoria reported 74.1% of cyclists involved in a collision were wearing a helmet (Beck *et al.* 2016, Boufous *et al.* 2012). In the Victoria study, it was also found that not wearing a helmet increased likelihood of a severe injury by 56.0% (Boufous *et al.* 2012).

2.1.2 Environmental Characteristics

Several environmental characteristics were considered throughout the literature, the most predominant being the time of day. It was found that the largest frequency of pedestrian or cyclist collisions occurred during daylight hours. In four separate studies, the frequency of VRU collisions occurring throughout the day ranged from 57.4% to 81.0% (Scott 2016, Miles and Verzosa 2016, Beck *et al*. 2016, Boufous *et al.* 2012). Considering a higher volume of pedestrian and cyclist travel during the day it is expected that there would be a higher proportion of collisions during daylight hours.

Weather and road conditions were explored in several publications. In most cases, collisions involving pedestrians and cyclists occurred in clear weather and on dry roads. This can be seen in a study conducted in Melbourne where clear weather conditions made up 79.0% of all cyclist collisions; likewise, 54.7% of collisions involving pedestrians occurred in ideal conditions (Beck *et al.* 2016, Scott 2016). These type of road users are more likely to walk or bike when the weather is clear, resulting in more collisions taking place in dry conditions.

Finally, the majority of pedestrian- and cyclist-related collisions in the various studies occurred mainly in urban settings. Based on findings from United States and Australia, the number of collisions that took place in urban areas was 72.6% and 94.6%, respectively

(Chong *et al.* 2018, Senserrick *et al.* 2014). Although urban environments hold the highest frequency of collisions, the most severe injuries arose in rural environments. This could be a result of higher speeds and/or a lack of pedestrian and cyclist infrastructure in these areas.

2.1.3 Collision Characteristics

The prevailing collision characteristics throughout the literature were the speed limit, crash configurations, and road characteristics. In many studies, the bulk of the collisions involving pedestrians or cyclists occurred in speed zones of 60 km/h or less. To highlight, approximately 80.0% of pedestrian and 64.7% of cyclist casualties were experienced in speed zones of 60 km/h or less in two different studies carried out in Victoria, Australia (Senserrick *et al.* 2014, Boufous *et al*. 2012). Similarly, 35.3% of collisions involving pedestrians resulting in a major injury occurred on roads with a speed limit of 50 km/h in rural NB; however, more fatalities occurred in 80 km/h zones (Scott 2016). Given that most urban streets are posted at 60 km/h or less, it is reasonable to see more collisions in these areas.

The configuration of a collision is difficult to analyze considering there are a number of different configuration possibilities, especially when considering pedestrians and cyclists. As a result, there was no definitive conclusion reached for the highest frequency of a specific crash configuration when looking at all the literature. Nonetheless, the leading crash type for cyclists in Victoria were *vehicles from the same direction* with 22.7% of collisions, *vehicles from adjacent directions (intersections only)* at 21.8%, and *maneuvering (bike emerging from path or vehicle emerging from driveway*) at 21.1%

(Boufous *et al.* 2012). On the other hand, the main pedestrian-related collision configuration was a pedestrian *crossing from either side of the road* occurring in 60.0% of collisions (Senserrick *et al.* 2014). An alternative study in Sweden found that 78.1% of cyclist-related collisions resulted in a bicycle and car crossing each other's path with 53.4% of those due to a cyclist crossing a road while along a bike path (Isaksson-Hellman and Werneke 2017). Finally, the rural NB study concluded that pedestrians walking *on sidewalk/shoulder/boulevard* had the highest frequency accounting for 13.3% of injury-related collisions, whereas pedestrians walking on roadway with traffic accounted for 23.4% of fatality-related collisions (Scott 2016).

There are certain road characteristics that can be important to examine in a collision study; these include curvature, paving conditions, number of lanes, and road type. The frequency of pedestrian-related collisions in respect to the number of lanes was only studied in one of the publications, resulting in 45% of collisions occurring on roads with 1 or 2 lanes and 43.0% occurring on roads with 3 or more lanes (Miles and Verzosa 2016). Another study found that 98.1% of pedestrian-related collisions took place on straight roads, 96.6% occurred on paved roads, 55.8% on arterial and 42.5% on local roads, and 54.4% took place at non-intersections (Senserrick *et al.* 2014). Similarly, 72.4% of pedestrian-vehicle collisions in the US occurred at non-intersections (Chong *et al.* 2018). Again, no definite conclusions could be reached considering few studies have investigated all of these road characteristics.

The type of vehicle involved in pedestrian and cyclist collisions was briefly discussed in the literature. Overall, passenger cars made up the majority of vehicles involved in a collision with a VRU. Specifically, 41.0% and 36.0% of collisions involved a passenger car and a pedestrian in two separate studies (Chong *et al.* 2018, Miles and Verzosa 2016). Similarly, the frequency of cyclist and passenger car collisions in a publication in Victoria was 83.7% (Boufous *et al.* 2012).

2.1.4 Behavioral Characteristics

Behavioral characteristics such as pedestrian, cyclist and driver action are difficult to capture due to the many factors that lead to a collision. Nonetheless, the NB study found that the major contributing factor (MCF) of rural collisions was pedestrian error accounting for 25.7% of injury-related collisions and 43.8% of fatality-related collisions (Scott 2016). In both cases, the next highest MCF was driver inattention accounting for 19.4% of injury-related collisions and 14.1% of fatality-related collisions (Scott 2016). This collision attribute was not analyzed in any other publication.

The use of alcohol and drugs at the time of the collision was explored in two studies in the US and Australia. Blood alcohol concentration was measured in both pedestrians and drivers at the time of the collision in the US. It was concluded that 25.8% of pedestrians and 4.4% of drivers had a concentration greater than 0.08 (Chong *et al.* 2018). The study conducted in Australia found that 25.0% of pedestrians consumed alcohol at the time of the collision and 31.4% of pedestrians had taken some form of drug (Senserrick *et al.* 2014).

Many of the collision characteristics discussed will be utilized in the frequency and trend analysis. However, there were a considerable number of characteristics that were explored in the literature that will not be explored in the analysis of this research, due to a lack of data available in NB and time. Among these were health problems of road users, specific injury type, use of alcohol or drugs, heavy vehicles, collisions in school zones, and collisions on cyclist and pedestrian paths.

2.2 Collision Trends

A very limited number of publications regarding VRU-to-vehicle collisions performed comprehensive trend analyses. Therefore, there were few studies that could be compared and common trend analysis methods and results throughout the literature were limited. Nonetheless, one study conducted in Sweden demonstrated that bicycle collisions with motor vehicles that resulted in a fatality steadily decreased between 1960 and 2011 (Isaksson-Hellman and Werneke 2017). On the other hand, a publication on pedestrian casualty collisions revealed that collisions resulting in severe non-fatal injuries increased over a 5-year period (Senserrick *et al.* 2014). Ultimately, the latter results were considered less reliable given that short term data was utilized. On the subject of severity of collisions, one publication looked at the severity of a collision compared to the impact speed of a motor vehicle. Based on the data, it was revealed that as the impact speed increased the severity of the collision involving a pedestrian increased (Bushell and Zegeer 2012).

Further, a publication introduced the trends associated with pedestrian fatality rate per 100,000 population and age between 2006 and 2015. The results revealed that fatalities resulting from a collision with a motor vehicle increased with age (Chong *et al.* 2018). Moreover, from 2011 to 2015, the data showed that the fatality rates for pedestrians aged 25 and over significantly increased (Chong *et al*. 2018).

Lastly, a study done in Australia looked at the trend of collisions based on time of day and day of week. The data revealed that the frequency of pedestrian collisions peaked between 2:00 PM and 6:00 PM on weekdays and peaked between 10:00 PM and 2:00 AM on weekends (Senserrick *et al.* 2014).

Regrettably, the literature did not extensively investigate the long-term trends of VRU and motor vehicle collisions. The approaches most widely utilized in the literature were binomial and multivariable logistic regression models. These models were used to identify relationships between severity of collisions and individual factors, identify predictors of severe injury collisions, determine the statistical significance of specific trends, and predict the odds of a fatal collision occurring (Miles and Verzosa 2016, Boufous *et al.* 2012, Boufous *et al.* 2012, Chong *et al.* 2018). This research will be more focused on frequency and trend analysis of specific collision attributes due to the limited understanding of VRU-to-vehicle collisions in NB currently.

2.3 Safety Countermeasures

Effective countermeasures aim to improve the safety of VRUs as well as motor vehicle drivers through reducing the severity of a collision. There are numerous safety countermeasures that were proven effective including leading pedestrian intervals (LPI), medians and pedestrian crossing islands, well-designed walkways and shared paths, reducing speed limit, road diets, etc. (Federal Highway Administration 2017). However, the more prevalent countermeasures discussed in the literature were related to education and training, improving, and implementing new VRU infrastructure, and reducing driver speed (Scott 2016, Isaksson-Hellman and Werneke 2017, Boufous *et al.* 2012, Jiménez-Mejías *et al.* 2016).

2.3.1 Training and Education

Educating the public to improve VRU safety was described in several publications, which included road safety education at schools and driver training centers as well as counseling for senior drivers (Scott 2016, Jiménez-Mejías *et al.* 2016, Desipryia *et al*. 2013, Bushell and Zegeer 2012, Isaksson-Hellman and Weneke 2017). Given that young and senior drivers are more likely to be involved in a collision, this additional education and training can help shape behavior of these drivers and highlight the importance of safety. In particular, the literature mentioned educating young pedestrians and cyclists on the proper use of helmets and road safety. In one study where there was a large frequency of senior drivers involved in VRU-related collisions, it was recommended that senior drivers be periodically screened or provided different alternatives to driving (Jiménez-Mejías *et al.* 2016). By conducting these screenings, issues that potentially impair the ability of seniors to drive safely can be assessed including physical, visual, hearing, and cognitive impairments. Further, publications mentioned educating the public on the vulnerability and needs of VRUs, specifically emphasizing the correlation between vehicle speed and VRU injury. Generally, as the speed of a motor vehicle increases, the injury severity experienced by a VRU involved in a collision with a motor vehicle increases.

Unfortunately, training and education efforts have not directly shown a reduction in the frequency or severity of VRU-related collisions (Senserrick *et al.* 2014, Bushell and Zegeer 2012). However, it is a low-cost measure that is important in improving driver behavior, pedestrian behavior, and raising awareness to more VRUs such as pedestrians and cyclists.

2.3.2 Implementing and Improving VRU Infrastructure

There were several safety improvements that were discussed in the literature pertaining to implementing new infrastructure as well as improving current infrastructure. In terms of pedestrians, two recurring safety countermeasures discussed were well designed sidewalks and walkways as well as improved illumination (Bushell and Zegeer 2012, Boufous *et al.* 2012). Sidewalks and walkways that provide shield from errant motor vehicles on high-speed roads and illumination in high pedestrian traffic areas are critical in improving VRU safety. Other safety improvements included pedestrian refuge islands to allow pedestrians and cyclists refuge while crossing the road, a LPI to allow separate pedestrian and motor vehicle movements, and enforcing the use of retroreflective gear while traveling at night (Bushell and Zegeer 2012, Isaksson-Hellman and Weneke 2017). Cyclists especially are recommended to wear retroreflective gear at night while sharing the road with motor vehicles, given that it increases visibility of cyclists.

Regarding specific cyclist infrastructure, a major safety countermeasure that was mentioned was enforcing the use of helmets, especially in younger cyclists (Boufous *et al.* 2012, Isaksson-Hellman and Weneke 2017). Additionally, two studies recommended implementing well designed bicycle paths in areas with a speed limit greater than 60 km/h as well as improve bicycle path connectivity (Boufous et al. 2012, Isaksson-Hellman and Weneke 2017). Creating new and improving bicycle paths was proven to considerably reduce the frequency of cyclist-to-vehicle collisions. A final countermeasure that was notable was the modification of curved sections of roadway (Boufous *et al.* 2012). Specifically, the study mentioned improving the curve length, degree of curvature, and placement of street furniture (Boufous *et al.* 2012). Ultimately, improving and implementing more well-designed pedestrian and cyclist infrastructure should result in safer facilities and potentially increase active transportation.

Unfortunately, no safety countermeasures related to infrastructure improvements were found for PABSs.

2.3.3 Reducing Speed Limit

Finally, a common but debatable countermeasure discussed in the literature was the process of reducing the speed limit along certain streets (Isaksson-Hellman and Werneke 2017, Boufous *et al.* 2012, Jiménez-Mejías *et al.* 2016, Miles and Verzosa 2016). There are two primary measures that can be utilized to enforce slower driver speeds, posted speed limit reduction and traffic calming measures. Traffic calming measures, for instance, involves speed humps, chicanes, traffic circles, median islands, etc. Generally, these speed reduction measures would be enforced near school zones, high pedestrian or cyclist traffic areas, or along sharp curves.

Based on the pedestrian safety report, it was estimated that VRUs are eight times more likely to be killed being struck by a vehicle driving at 50 km/h rather than by a vehicle traveling at 30 km/h (Desapriya *et al*. 2013). Other studies have shown that attempting to reduce driver speed failed, given that drivers are already accustomed to the former posted speed limit. Nonetheless, lowering the speed limit or incorporating traffic calming measures along high pedestrian and cyclist activity areas are low-cost countermeasures that have the potential to reduce the severity of VRU-to-vehicle collisions and increase driver attention.

Although there were a vast number of publications solely on VRU safety countermeasures, few studies that analyzed pedestrian- and cyclist-related collision characteristics thoroughly discussed safety countermeasures. As a result, more research will be required to identify and recommend cost-effective countermeasures based on the frequency and trend analysis results to improve VRU safety.

2.4 Gaps

While there has been much research on pedestrian, cyclist, and even motorcyclist collisions, few studies have analyzed the patterns and trends associated with PABS collisions. The use of PABS's has increased in popularity in NB over recent years and collisions have potentially increased. At present, there is no research on PABS collisions in NB; therefore, analyzing the data would result in identifying major factors influencing these types of collisions.

Another gap in the research was that most studies focused on collisions occurring in urban environments as opposed to rural areas. Since nearly half of the NB population lives in rural communities and the other half in urban communities, understanding differences in collision patterns in both areas is beneficial to recommend safety countermeasures for road authorities to implement.

It is also worth noting the lack of comprehensive studies reflecting northern environments in both urban and rural areas. Unlike the studies conducted in countries outside of Canada, NB receives a considerable amount of annual snowfall resulting in harsher driving conditions. Evaluating VRU collisions occurring in these more severe conditions will assist in identifying countermeasures that have not been discussed in the studies reviewed thus far.

In terms of road characteristics, the literature fails to explore the effects of key attributes such as road shoulder widths, the presence of rumble strips, and lighting conditions. Some of these attributes are not provided on accident report forms; however, they are important to investigate when establishing safety countermeasures.

Another major gap in the research was the lack of comprehensive discussion on recommendations for cost-effective safety countermeasures. A limited number of publications included a brief discussion of countermeasures, and none had provided recommendations for urban versus rural settings. Considering the population is evenly split between urban and rural NB and the different road networks, it is important to consider safety countermeasures in both areas separately.

Finally, several publications did not make use of long-term data in their research. Instead, most of the literature looked at analyzing pedestrian and cyclist collisions over a four to eight-year period and therefore, was not able to examine long-term trends. Consequently, the results in past publications could not be adequately compared to the trend analysis results presented in this research. This research project will aim to investigate a long collision history of 25 years, which will potentially reveal patterns and long-term trends in the collision data.

3. METHODOLOGY

To complete this research, the approach consisted of two steps that align with the objectives of the project. The first step required classifying the data to determine the number of VRU collisions in NB. Step two involved conducting a statistical analysis of all relevant collision attributes to determine patterns and long-term trends. This section aims to explain the significance of this approach in further detail.

3.1 Data Sorting

The data that were used for this project was provided by the NBDTI. In the event of a collision, the 'Report of Motor Vehicle Accident' form is filled out by police, submitted to NBDTI, and is entered into a database. A copy of the 'Report of Motor Vehicle Accident' form can be found in Appendix A. It should be noted that the reported collisions represent only those incidents where there was at least $1,000 in property damage or injury. Consequently, a VRU that is struck by a motor vehicle where damages are small and there are no injuries does not get included in the dataset; therefore, it is considered a subset of all incidents. Nevertheless, the department then converts the collision data into an Excel spreadsheet, omitting confidential information, and sends the datasets to UNB. The datasets, containing all reported collisions in NB, contain data from 1993 until 2017 and are provided in quarterly files.

The first step required taking all the files provided and converting them into one Excel file comprising of all the data over the 25-year period. The dataset was comprised of numerous collision attributes such as the date, injury severity, collision configuration, environmental conditions, age, gender, vehicle type, etc. There were several attributes that were not required for the analysis, including vehicle year, location of impact, network name, etc., and therefore, were removed before the data were sorted by VRU type.

To determine the number collisions involving a pedestrian, the column termed ‘Position In / On Vehicle’ was filtered to only display the number 12 which signifies a pedestrian. All collisions displayed were transferred into another separate sheet within the Excel file. Cyclists involved in a collision were identified by filtering the ‘Vehicle Type’ column to only display the number eight which indicates a bicycle. Again, all collisions displaying eight under vehicle type were transferred into a third sheet within the Excel file. Finally, to establish the number of PABSs involved in a collision, the ‘Vehicle Type’ column was filtered to display the number seven. The collisions displayed were then copied and pasted into a fourth sheet within the Excel file. Based on the results of the sorting, the number of pedestrian-, cyclist-, and PABS-related collisions were determined. For a collision involving a cyclist or PABS, it was ensured that at least one motor vehicle was involved in the collision. If no motor vehicle was present in the collision and only involved another VRU, the collision was removed from the dataset.

Further, each VRU collision dataset was filtered to separate the collisions by urban and rural locations. According to GNB, an urban area has a minimum population of 1,000 persons and a population density of at least 400 persons per square kilometre whereas a rural area is all other territory outside of urban areas (Government of New Brunswick 2006). Urban collisions were identified by filtering the ‘Location Type’ column to display numbers one through five. On the other hand, identifying rural collisions for each VRU type required filtering the ‘Location Type’ column to display numbers six through nine.

3.2 Data Analysis

The data analysis techniques that were used for this research project were frequency and trend analysis. With these two methods, the factors and patterns likely contributing to pedestrian-, cyclist-, and PABS-to-vehicle collisions were identified.

3.2.1 Frequency Analysis

To determine the factors and characteristics potentially contributing to VRU collisions, frequency analysis was utilized. The frequency of each characteristic was converted to a percentage and the results of each were summarized in individual tables. In Excel, the SUMPRODUCT and COUNTIF function were utilized to count the number of cells in a range that meet a single condition as well as exclude all collisions with more than one driver or VRU involved. For example, if the collision ID is in row "A" and the frequency of a specific collision attribute must be determined, the function utilized was "=SUMPRODUCT(1/COUNTIF(A1:A20,A1:A20)". The collision attributes that were analyzed using the above method were the following:

- Collision Year/Month
- Collision Day of Week
- Collision Time
- Collision Severity
- Legal Speed Limit
- Lighting Conditions
- Weather Conditions

- Roadway Characteristics (surface type, condition, alignment, character, traffic control)
- Major Contributing Factor
- Vehicle Type
- Pedestrian/Cyclist/PABS Age and Gender
- Pedestrian Action
- Driver Age, Gender, and Experience
- Safety Equipment Used
- Fatalities and Legal Speed Limit

3.2.2 Trend Analysis

Trend analysis was used to quantify and explain patterns as well as determine if long-term trends are increasing, decreasing, or remaining constant over time. The analysis consisted of plotting certain collision attribute data over the 25-year period. In Excel, a scatter plot with straight lines was chosen and the relevant data were selected and added to the plot. In certain cases, all the categories within the collision attribute were included in the graph and in others, only the most frequently reported were included. Given that each graph compared several different trend lines, each line was assigned a distinct color to differentiate between each series. The data that were analyzed for this section were:

- Pedestrian, Cyclist, and PABS Collisions by Year
- VRU Collisions by Month
- VRU Collisions by Day
- Pedestrians, Cyclists and PABS Drivers by Age

- Pedestrian, Cyclist, and PABS Drivers by Gender
- Pedestrian, Cyclist, and PABS Collisions by Severity
- Pedestrian, Cyclist, and PABS Collisions by Major Contributing Factor
- Pedestrian, Cyclist, and PABS Collisions by Light Condition
- Pedestrian, Cyclist, and PABS Collisions by Legal Speed Limit

4. ANALYSIS AND RESULTS

The following sections include the results of the frequency and trend analysis used to determine the patterns and long-term trends of VRU-to-vehicle collisions in NB. Each section within this chapter is based on a specific collision attribute from NBDTIs Report of Motor Vehicle Accident form. It should be emphasized that collision data involving pedestrians are represented from 1995 to 2016 and collisions involving cyclists and PABS drivers are represented from 1993 to 2017.

4.1 Temporal Factors

4.1.1 Annual Trends

Between 1995 and 2016, there has been a total of 3143 pedestrian-to-vehicle collisions in NB. Additionally, there has been a total of 2214 cyclist-to-vehicle collisions and 203 PABS-to-vehicle collisions from 1993 to 2017 in NB. Consistent with the results found in the literature review, the greatest number of pedestrian-, cyclist-, and PABS driver-to-vehicle collisions occurred in urban areas, with a frequency of 2697 collisions (85.8%), 1905 collisions (86.0%), and 168 collisions (82.8%), respectively. Considering the population distribution being relatively evenly split in NB, collisions occurring in urban areas were significantly overrepresented in the data. It should be noted that there may be some discrepancies between the urban/rural population data and what is recorded as urban/rural on the Report of Motor Vehicle Accident form by police.

Tables 4.1, 4.2, and 4.3 below summarize the frequency of pedestrian, cyclist, and PABS collisions per year in both urban and rural NB. Based on Table 4.1, the largest frequency of pedestrian-vehicle collisions occurred in 1995, 6.4% (174 collisions) and 11.2% (49 collisions) in urban and rural NB, respectively. Similarly, 9.7% (30 collisions) of rural collisions involving cyclists occurred in 1995; however, 7.6% (145 collisions) took place in urban areas in 1994, based on Table 4.2. Finally, Table 4.3 shows that 13 PABS-to-vehicle collisions (7.7%) occurred in 2010 in urban NB whereas in rural areas, 4 PABS collisions (11.4%) took place in 2005.

Table 4.1: Number of Pedestrian-to-Vehicle Collisions by Year

Year	Urban	%	Rural	%
2017	NA	0.0	NA	0.0
2016	79	2.9	11	2.5
2015	87	3.2	12	2.7
2014	85	3.2	5	1.1
2012	85	3.2	12	2.7
2011	115	4.3	15	3.4
2010	141	5.2	18	4.1
2009	123	4.6	13	3.0
2008	131	4.9	15	3.4
2007	122	4.5	19	4.3
2006	124	4.6	20	4.6
2005	116	4.3	14	3.2
2004	132	4.9	19	4.3
2003	142	5.3	17	3.9
2002	126	4.7	29	6.6
2001	148	5.5	26	5.9
2000	141	5.2	23	5.3
1999	154	5.7	28	6.4
1998	156	5.8	28	6.4
1997	155	5.7	31	7.1
1996	161	6.0	33	7.6
1995	174	6.5	49	11.2
1994	NA	0.0	NA	0.0
1993	NA	0.0	NA	0.0
Total	2697 (85.8%)	100	437 (13.9%)	100
Annual Average	128	-	21	-

Table 4.2: Number of Cyclist-to-Vehicle Collisions by Year

Year	Urban	%	Rural	%
2017	68	3.6	4	1.3
2016	62	3.3	6	1.9
2015	54	2.8	3	1.0
2014	62	3.3	5	1.6
2012	60	3.1	7	2.3
2011	60	3.1	9	2.9
2010	47	2.5	7	2.3
2009	50	2.6	11	3.6
2008	67	3.5	8	2.6
2007	65	3.4	9	2.9
2006	84	4.4	10	3.2
2005	68	3.6	7	2.3
2004	71	3.7	9	2.9
2003	68	3.6	10	3.2
2002	70	3.7	17	5.5
2001	62	3.3	27	8.7
2000	69	3.6	21	6.8
1999	103	5.4	13	4.2
1998	110	5.8	16	5.2
1997	112	5.9	14	4.5
1996	103	5.4	14	4.5
1995	109	5.7	30	9.7
1994	145	7.6	25	8.1
1993	136	7.1	27	8.7
Total	1905 (86.0%)	100.0	309 (14.0%)	100.0
Annual Average	79	-	13	-

Table 4.3: Number of Power-Assisted Bike and Scooter-to-Vehicle Collisions by Year

Year	Urban	%	Rural	%
2017	4	2.4	1	2.9
2016	8	4.8	0	0.0
2015	5	3.0	1	2.9
2014	6	3.6	2	5.7
2012	6	3.6	0	0.0
2011	7	4.2	1	2.9
2010	13	7.7	3	8.6
2009	7	4.2	3	8.6
2008	4	2.4	1	2.9
2007	5	3.0	0	0.0
2006	7	4.2	0	0.0
2005	9	5.4	4	11.4
2004	10	6.0	1	2.9
2003	3	1.8	1	2.9
2002	9	5.4	2	5.7
2001	4	2.4	2	5.7
2000	8	4.8	1	2.9
1999	7	4.2	0	0.0
1998	7	4.2	1	2.9
1997	7	4.2	3	8.6
1996	8	4.8	2	5.7
1995	7	4.2	1	2.9
1994	8	4.8	3	8.6
1993	9	5.4	2	5.7
Total	168 (82.8%)	100.0	35 (17.2%)	100.0
Annual Average	7	-	1	-

The number of VRU-to-motor vehicle collisions in NB were plotted to identify trends over the 25-year period. Figure 4.1 presents the pedestrian-related collisions by year for both urban and rural NB. Considering urban collisions, a gradual decrease was observed between 1995 and 2000 and a fluctuation in the data between 2001 and 2010. In addition, collisions decreased sharply between 2010 and 2012 and finally, levelled off past 2012. In terms of rural pedestrian-related collisions, a gradual decline was identified over the 22-year period. The following figure, Figure 4.2, displays the cyclist-related collisions by year. In urban areas, there was a steep decrease in collisions between 1994 and 2001 and following 2001, collisions leveled off until 2017. Regarding rural cyclist-related collisions, a gradual decline was identified over the 25-year period. Finally, Figure 4.3 presents the PABS-related collisions taking place in both urban and rural NB. Both lines reveal a fluctuation in the number of collisions over the period of 25 years. The largest rapid decline in collisions occurred between 1999 and 2001 and the largest rapid increase in collisions occurred between 2008 and 2010 in urban NB. There were no significant increases or decreases in PABS-related collisions in rural NB.

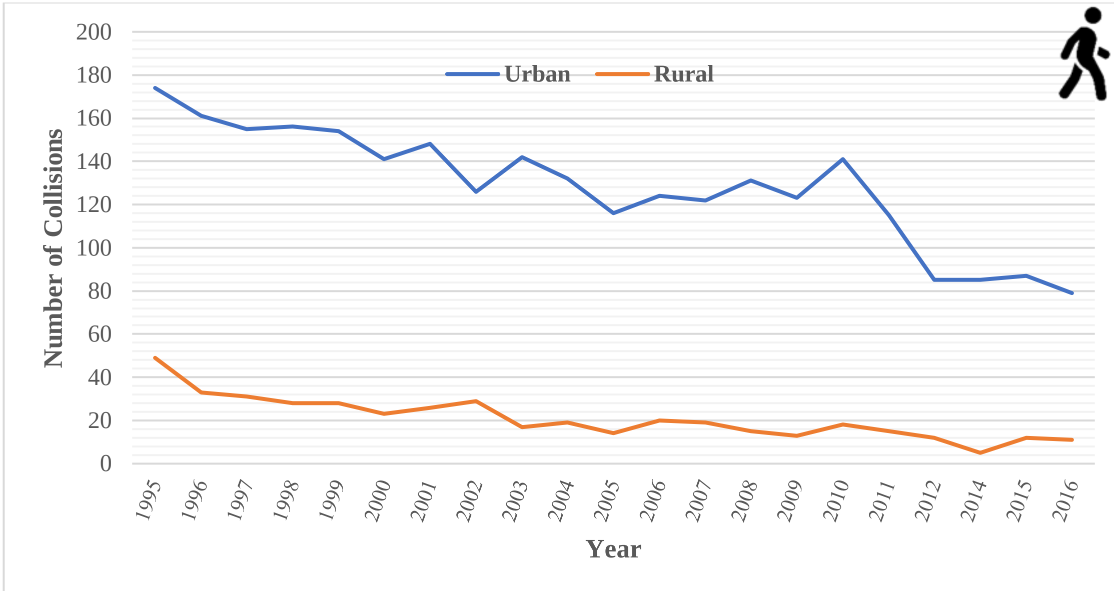

Figure 4.1. Pedestrian collisions by year

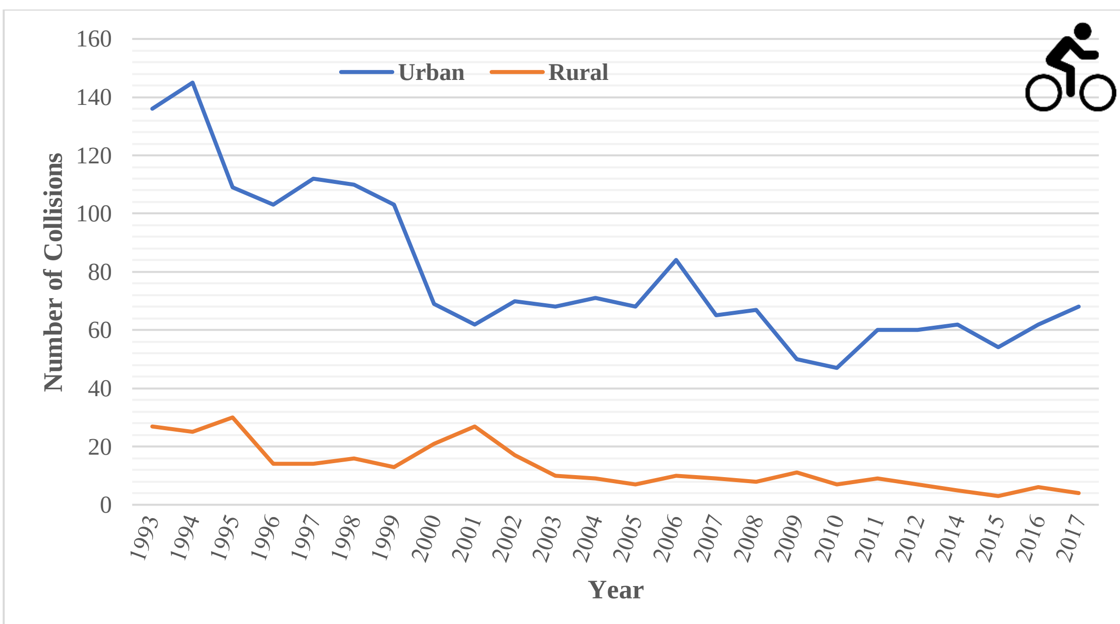

Figure 4.2. Cyclist collisions by year

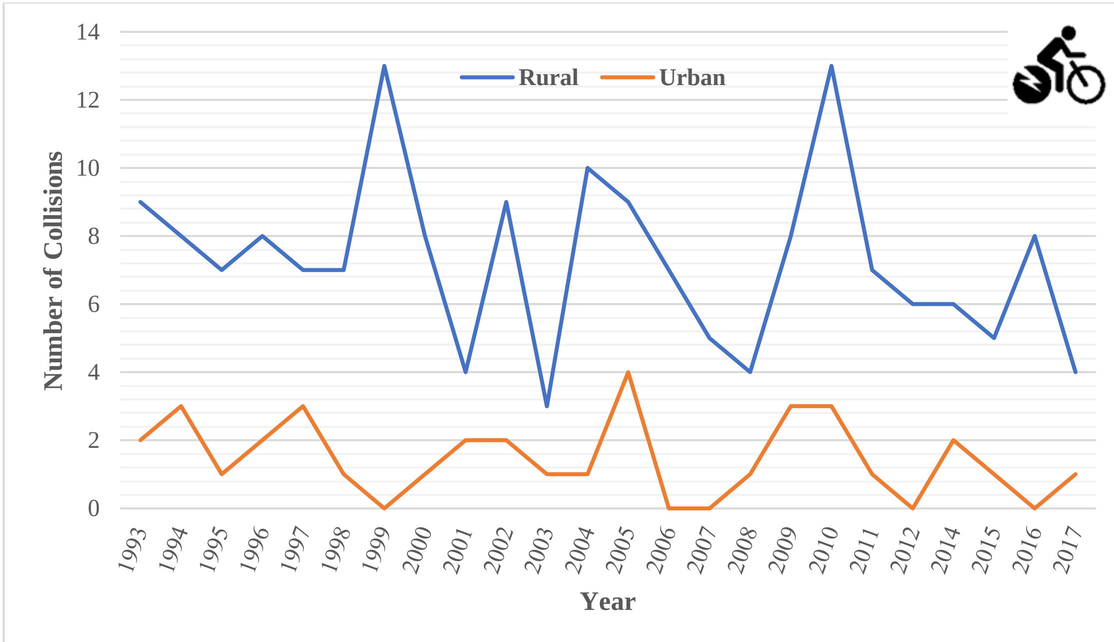

Figure 4.3. Power-Assisted Bike and Scooter collisions by year

4.1.2 Monthly Distributions

In terms of pedestrian-related collisions, Table 4.4 presents the frequencies of VRU collisions by month over the 25-year period. Interestingly, the winter months are overrepresented in collisions involving a pedestrian, with 12.1% (326 collisions) of urban collisions occurring in November and 11.9% (52 collisions) of rural collisions taking place in January. Conversely, cyclist and PABS collision results indicate the largest frequency of collisions occurred in the summer season. Based on Tables 4.5 and 4.6, 19.2% (365 collisions) and 23.2% (39 collisions) of cyclist and PABS collisions in urban areas occurred in the month of July. Additionally, approximately 20% of both cyclist and PABS collisions were reported in rural areas in the month of August.

Table 4.4: Pedestrian-to-Vehicle Collisions by Month

Month	Urban	%	Rural	%
January	242	9.0	52	11.9
February	222	8.2	28	6.4
March	206	7.6	35	8.0
April	171	6.3	26	5.9
May	153	5.7	16	3.7
June	160	5.9	19	4.3
July	194	7.2	41	9.4
August	193	7.2	43	9.8
September	235	8.7	41	9.4
October	290	10.8	46	10.5
November	326	12.1	40	9.2
December	305	11.3	50	11.4

Table 4.5: Cyclist-to-Vehicle Collisions by Month

Month	Urban	%	Rural	%
January	11	0.6	4	1.3
February	8	0.4	1	0.3
March	29	1.5	7	2.3
April	88	4.6	20	6.5
May	216	11.3	44	14.2
June	322	16.9	51	16.5
July	365	19.2	56	18.1
August	359	18.8	62	20.1
September	237	12.4	38	12.3
October	158	8.3	14	4.5
November	75	3.9	7	2.3
December	37	1.9	5	1.6

Table 4.6: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Month

Month	Urban	%	Rural	%
January	2	1.2	2	5.7
February	1	0.6	1	2.9
March	1	0.6	1	2.9
April	9	5.4	1	2.9
May	15	8.9	5	14.3
June	34	20.2	6	17.1
July	39	23.2	3	8.6
August	24	14.3	7	20.0
September	21	12.5	3	8.6
October	13	7.7	2	5.7
November	6	3.6	1	2.9
December	3	1.8	3	8.6

Figure 4.4 presents the trends associated with the number of pedestrian-, cyclist-, and PABS-related collisions over a 12-month period in both urban and rural NB. In terms of

collisions involving pedestrians, the number of collisions dropped gradually from January to May and increased significantly from May to November. Alternatively, the graph shows the lowest number of collisions involving cyclists and PABS occurred early in the year and significantly increased from March to August as the weather became warmer. After the month of August there was a sharp decline in the number of collisions as the weather becomes colder.

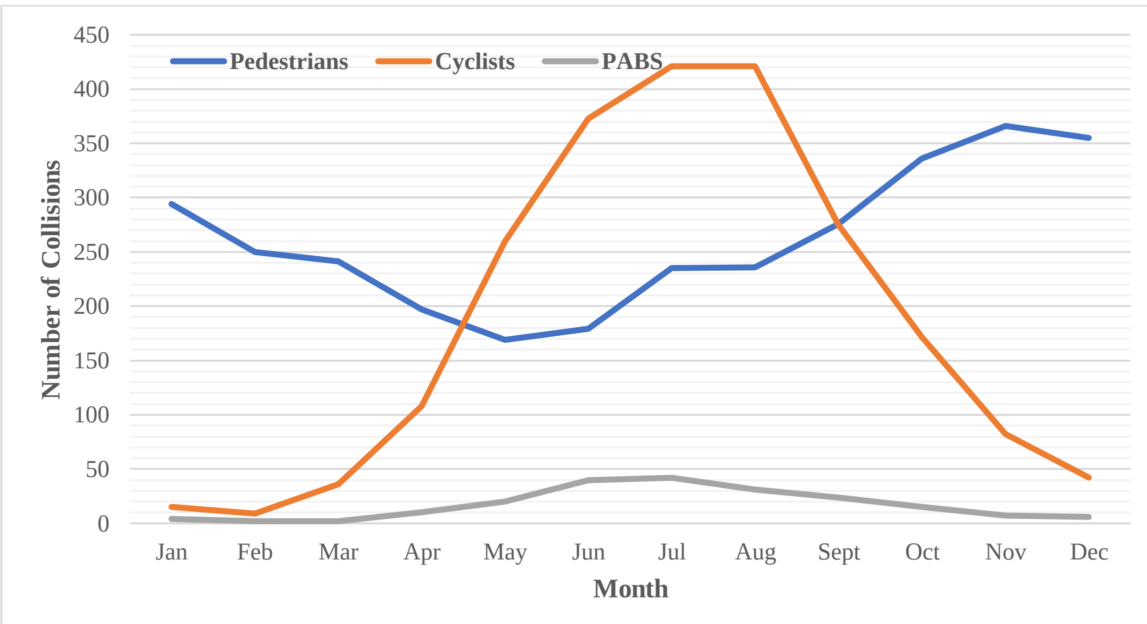

Figure 4.4. Vulnerable road user-related collisions by month (urban and rural)

4.1.3 Daily Distributions

The data in tables 4.7, 4.8, and 4.9 synthesize the results of the number of pedestrian, cyclist, and PABS collisions by day of week. From the results, the majority of collisions in both urban and rural areas occurred later in the week as well as the weekend. Additionally, it was determined that in urban areas, the majority of collisions involving all three VRUs occurred on a Friday. The number of pedestrian-, cyclist-, and PABS-to-vehicle collisions taking place on a Friday in urban areas was 501 (18.6%), 329 (17.3%), and 35 (20.8%), respectively. Similarly, in rural areas, 77 pedestrian-vehicle collisions (17.6%) and 8 PABS-vehicle collisions (22.9%) occurred on a Friday; however, the same frequency, 17.6%, of pedestrian-vehicle collisions in rural NB also took place on a Sunday. Finally, 65 collisions (21.0%) involving a cyclist occurred on a Saturday.

Table 4.7: Pedestrian-to-Vehicle Collisions by Day of Week

Day	Urban	%	Rural	%
Monday	347	12.9	53	12.1
Tuesday	409	15.2	56	12.8
Wednesday	440	16.3	57	13.0
Thursday	457	16.9	60	13.7
Friday	501	18.6	77	17.6
Saturday	329	12.2	57	13.0
Sunday	214	7.9	77	17.6

Table 4.8: Cyclist-to-Vehicle Collisions by Day of Week

Day	Urban	%	Rural	%
Monday	287	15.1	40	12.9
Tuesday	267	14.0	32	10.4
Wednesday	309	16.2	50	16.2
Thursday	313	16.4	40	12.9
Friday	329	17.3	41	13.3
Saturday	207	10.9	65	21.0
Sunday	193	10.1	41	13.3

Table 4.9: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Day of Week

Day	Urban	%	Rural	%
Monday	15	8.9	4	11.4
Tuesday	24	14.3	5	14.3
Wednesday	21	12.5	5	14.3
Thursday	30	17.9	2	5.7
Friday	35	20.8	8	22.9
Saturday	22	13.1	7	20.0
Sunday	21	12.5	4	11.4

Figure 4.5 was presented to identify any evolving trends of pedestrian-, cyclist-, and PABS-related collisions over each day of the week in both urban and rural NB. Based on the figure, there was a gradual increase in the number of VRU-related collisions from the

start of the week, Monday, to the end of the week, Friday. Interestingly, the number of collisions significantly decreased over the weekend days, Saturday to Sunday.

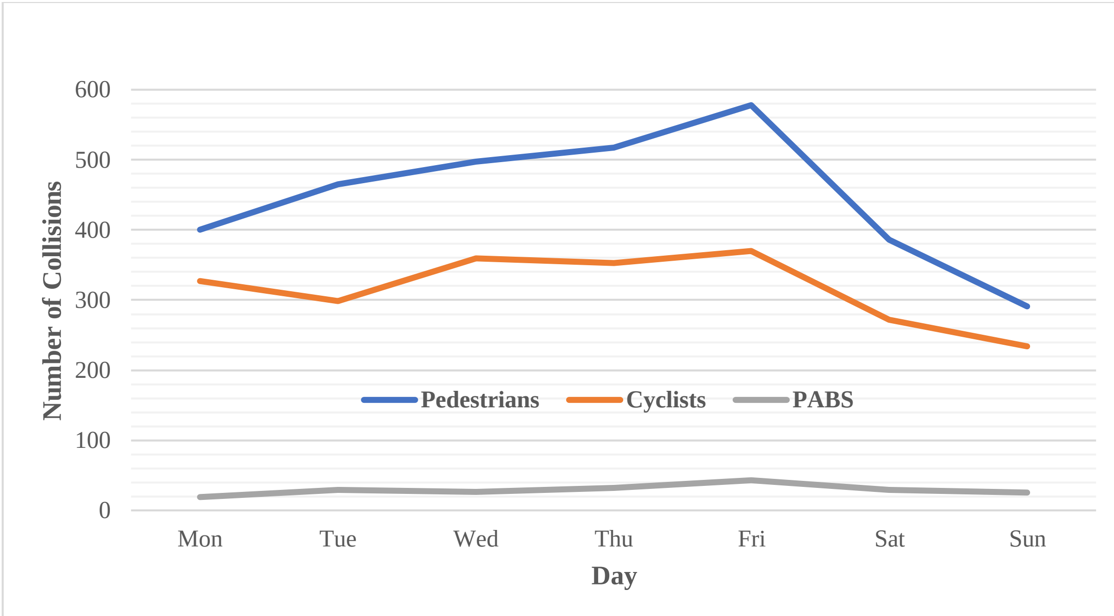

Figure 4.5. Vulnerable road user-related collisions by day (urban and rural)

4.1.4 Hourly Distributions

The frequency of VRU collisions occurring during different times of the day was analyzed. It was determined, from Tables 4.10, 4.11, and 4.12, that the majority of these collisions had taken place between 12:01 p.m. and 6:00 p.m. Specifically, collisions in urban areas involving pedestrians, cyclists, and PABS drivers, 39.7% (1071 collisions), 50.6% (964 collisions), and 53.0% (89 collisions), occurred between noon and 6:00 p.m., respectively. Similarly, 57.9 % of cyclist-vehicle collisions (179 collisions) and 45.7% of PABS-vehicle collisions (16 collisions) took place between the same time in rural areas of NB. Conversely, the majority of pedestrian related collisions in rural areas occurred between 6:01 p.m. and 12:00 a.m. at 41.2 % (180 collisions).

Table 4.10: Pedestrian-to-Vehicle Collisions by Time of Day

Time of Day	Urban	%	Rural	%
12:01 a.m. – 6:00 a.m.	184	6.8	54	12.4
6:01 a.m. – 12:00 p.m.	574	21.3	72	16.5
12:01 p.m. – 6:00 p.m.	1071	39.7	126	28.8
6:01 p.m. – 12:00 a.m.	832	30.8	180	41.2
Unknown	36	1.3	5	1.1

Table 4.11: Cyclist-to-Vehicle Collisions by Time of Day

Time of Day	Urban	%	Rural	%
12:01 AM – 6:00 AM	34	1.8	6	1.9
6:01 AM – 12:00 PM	331	17.4	32	10.4
12:01 PM – 6:00 PM	964	50.6	179	57.9
6:01 PM – 12:00 AM	545	28.6	89	28.8
Unknown	31	1.6	3	1.0

Table 4.12: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Time of Day

Time of Day	Urban	%	Rural	%
12:01 AM – 6:00 AM	3	1.8	1	2.9
6:01 AM – 12:00 PM	31	18.5	6	17.1
12:01 PM – 6:00 PM	89	53.0	16	45.7
6:01 PM – 12:00 AM	43	25.6	12	34.3
Unknown	2	1.2	0	0.0

4.2 Road User Characteristics

4.2.1 VRU and Driver Gender

The gender of VRUs involved in collisions in urban and rural NB was investigated. It should be noted that data regarding the gender of pedestrians were not available to analyze. Additionally, the results are presented in terms of the frequency of VRUs and drivers involved in a collision and not by the number of collisions. Nevertheless, the results, found in Tables 4.13, 4.14, and 4.15, revealed that males were predominantly involved in collisions, as both the VRU and the driver. These results were consistent with those found in the literature review. In terms of VRUs, male cyclists made up 81.1% (1558 cyclists) and male PABS drivers made up 86.3% (145 PABS drivers) of urban collisions. Similarly, 74.8% (235 cyclists) of cyclists and 91.4% (32 PABS drivers) of PABS drivers involved in rural collisions were male. With regards to motor-vehicle drivers in urban areas, 60.8% (1695 drivers) and 59.3% (1137 drivers) of drivers involved in pedestrian and cyclist collisions, respectively, were male. Further, the majority of rural collisions involving a male operating the motor-vehicle was 64.1% (322 drivers) for pedestrian-related collisions and 67.3% (210 drivers) for cyclist-related collisions. Concerning PABS-related collisions in urban areas, 55.2% (96 drivers) of motor-vehicle drivers were male whereas 42.0% (73 drivers) were female. Finally, PABS-related collisions in rural areas revealed that exactly 50.0% (18 drivers) of motor-vehicle drivers were male and exactly 50.0% (18 drivers) were female.

Table 4.13: Pedestrians and Motor Vehicle Drivers Involved in a Collision by Gender

Gender	Pedestrian				Driver			
	Urban	%	Rural	%	Urban	%	Rural	%
Male	NA	0.0	NA	0.0	1695	60.8	322	64.1
Female	NA	0.0	NA	0.0	831	29.8	113	22.5
Unidentified	NA	0.0	NA	0.0	260	9.3	67	13.3

Table 4.14: Cyclists and Motor Vehicle Drivers Involved in a Collision by Gender

Gender	Cyclist				Driver			
	Urban	%	Rural	%	Urban	%	Rural	%
Male	1558	81.1	235	74.8	1137	59.3	210	67.3
Female	332	17.3	70	22.3	687	35.8	92	29.5
Unidentified	31	1.6	9	2.9	93	4.9	10	3.2

Table 4.15: Power-Assisted Bike and Scooter Drivers and Motor Vehicle Drivers Involved in a Collision by Gender

Gender	Power-Assisted Bike and Scooter Drivers				Driver			
	Urban	%	Rural	%	Urban	%	Rural	%
Male	145	86.3	32	91.4	96	55.2	18	50.0
Female	20	11.9	3	8.6	73	42.0	18	50.0
Unidentified	3	1.8	0	0.0	5	2.9	0	0.0

Due to confidentiality, pedestrian gender was not available and therefore, trend analysis could not be completed for this collision attribute. To determine any evolving trends of cyclists involved in a collision based on gender, Figures 4.6 and 4.7 were developed. In both urban and rural areas, there was a considerable decline in the number of male cyclists involved in a motor vehicle collision over the 25-year period. Moreover, Figure 4.7 revealed two major peaks in male cyclists in 1995 and 2001. In terms of female cyclists in urban areas, the data show the number of female cyclists remained relatively constant over the 25-year period. Conversely, the number of female cyclists in rural areas saw a gradual drop over the 25 years, with a small peak in 1999.

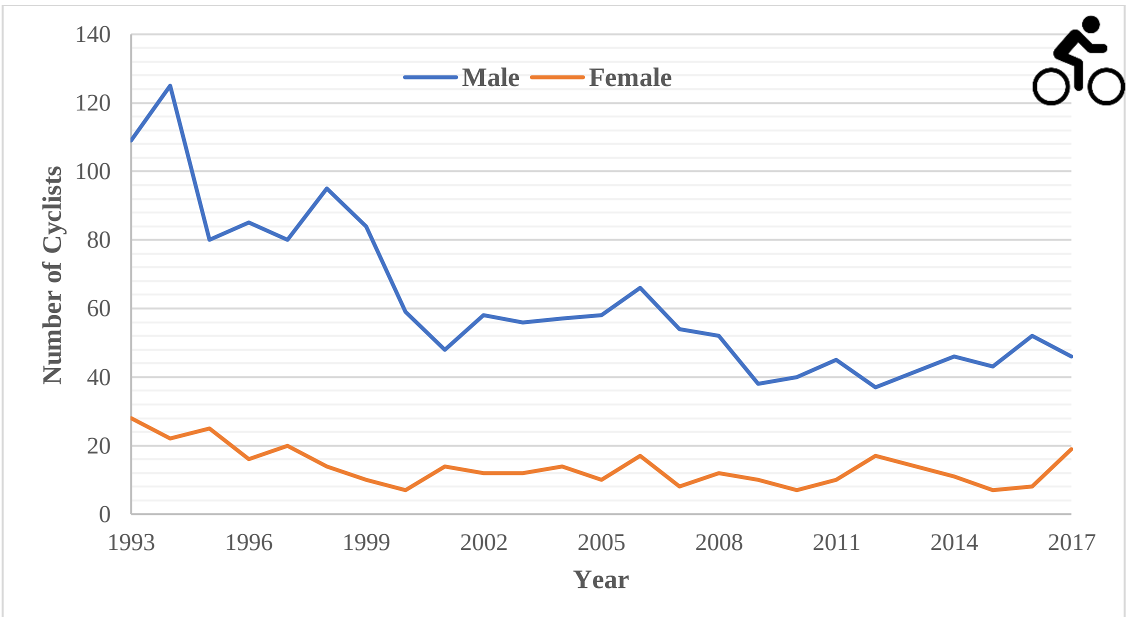

Figure 4.6. Cyclists involved in a motor vehicle collision by gender (urban)

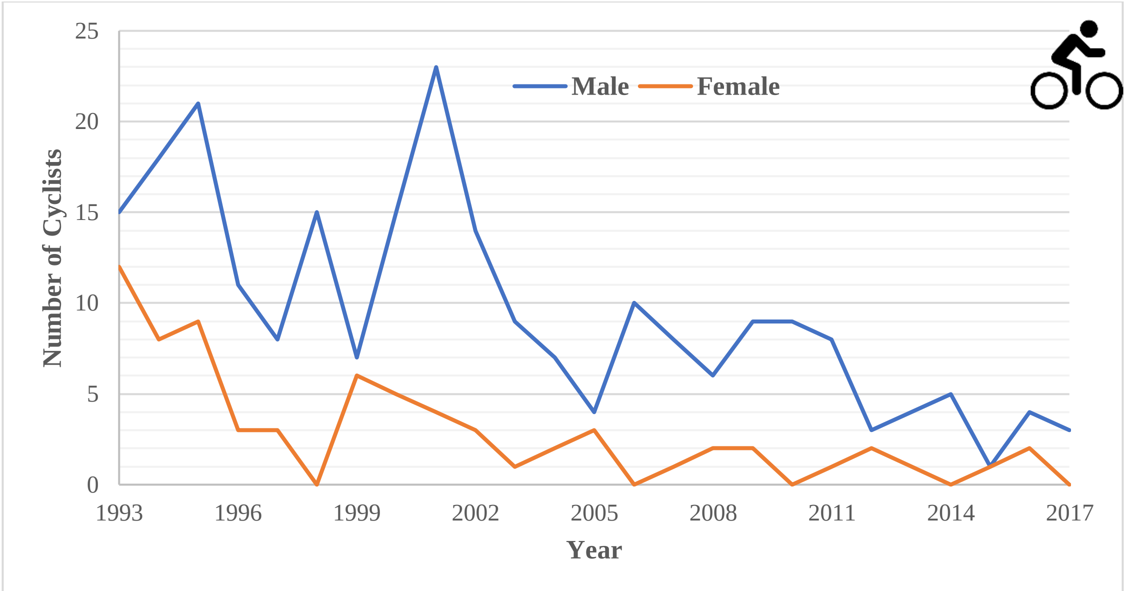

Figure 4.7. Cyclists involved in a motor vehicle collision by gender (rural)

Figure 4.8 presents the number of PABS drivers involved in a motor vehicle collision by gender over a 25-year period. Considering the low number of PABS-related collisions, the urban and rural collisions were grouped together. All the data in the figure reveal significant fluctuations in the number of PABS drivers involved in a collision who identified as male or female. Interestingly, between 2014 and 2017, the number of male PABS drivers saw a substantial decline whereas the number of female PABS drivers saw a sharp increase.

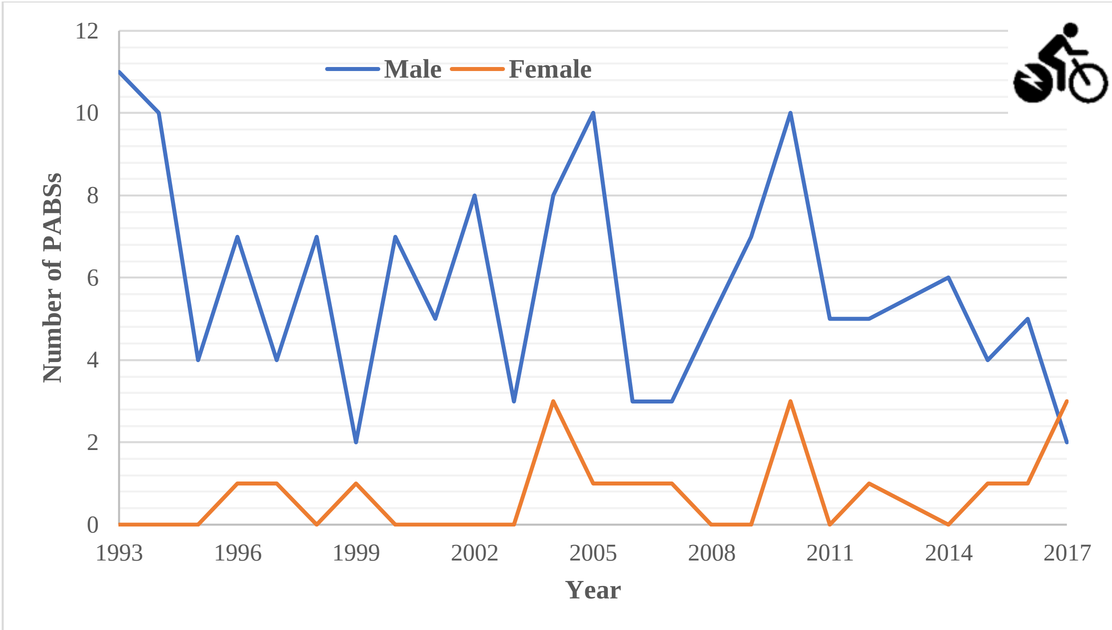

Figure 4.8. Power-assisted bike and scooter collisions by gender (urban and rural*)*

4.2.2 VRU and Driver Age

The number of VRUs and drivers involved in VRU-to-vehicle collisions based on age can be found in the tables below. The broad findings related to age was that the majority of VRUs were younger in age whereas motor vehicle drivers were older in age. However, in terms of pedestrian-vehicle collisions, the frequency of pedestrians is roughly the same for all age groups. In Table 4.16, 32.0% (905 pedestrians) of pedestrians were between the age of 15-29 whereas 26.5% (751 pedestrians) of pedestrians were 50+ years old in urban areas. In rural areas, the largest frequency of pedestrians 50+ years old was approximately 30.0% (136 pedestrians) and nearly 25.0% (114 pedestrians) were between the ages of 15 and 29. On the other hand, the number of motor-vehicle drivers between the ages of 20 and 39 was exactly 35.0% (973 drivers) and 36.8% (185 drivers) in urban and rural NB, respectively. Additionally, 48.3% (1348 drivers) of drivers in urban areas and 43.4% (218 drivers) of drivers in rural areas were 40+ years old.

Table 4.17 presents the number of cyclists and drivers involved in cyclist-vehicle collisions by age. It was determined that, in urban areas, 56.4% (1084 cyclists) of cyclists were between the ages of 10 and 29 whereas in rural areas, nearly 66.6% (209 cyclists) of cyclists were between the ages of 0 and 19. Conversely, for motor vehicle drivers involved in cyclist-vehicle collisions, the frequency of each age group including and following ages 20-29 was roughly the same in both urban and rural areas. The 40-49 age group had the largest frequency with 19.2% (369 drivers) of drivers, 18.1% (347 drivers) were 60+ years old, and 17.8% (341 drivers) were between the ages of 30-39. In rural areas, 20.2% (63 drivers) of drivers were in the age group 20-29, 17.9% (56 drivers) were between 50 and 59, and 17.3% (54 drivers) were between 40 and 49.

Based on the results of Table 4.18, which presents the number of PABS drivers and motor vehicle drivers involved in PABS-vehicle collisions, approximately 50.0% (85 PABS drivers) of PABS drivers were between the ages of 15 and 29 in urban areas whereas nearly 57.0% (20 PABS drivers) of PABS drivers in rural areas were in the same age range. Additionally, 22.9% (8 PABS drivers) of PABS drivers involved in collisions in rural areas were in the age group 50-59. Regarding motor vehicle drivers, exactly 70.0% (122 drivers) and 77.8% (28 drivers) in urban and rural NB, respectively, were 30+ years old.

Table 4.16: Pedestrians and Motor Vehicle Drivers Involved in a Collision by Age

Age	Pedestrian				Driver			
	Urban	%	Rural	%	Urban	%	Rural	%
0-9	288	10.2	70	15.2	0	0.0	0	0.0
10-14	283	10.0	35	7.6	0	0.0	0	0.0
15-19	397	14.0	57	12.4	182	6.5	32	6.4
20-29	508	18.0	55	12.0	517	18.6	111	22.1
30-39	286	10.1	50	10.9	456	16.4	74	14.7
40-49	305	10.8	54	11.7	436	15.6	81	16.1
50-59	292	10.3	50	10.9	382	13.7	52	10.4
60+	459	16.2	86	18.7	530	19.0	85	16.9
Unknown	9	0.3	3	0.7	283	10.2	67	13.3

Table 4.17: Cyclists and Motor Vehicle Drivers Involved in a Collision by Age

Age	Cyclist				Driver			
	Urban	%	Rural	%	Urban	%	Rural	%
0-9	105	5.5	38	12.1	0	0.0	0	0.0
10-14	377	19.6	112	35.7	0	0.0	0	0.0
15-19	375	19.5	59	18.8	91	4.7	29	9.3
20-29	332	17.3	23	7.3	338	17.6	63	20.2
30-39	200	10.4	17	5.4	341	17.8	51	16.3
40-49	162	8.4	16	5.1	369	19.2	54	17.3
50-59	99	5.2	15	4.8	328	17.1	56	17.9
60+	74	3.9	7	2.2	347	18.1	50	16.0
Unknown	197	10.3	27	8.6	103	5.4	9	2.9

Table 4.18: Power-Assisted Bike and Scooter Drivers and Motor Vehicle Drivers Involved in a Collision by Age

Age	Power-Assisted Bike and Scooter Drivers				Driver			
	Urban	%	Rural	%	Urban	%	Rural	%
0-9	0	0.0	0	0.0	0	0.0	0	0.0
10-14	11	6.5	3	8.6	0	0.0	0	0.0
15-19	52	31.0	14	40.0	20	11.5	3	8.3
20-29	33	19.6	6	17.1	26	14.9	5	13.9
30-39	19	11.3	3	8.6	30	17.2	10	27.8
40-49	17	10.1	0	0.0	24	13.8	8	22.2
50-59	13	7.7	8	22.9	30	17.2	4	11.1
60+	18	10.7	1	2.9	38	21.8	6	16.7
Unknown	5	3.0	0	0.0	6	3.4	0	0.0

Based on Statistics Canada data, the age of VRUs involved in a motor vehicle collision were compared to the NB population within each age group to identify the groups that were overrepresented (Statistics Canada, 2021). Table 4.19 presents the percentage of the NB population based on age group, which is comprised of both urban and rural areas. It was revealed that in both urban and rural NB, pedestrians from ages 0 to 29 were overrepresented in the pedestrian-related collision data compared to the province's population data. Further, in terms of the rate of pedestrians involved in a motor vehicle collision, 19 per 10,000 population and 3 per 10,000 population were calculated for urban and rural areas, respectively. In addition, cyclists between the ages of 10 and 29 in urban areas and 0 and 19 in rural areas were significantly overrepresented in the collision analysis. These values equate to a 14 per 10,000 rate in urban areas and a 3 per 10,000 rate in rural areas. Finally, it was determined that, in both urban and rural areas, PABS drivers between the ages of 10 and 29 were considerably overrepresented. Specifically, between 30.0% and 40.0% of PABS drivers involved in motor vehicle collision were between the ages 15 to 19, whereas the percent of the population of this age group is 5.2%. The rate of PABS drivers involved in a motor vehicle collision was 2 per 10,000 in urban NB and 1 per 10,000 in rural NB.

Table 19: Percent of New Brunswick Population by Age

Age	% of NB Population
0-9	9.2
10-14	5.2
15-19	5.2
20-29	11.2
30-39	11.7
40-49	12.8
50-59	15.0
60+	30.0

Figures 4.9 and 4.10 were presented to uncover whether there were any concerning trends evolving that involve specific age groups. It was found that in both urban and rural NB, there was a gradual but significant decline in the number of pedestrians between the ages of 0 and 19 involved in a motor vehicle collision. In addition, there was a slight decline

in the number of pedestrians aged 20 years and older over the 22-year period in both areas of NB; however, it was further identified that there was significant fluctuation in the data for pedestrians over the age of 20. Lastly, in recent years, the graphs show a larger number of collisions involving pedestrians over the age of 40.

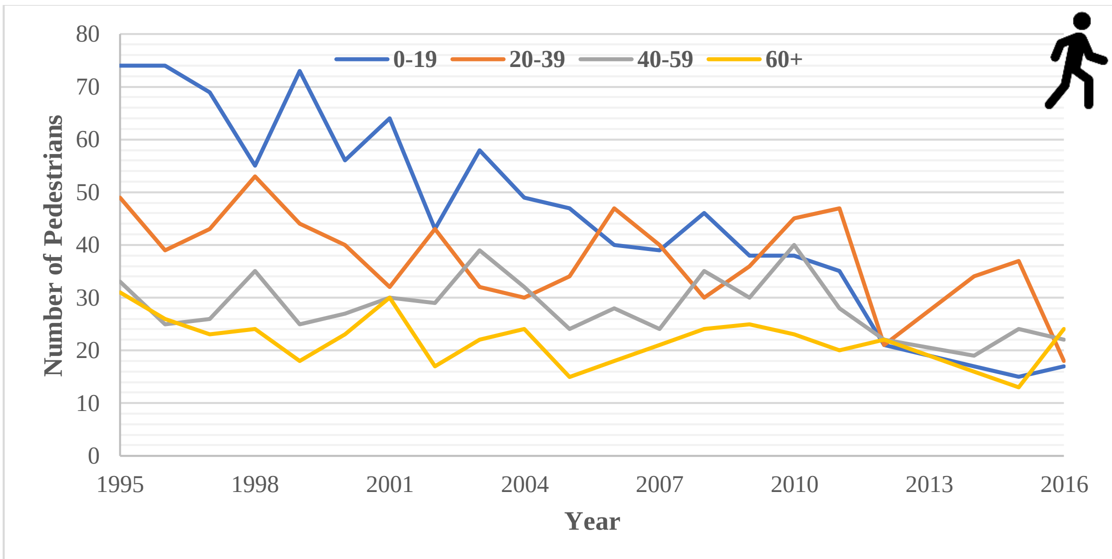

Figure 4.9. Pedestrians involved in a motor vehicle collision by age (urban)

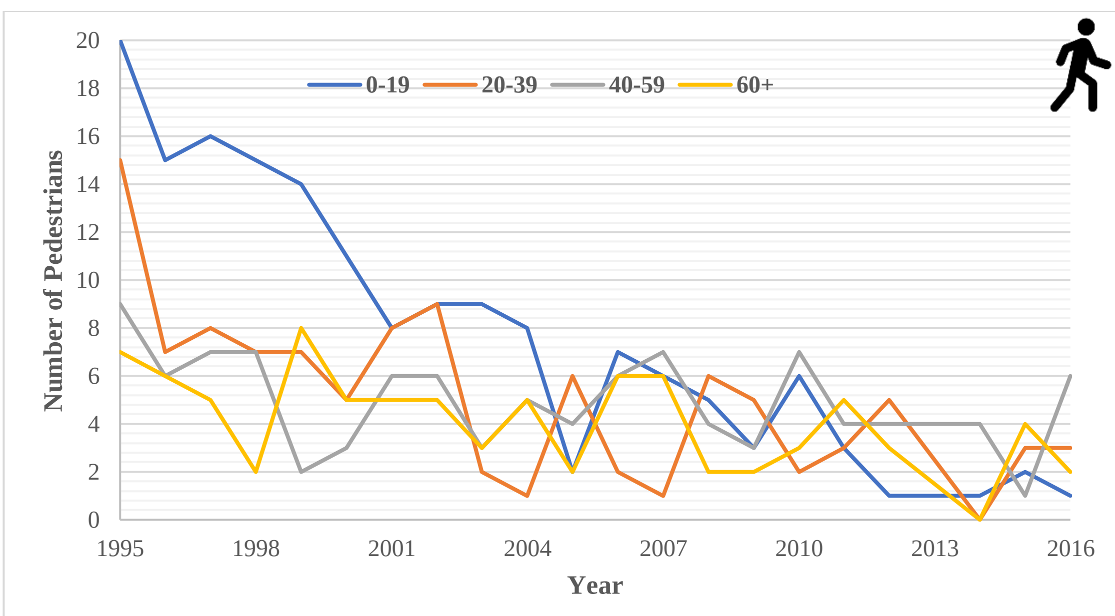

Figure 4.10. Pedestrians involved in a motor vehicle collision by age (rural)

The number of cyclists involved in a motor vehicle collision based on age group over a 25-year period for both urban and rural NB is presented in Figures 4.11 and 4.12, respectively. Similar to the pedestrian collision data above, there was a considerable decline in the number of cyclists between the ages of 0 and 19 in both areas. Conversely, two major peaks in 1995 and 2001 were observed in rural areas for cyclists aged 0 to 19. In terms of Figure 4.11, there was a slight decrease in cyclists aged 20 to 29 and conversely, a slight rise in cyclists between 40 and 59 years old in urban areas. Further, the number of cyclists over the age of 60 involved in a motor vehicle collision remained constant over the 25-year period. Finally, regarding Figure 4.12, the number of cyclists over the age of 20 in rural areas were relatively low and therefore, no major conclusions could be drawn from the data.

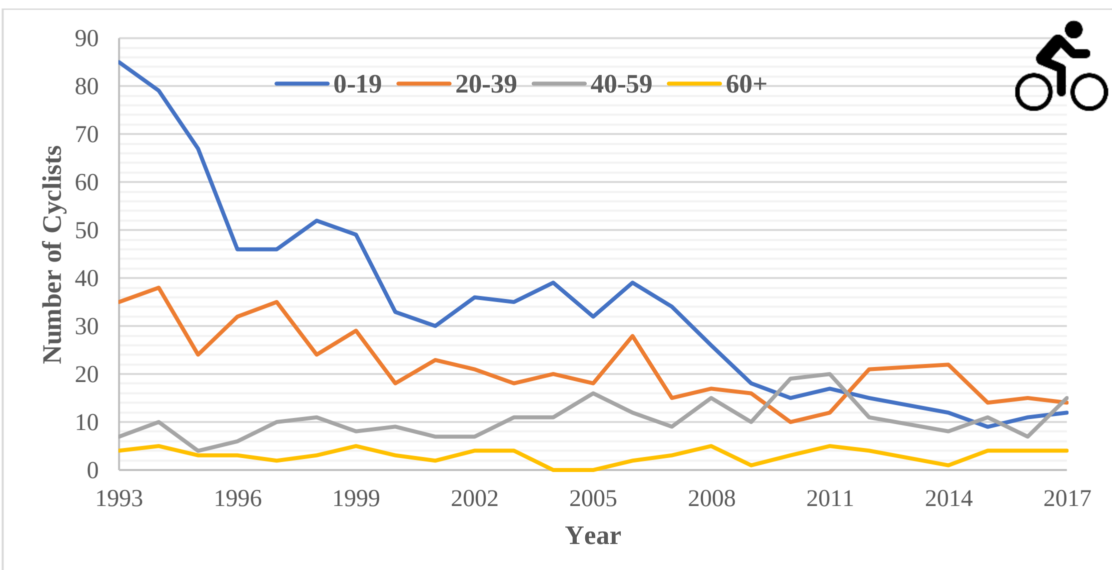

Figure 4.11. Cyclists involved in a motor vehicle collision by age (urban)

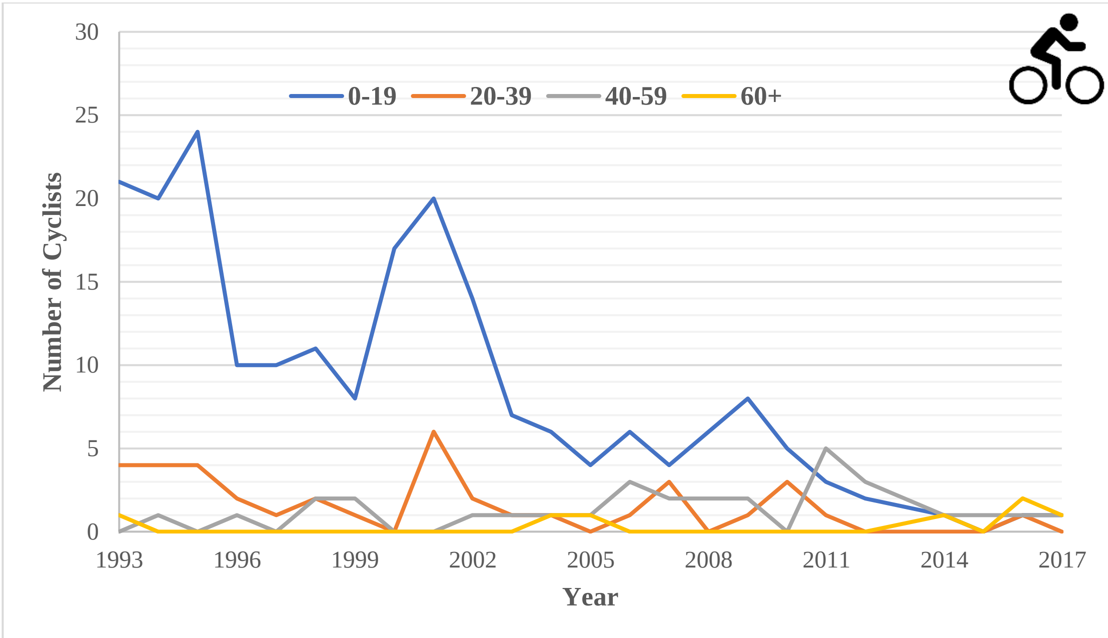

Figure 4.12. Cyclists involved in a motor vehicle collision by age (rural)

Figure 4.13 presents the number of PABS drivers involved in a motor vehicle collision by age group over a 25-year period. Considering the low number of PABS-related collisions, the urban and rural collisions were grouped together. All the data in the figure reveal a major fluctuation in the number of PABS drivers involved in a collision in all age groups and therefore, no conclusions could be drawn from the data.

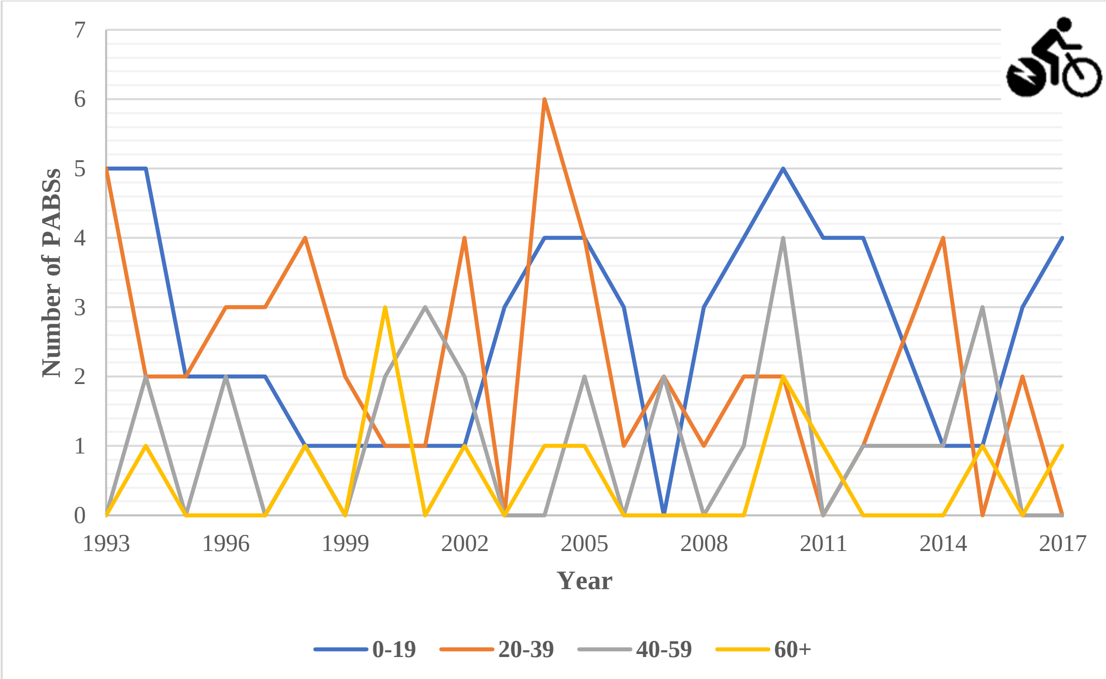

Figure 4.13. Power-assisted bike and scooter drivers involved in a motor vehicle collision by age (urban and rural)

4.2.3 Safety Equipment Used

The type of safety equipment used at the time of a collision was analyzed for cyclists, Table 4.20, and PABS drivers, Table 4.21. It should be noted that for this attribute, the data were only available from 1995 until 2016. In terms of the safety equipment used by cyclists in urban NB, 36.7% (576 cyclists) were unknown, 24.9% (390 cyclists) of cyclists used a helmet, and 22.2% (348 cyclists) reported safety equipment was not available to them. Similarly, in rural NB, the largest frequency of cyclist equipment was unknown whereas 22.7% (58 cyclists) of cyclists wore a helmet and 20.3% (52 cyclists) of cyclists reported that safety equipment was not available. These results were significantly dissimilar from those found in the literature review, considering over 74.0% of cyclists in both studies reported wearing a helmet. Regarding PABS drivers in urban areas, nearly half of all PABS drivers wore a helmet, 54.4% (80 PABS drivers) in urban NB and 48.3%

(14 PABS drivers) in rural NB. Finally, over a third of all PABS drivers involved in a collision had not reported the safety equipment utilized or was unknown in both urban and rural areas.

Table 4.20: Cyclists Involved in a Motor Vehicle Collision by Safety Equipment Used

Safety Equipment	Urban	%	Rural	%
Helmet	390	24.9	58	22.7
Protective Equipment	8	0.5	1	0.4
Not Available	348	22.2	52	20.3
Available but Not Used	246	15.7	50	19.5
Unknown	576	36.7	95	37.1

Table 4.21: Power-Assisted Bike and Scooter Drivers Involved in a Motor Vehicle Collision by Safety Equipment Used

Safety Equipment	Urban	%	Rural	%
Helmet	80	54.4	14	48.3
Protective Equipment	0	0.0	0	0.0
Not Available	14	9.5	3	10.3
Available but Not Used	1	0.7	1	3.4
Unknown	52	35.4	11	37.9

4.2.4 Driver Experience

The number of cyclists, PABS drivers, and motor vehicle drivers involved in VRU-to-vehicle collisions based on years of experience was analyzed. In a large frequency of collisions, the experience of the driver was unknown or between 0 and 20 years. Table 4.22 presents the number of motor vehicle drivers involved in pedestrian-related collisions by years of experience. Based on the table, the largest frequency of driver experience was unknown; however, nearly the same frequency was found for drivers with 0 to 20 years of experience. Approximately 33.0% (929 drivers) of drivers in urban areas and 39.0% (195 drivers) of drivers in rural areas had 0 to 20 years of experience. Pedestrians are not operating any type of vehicle and therefore, were not included in the analysis.

The number of cyclist and motor vehicle drivers based on years of experience can be found in Table 4.23. In terms of the cyclists, the highest frequency based on cycling experience was unknown with 81.0% (1556 cyclists) and 72.9% (229 cyclists) in urban and rural NB, respectively. Additionally, 18.5% (355 cyclists) traveling in urban areas and 26.4% (83 cyclists) traveling in rural areas reported having 0 to 9 years of experience. Again, motor vehicle drivers experience was unknown for 35.2% (674 drivers) in urban NB and 30.8% (96 drivers) in rural NB. However, nearly 19.0% (360 drivers) of drivers had 10 to 20 years of experience and nearly 48.0% (926 drivers) of drivers involved in cyclist-related collisions had 30 years or less of experience in urban areas. In rural areas, 22.1% (69 drivers) of drivers reported having 0 to 9 years of experience and approximately 55.0% (171 drivers) of drivers had 30 years of experience or less.

Table 4.24 presents the number of PABS drivers and motor vehicle drivers involved in a collision based on driver experience. Unlike previous results, the largest number of PABS drivers with 0 to 9 years of driving experience was 40.2% (68 PABS drivers) and 38.5% (65 PABS drivers) were unknown in urban areas. Inversely, 45.7% (16 PABS drivers) of PABS driver experience was reported as unknown and 34.3% (12 PABS drivers) had 9 years of experience or less in rural areas. In terms of motor vehicle drivers, 32.8% (57 drivers) and 30.6% (11 drivers) of drivers had not reported their experience or it was unknown in urban and rural areas, respectively. In urban NB, 21.3% (37 drivers) of drivers reported of having 0 to 9 years of experience and 15.5% (27 drivers) had 10 to 20 years of experience. Similarly, in rural areas, 19.4% (7 drivers) reported having 0 to 9 years of experience and 19.4% (7 drivers) reported having 21 to 30 years of experience.

Table 4.22: Motor Vehicle Drivers Involved in a Pedestrian-Related Collision by Driver Experience

Driver Experience Years	Driver Urban	%	Rural	%
0-9	491	17.6	116	23.1
10-20	438	15.7	79	15.7
21-30	326	11.7	59	11.8
31-40	200	7.2	32	6.4
41-50	112	4.0	21	4.2
51-60	52	1.9	8	1.6
61+	17	0.6	5	1.0
Unknown	1150	41.3	182	36.3

Table 4.23: Cyclists and Motor Vehicle Drivers Involved in a Collision by Driver Experience

Driver Experience Years	Cyclist				Driver			
	Urban	%	Rural	%	Urban	%	Rural	%
0-9	355	18.5	83	26.4	315	16.4	69	22.1
10-20	7	0.4	2	0.6	360	18.8	58	18.6
21-30	1	0.1	0	0.0	248	12.9	44	14.1
31-40	1	0.1	0	0.0	201	10.5	26	8.3
41-50	1	0.1	0	0.0.	69	3.6	13	4.2
51-60	0	0.0	0	0.0	39	2.0	4	1.3
61+	0	0.0	0	0.0	11	0.6	2	0.6
Unknown	1556	81.0	229	72.9	674	35.2	96	30.8

Table 4.24: Power-Assisted Bike and Scooter Drivers and Motor Vehicle Drivers Involved in a Collision by Driver Experience

Driver Experience Years	Power-Assisted Bike and Scooter Driver				Driver			
	Urban	%	Rural	%	Urban	%	Rural	%
0-9	68	40.2	12	34.3	37	21.3	7	19.4
10-20	16	9.5	5	14.3	27	15.5	6	16.7
21-30	10	5.9	2	5.7	17	9.8	7	19.4
31-40	2	1.2	0	0.0	22	12.6	5	13.9
41-50	4	2.4	0	0.0	8	4.6	0	0.0
51-60	3	1.8	0	0.0	3	1.7	0	0.0
61+	1	0.6	0	0.0	3	1.7	0	0.0
Unknown	65	38.5	16	45.7	57	32.8	11	30.6

4.2.5 Vehicle Identification

The frequency of the type of vehicle involved in pedestrian-, cyclist-, and PABS-related collisions can be found in Tables 4.25, 4.26, and 4.27, respectively. Consistent with the results found in the literature review, passenger cars were involved in the majority of collisions for all three types of VRUs in both urban and rural NB. With respect to pedestrian-vehicle collisions, 65.6% (1828 vehicles) and 59.8% (300 vehicles) of vehicles in urban and rural NB, respectively, were passenger cars. Similarly, passenger cars in urban and rural areas made up 70.8% (1357 vehicles) and 68.6% (214 vehicles) of vehicles involved in cyclist-related collisions. Finally, the frequency of passenger cars implicated in PABS collisions was 73.8% (128 vehicles) in urban areas and 72.2% (26 vehicles) in rural areas. However, it is interesting to note that pickup trucks under 4500 kg and multi-purpose vehicles/passenger vans were reported significantly in both urban and rural NB.

Table 4.25: Number of Vehicles Involved in Pedestrian-to-Vehicle Collisions by Vehicle Type

Vehicle Type	Urban	%	Rural	%
Passenger Car	1828	65.6	300	59.8
Pickup Trucks under 4500 kg	419	15.0	107	21.3
Panel/Cargo Van under 4500 kg	40	1.4	5	1.0
Trucks 4500 kg and over	21	0.8	9	1.8
Truck Tractor (Bobtail)	4	0.1	0	0.0
Motorcycle	14	0.5	4	0.8
Transit Bus	14	0.5	0	0.0
Inter-City Bus	2	0.1	0	0.0
School Bus	8	0.3	4	0.8
Other Bus	1	0.0	2	0.4
Ambulance/Police/Fire	9	0.3	2	0.4
Motorhome	1	0.0	1	0.2
Motorized Snow Vehicle	3	0.1	0	0.0
Construction & Maintenance Equipment	6	0.2	0	0.0
Farm Equipment	0	0.0	1	0.2
Off Highway Vehicle	0	0.0	1	0.2
Multi-Purpose Vehicle/Passenger Van	388	13.9	40	8.0
Truck Tractor with Tow Unit	15	0.5	18	3.6
Unknown	13	0.5	8	1.6

Table 4.26: Number of Vehicles Involved in Cyclist-to-Vehicle Collisions by Vehicle Type

Vehicle Type	Urban	%	Rural	%
Passenger Car	1357	70.8	214	68.6
Pickup Trucks under 4500 kg	250	13.0	53	17.0
Panel/Cargo Van under 4500 kg	23	1.2	1	0.3
Trucks 4500 kg and over	13	0.7	0	0.0
Truck Tractor (Bobtail)	0	0.0	0	0.0
Motorcycle	12	0.6	9	2.9
Transit Bus	7	0.4	0	0.0
Inter-City Bus	0	0.0	0	0.0
School Bus	6	0.3	0	0.0
Other Bus	0	0.0	0	0.0
Ambulance/Police/Fire	4	0.2	0	0.0
Motorhome	1	0.1	3	1.0
Motorized Snow Vehicle	0	0.0	0	0.0
Construction & Maintenance Equipment	0	0.0	0	0.0
Farm Equipment	0	0.0	0	0.0
Off Highway Vehicle	0	0.0	0	0.0
Multi-Purpose Vehicle/Passenger Van	225	11.7	27	8.7
Truck Tractor with Tow Unit	15	0.8	3	1.0
Unknown	4	0.2	2	0.6

Table 4.27: Number of Vehicles Involved in PABS Driver-to-Vehicle Collision by Vehicle Type

Vehicle Type	Urban	%	Rural	%
Passenger Car	128	73.8	26	72.2
Pickup Trucks under 4500 kg	14	8.0	4	11.1
Panel/Cargo Van under 4500 kg	2	1.1	0	0.0
Trucks 4500 kg and over	2	1.1	0	0.0
Truck Tractor (Bobtail)	0	0.0	0	0.0
Motorcycle	1	0.6	1	2.8
Transit Bus	0	0.0	0	0.0
Inter-City Bus	0	0.0	0	0.0
School Bus	0	0.0	0	0.0
Other Bus	0	0.0	0	0.0
Ambulance/Police/Fire	0	0.0	0	0.0
Motorhome	1	0.6	0	0.0
Motorized Snow Vehicle	0	0.0	0	0.0
Construction & Maintenance Equipment	1	0.6	0	0.0
Farm Equipment	0	0.0	0	0.0
Off Highway Vehicle	0	0.0	0	0.0
Multi-Purpose Vehicle/Passenger Van	24	13.8	3	8.3
Truck Tractor with Tow Unit	1	0.6	2	5.6
Unknown	0	0.0	0	0.0

4.3 Collision Factors

4.3.1 Collision Severity

Vulnerable road user-related collisions that resulted in property damage, personal injury or a fatality were analyzed. The results of the analysis for collisions involving pedestrians, cyclists, and PABS drivers can be found in Tables 4.28, 4.29, and 4.30, respectively. A significant majority of collisions, in both urban and rural areas, resulted in personal injury for all three types of VRUs. However, it is worthy to note that collisions occurring in rural areas are more likely to result in a fatality than ones in urban areas. In urban NB, 2568 pedestrian-vehicle collisions (95.2%), 1834 cyclist-vehicle collisions (96.3%), and 129 PABS-vehicle collisions (76.8%) lead to a personal injury. Likewise, 354 (81.0%), 286 (92.6%), and 24 (68.6%) collisions involving pedestrians, cyclists, and PABS drivers in rural NB, respectively, resulted in personal injury. The low frequency of collisions resulting in property damage is likely a reflection of the reporting criteria, considering a collision with less than $1,000 in property damage is not likely to be reported.

Table 4.28: Pedestrian-to-Vehicle Collisions by Injury Severity

Injury Severity	Urban	%	Rural	%
Property Damage	1	0.0	0	0.0
Personal Injury	2568	95.2	354	81.0
Fatal	128	4.8	83	19.0

Table 4.29: Cyclist-to-Vehicle Collisions by Injury Severity

Injury Severity	Urban	%	Rural	%
Property Damage	54	2.8	3	1.0
Personal Injury	1834	96.3	286	92.6
Fatal	17	0.9	20	6.5

Table 4.30: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Injury Severity

Injury Severity	Urban	%	Rural	%
Property Damage	37	22.0	8	22.9
Personal Injury	129	76.8	24	68.6
Fatal	2	1.2	3	8.6

The number of VRUs involved in a motor vehicle collision based on the severity rate of the collision were graphed over the 25-year period. Figures 4.14 and 4.15 present the number of pedestrians involved in a motor vehicle collision based on severity in urban and rural NB, respectively. In urban areas, Figure 4.14, the number of pedestrians having a minor injury dropped significantly between 1995 and 1997 and following, fluctuation in the data can be seen until 2010. Again, there was a significant drop in the number of pedestrians with a minor injury from 2010 to 2012. In terms of pedestrians with a major injury, the figure shows a gradual decline in the number of pedestrians over the 22-year period. Finally, although the number of fatalities is relatively low, the graph reveals that the number of pedestrian's fatality injured had stayed comparatively constant over the 22 years. Regarding Figure 4.15, the number of pedestrians with a minor injury saw a constant decline between 1995 and 2005, with a small peak in 1999. From 1995 until 2016, rural pedestrian data saw a fluctuation in the number of pedestrians with a minor injury. Lastly, the number of pedestrian major injuries and fatalities occurring in rural NB both reveal a fluctuation with a very slight decline over the 22-year period.

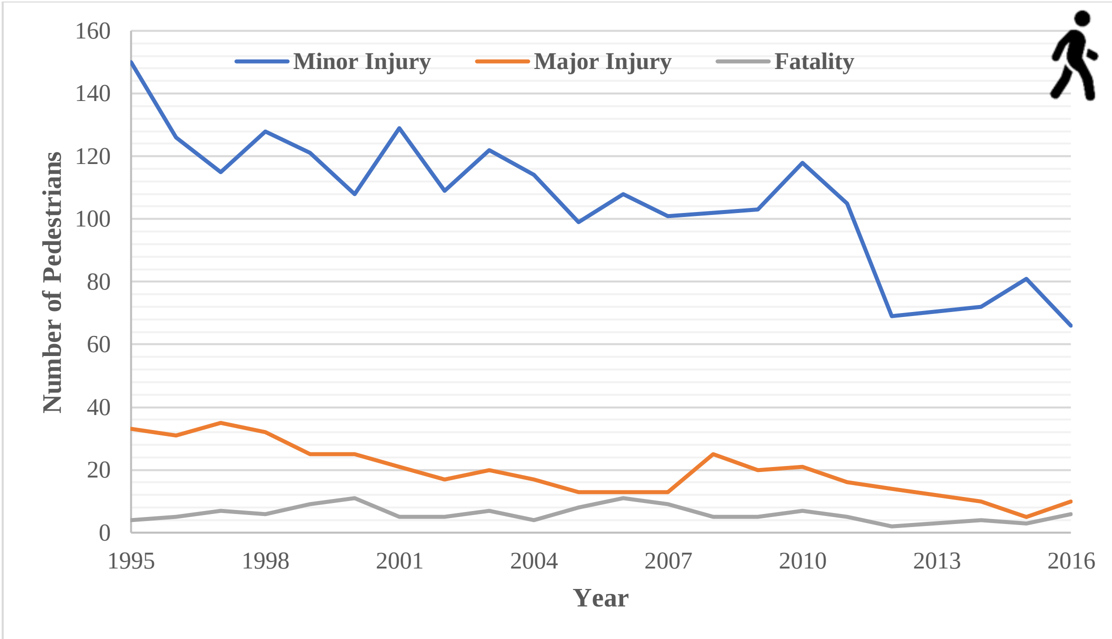

Figure 4.14. Pedestrians involved in a motor vehicle collision by severity (urban)

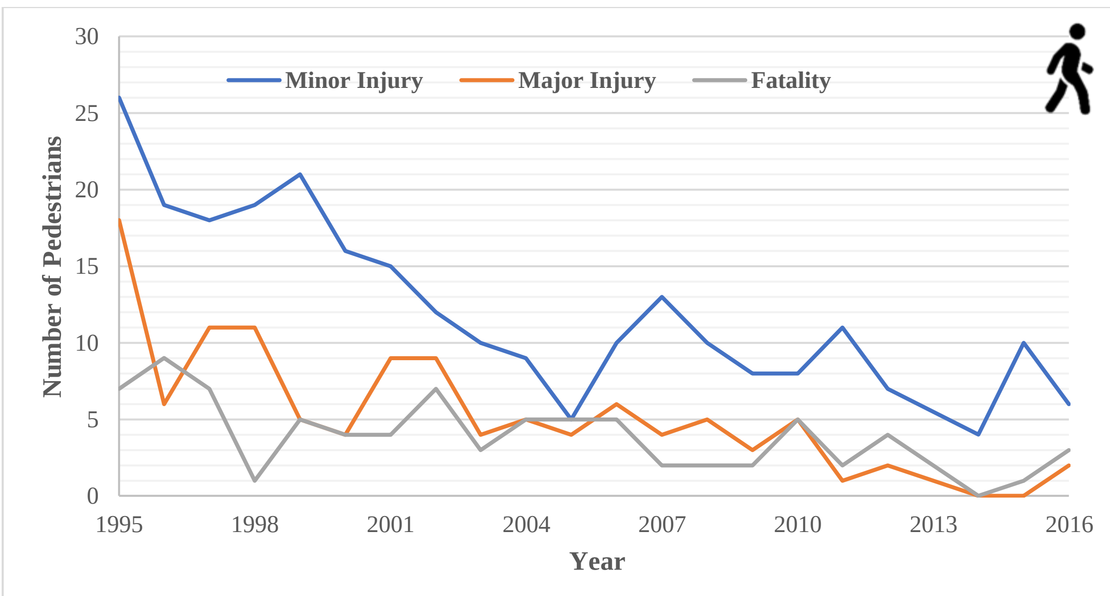

Figure 4.15. Pedestrians involved in a motor vehicle collision by severity (rural)

Figures 4.16 and 4.17 present the number of cyclists involved in a motor vehicle collision based on severity in urban and rural NB, respectively. In urban areas, there was a gradual decline in the number of cyclists-related collisions between 1993 and 2001, with two small peaks in 1994 and 1997. Following 2001, the number of collisions in urban NB plateaued until 2017 at roughly 60 cyclist-related collisions. The number of cyclists involved in an urban collision that resulted in no injury or a fatality were extremely low and therefore, no conclusions could be formed. In Figure 4.17, which presents rural collisions, there was a sharp decline in cyclist-related collisions between 1995 and 1996 and following, a similar sharp increase in collisions between 1999 and 2001. Further, there was another sharp decline in collisions from 2001 to 2004 and from 2004 on there was a gradual decline in cyclist-related collisions in rural NB. Again, the number of cyclists involved in a collision that resulted in no injury or a fatality were extremely low in rural areas and therefore, no conclusions could be drawn.

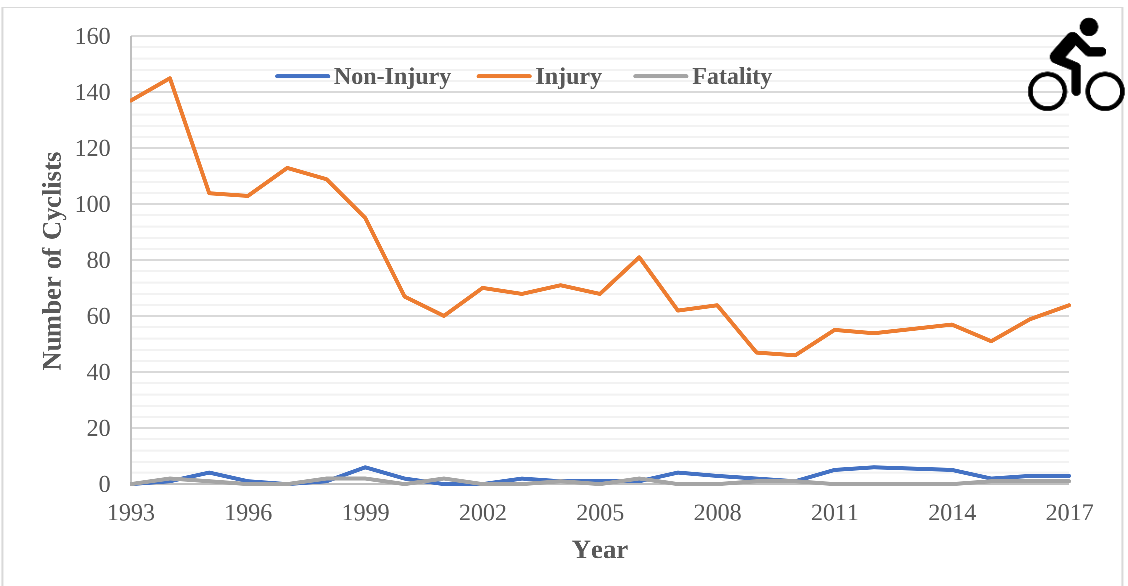

Figure 4.16. Cyclists involved in a motor vehicle collision by severity (urban)

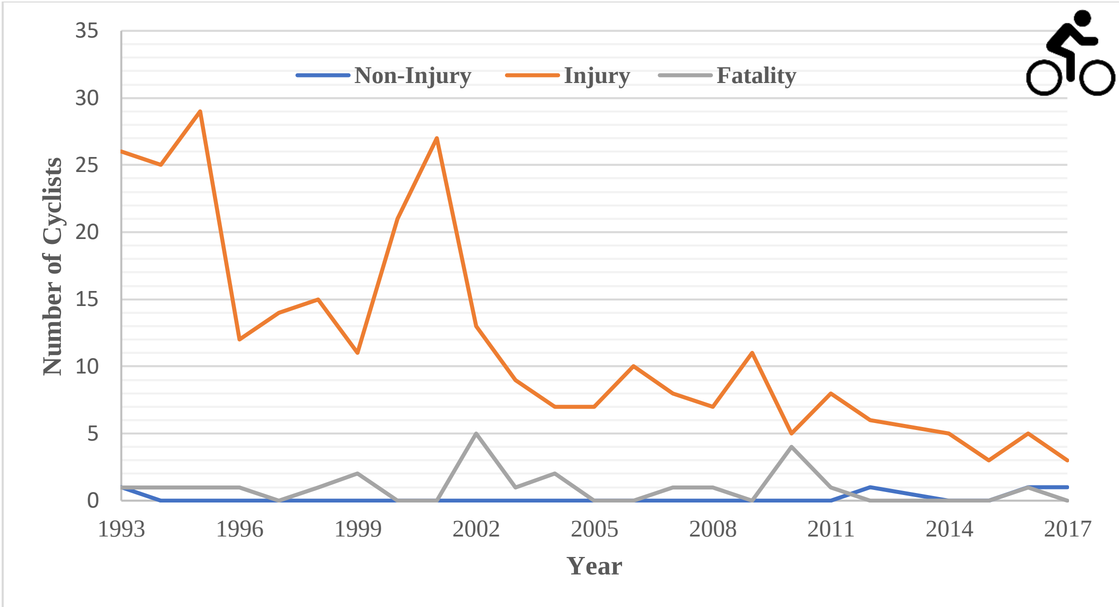

Figure 4.17. Cyclists involved in a motor vehicle collision by severity (rural)

Figures 4.18 and 4.19 display the number of PABS drivers involved in a motor vehicle collision based on severity rate in urban and rural NB, respectively. The graphs show the fluctuation in the number of collisions over the 25-year period. Based on Figure 4.18, there was a significant rise in collisions between 2003 and 2004 as well as the most significant drop between 2010 and 2011 in urban areas. Ultimately, no major conclusions could be drawn from Figures 4.18 and 4.19, considering the small quantity of PABS-related collisions in NB.

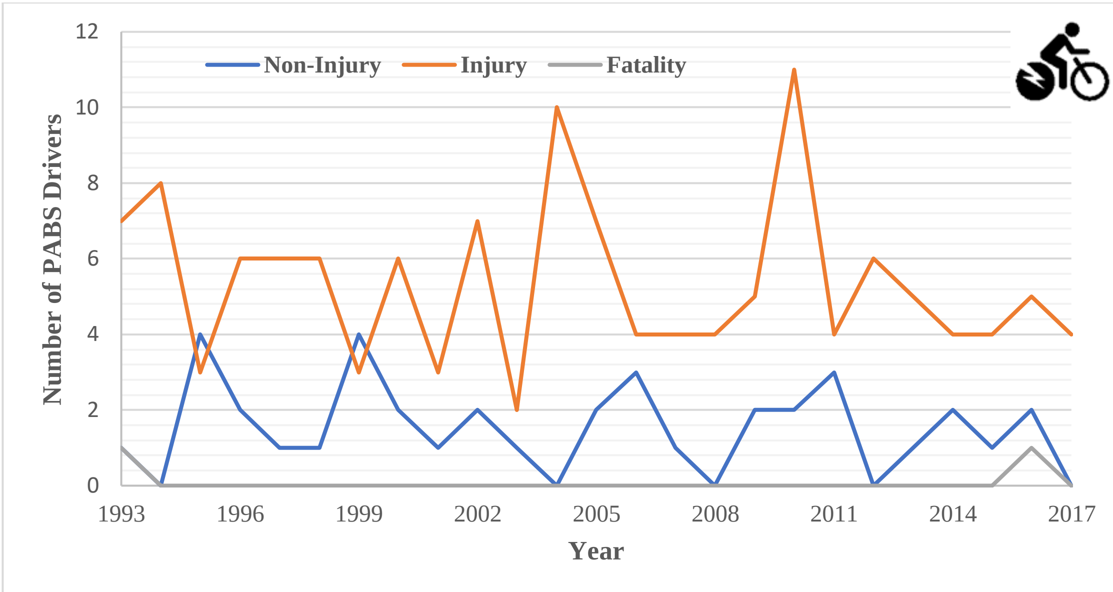

Figure 4.18. Power-assisted bike and scooter drivers involved in a motor vehicle collision by severity (urban)

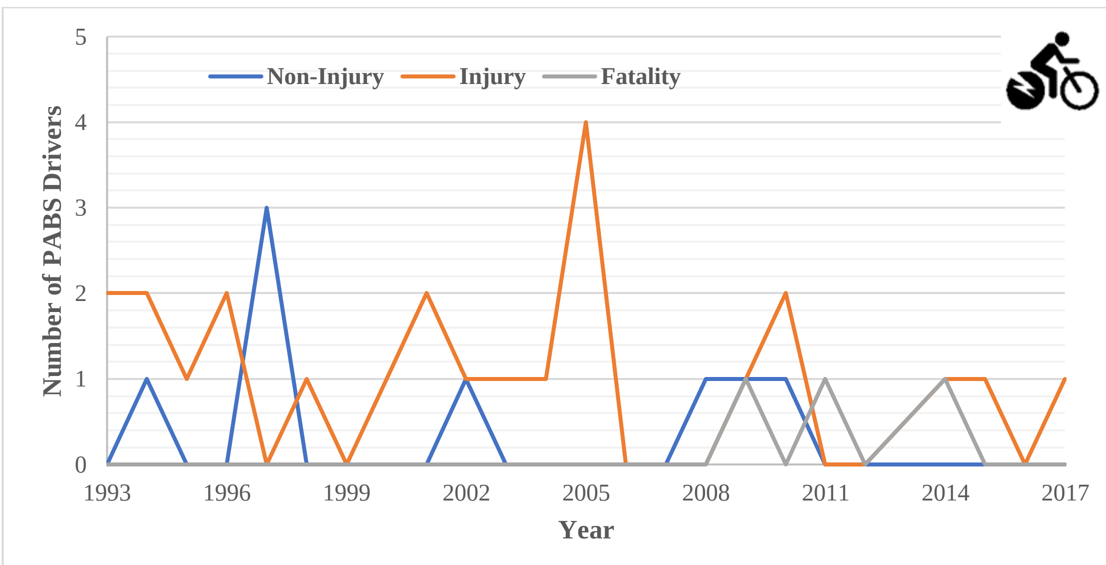

Figure 4.19. Power-assisted bike and scooter drivers involved in a motor vehicle collision by severity (rural)

4.3.2 Major Contributing Factor

The MCF that led to a collision was analyzed for collisions involving pedestrians, cyclists, and PABS drivers and can be found in Table 4.31, 4.32, and 4.33, respectively. For the most part, the MCF that led to a collision was driver inattention or unknown. Regarding motor vehicle drivers involved in a collision with a pedestrian in urban areas, the most notable MCFs were driver inattention, with 35.2% (982 collisions) of collisions, and pedestrian error/confusion, with 30.3% (844 collisions) of collisions. In rural NB, 32.9% (165 collisions) of collisions were caused by pedestrian error/confusion and only 16.7% (165 collisions) were as a result of driver inattention. These results were consistent with those identified in the literature review. In terms of VRUs, 37.7% (719 collisions) of urban collisions and 44.3% (137 collisions) of rural collisions were due to cyclist inattention whereas 29.7% (566 collisions) or urban collisions and 20.7% (64 collisions) of rural collisions were unknown. On the other hand, 29.9% (50 collisions) of urban collisions and 22.9% (8 collisions) of rural collisions were due to PABS driver inattention, while 44.6% (75 collisions) of urban collisions and 28.6% (10 collisions) of rural collisions were unknown. With regard to the motor vehicle driver, the MCF was unknown in 45.7% (870 collisions) of urban collisions and 54.4% (168 collisions) of rural collisions involving a cyclist. Similarly, the MCF was unknown in 42.3% (71 collisions) of urban collisions and 60.0% (21 collisions) of rural collisions involving an PABS driver. Finally, 36.1% (688 collisions) of urban collisions and 18.1% (56 collisions) of rural collisions involving a cyclist were caused by motor vehicle driver inattention, whereas 32.1% (54 collisions) of urban collisions and 17.1% (6 collisions) of rural collisions involving an PABS driver were caused by motor vehicle driver inattention.

Table 4.31: Pedestrian-to-Vehicle Collisions by Major Contributing Factor

Major Contributing Factor	Driver			
	Urban	%	Rural	%
Driver Inattention	982	35.2	84	16.7
Driver Distraction	90	3.2	14	2.8
Had Been Drinking	16	0.6	10	2.0
Driving While Impaired	29	1.0	12	2.4
Fell Asleep	2	0.1	1	0.2
Driver Inexperience/Confusion	28	1.0	13	2.6
Lost Consciousness	1	0.0	0	0.0
Physical Disability	1	0.0	1	0.2
Prescription Medication	0	0.0	1	0.2
Drugs (Illegal)	1	0.0	0	0.0
Illness	1	0.0	0	0.0
Excessive Hours of Service	0	0.0	0	0.0
Use of Electric Device	1	0.0	0	0.0
Failure to Yield Right-of-Way	160	5.7	1	0.2
Traffic Control Device Disregarded	31	1.1	5	1.0
Following Too Closely	3	0.1	0	0.0
Driving too Fast for Road Conditions	14	0.5	7	1.4
Exceeding Speed Limit	11	0.4	6	1.2
Turning Improper	4	0.1	0	0.0
Passing/Lane Usage Improper	7	0.3	2	0.4
Backing Unsafely	25	0.9	8	1.6
Pedestrian Error/Confusion	844	30.3	165	32.9
Failed to Signal	0	0.0	0	0.0
Wrong Way	0	0.0	0	0.0
Taking Avoiding Action	14	0.5	2	0.4
Crossed Centre Line	2	0.1	3	0.6
Defective Brakes	5	0.2	1	0.2
Vision Obstructed/Obscured	45	1.6	15	3.0
Defective Tires	1	0.0	2	0.4
Defective Tow Hitch/Connection	3	0.1	0	0.0
Engine/Power Train	2	0.1	0	0.0
Hood/Door Opening	1	0.0	0	0.0
Load Shift	0	0.0	0	0.0
Defective Headlights	0	0.0	0	0.0
Defective Rearlights	0	0.0	0	0.0
Animal Action (Moose)	0	0.0	1	0.2
Animal Action (Other)	0	0.0	1	0.2
Surface Slippery	48	1.7	17	3.4
Loose Gravel	0	0.0	0	0.0
Snow Drift	2	0.1	7	1.4
Obstruction/Debris	3	0.1	3	0.6
View Obstructed/Limited	94	3.4	28	5.6
Glare	71	2.5	12	2.4
Construction Zone	3	0.1	3	0.6
Shoulders Defective/Inadequate	1	0.0	1	0.2
Traffic Control Device Not Working	2	0.1	0	0.0
Uninvolved Vehicle	10	0.4	2	0.4
Uninvolved Pedestrian	4	0.1	0	0.0
Presence of Prior Accident	5	0.2	12	2.4
Unknown	218	7.8	62	12.4

Table 4.32: Cyclist-to-Vehicle Collisions by Major Contributing Factor

Major Contributing Factor	Cyclist				Driver			
	Urban	%	Rural	%	Urban	%	Rural	%
Driver Inattention	719	37.7	137	44.3	688	36.1	56	18.1
Driver Distraction	30	1.6	7	2.3	29	1.5	3	1.0
Had Been Drinking	22	1.2	9	2.9	5	0.3	5	1.6
Driving While Impaired	4	0.2	3	1.0	10	0.5	2	0.6
Fell Asleep	0	0.0	0	0.0	1	0.1	0	0.0
Driver Inexperience/Confusion	32	1.7	6	1.9	9	0.5	4	1.3
Lost Consciousness	0	0.0	0	0.0	1	0.1	0	0.0
Physical Disability	2	0.1	2	0.6	1	0.1	0	0.0
Prescription Medication	1	0.1	0	0.0	0	0.0	1	0.3
Drugs (Illegal)	1	0.1	0	0.0	0	0.0	0	0.0
Illness	2	0.1	0	0.0	0	0.0	1	0.3
Excessive Hours of Service	0	0.0	0	0.0	0	0.0	1	0.3
Use of Electric Device	1	0.1	0	0.0	1	0.1	0	0.0
Failure to Yield Right-of-Way	164	8.6	33	10.7	104	5.5	4	1.3
Traffic Control Device Disregarded	80	4.2	5	1.6	11	0.6	0	0.0
Following Too Closely	5	0.3	0	0.0	0	0.0	2	0.6
Driving too Fast for Road Conditions	12	0.6	1	0.3	0	0.0	0	0.0
Exceeding Speed Limit	2	0.1	0	0.0	4	0.2	5	1.6
Turning Improper	13	0.7	8	2.6	4	0.2	1	0.3
Passing/Lane Usage Improper	34	1.8	5	1.6	6	0.3	5	1.6
Backing Unsafely	0	0.0	0	0.0	5	0.3	0	0.0
Pedestrian Error/Confusion	4	0.2	0	0.0	1	0.1	2	0.6
Failed to Signal	4	0.2	3	1.0	0	0.0	0	0.0
Wrong Way	123	6.5	12	3.9	3	0.2	1	0.3
Taking Avoiding Action	12	0.6	1	0.3	13	0.7	18	5.8
Crossed Centre Line	8	0.4	2	0.6	0	0.0	1	0.3
Defective Brakes	21	1.1	1	0.3	1	0.1	0	0.0
Vision Obstructed/Obscured	3	0.2	0	0.0	26	1.4	3	1.0
Defective Tires	0	0.0	0	0.0	1	0.1	0	0.0
Defective Tow Hitch/Connection	0	0.0	0	0.0	0	0.0	0	0.0
Engine/Power Train	0	0.0	0	0.0	0	0.0	0	0.0
Hood/Door Opening	0	0.0	0	0.0	0	0.0	0	0.0
Load Shift	0	0.0	0	0.0	1	0.1	0	0.0
Defective Headlights	0	0.0	0	0.0	0	0.0	0	0.0
Defective Rearlights	11	0.6	0	0.0	0	0.0	0	0.0
Animal Action (Other)	0	0.0	5	1.6	0	0.0	0	0.0
Surface Slippery	2	0.1	0	0.0	2	0.1	3	1.0
Loose Gravel	1	0.1	1	0.3	0	0.0	0	0.0
Snow Drift	0	0.0	0	0.0	1	0.1	0	0.0
Obstruction/Debris	1	0.1	0	0.0	2	0.1	0	0.0
View Obstructed/Limited	17	0.9	3	1.0	79	4.1	18	5.8
Glare	0	0.0	0	0.0	12	0.6	2	0.6
Construction Zone	3	0.2	0	0.0	0	0.0	0	0.0
Shoulders Defective/Inadequate	1	0.1	1	0.3	0	0.0	0	0.0
Traffic Control Device Not Working	0	0.0	0	0.0	0	0.0	0	0.0
Uninvolved Vehicle	4	0.2	0	0.0	9	0.5	3	1.0
Uninvolved Pedestrian	0	0.0	0	0.0	3	0.2	0	0.0
Presence of Prior Accident	0	0.0	0	0.0	1	0.1	0	0.0
Unknown	566	29.7	64	20.7	870	45.7	168	54.4

Table 4.33: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Major Contributing Factor

Major Contributing Factor	Power-Assisted Bike and Scooter Driver				Driver			
	Urban	%	Rural	%	Urban	%	Rural	%
Driver Inattention	50	29.8	8	22.9	54	32.1	6	17.1
Driver Distraction	4	2.4	1	2.9	1	0.6	0	0.0
Had Been Drinking	4	2.4	1	2.9	0	0.0	0	0.0
Driving While Impaired	1	0.6	0	0.0	2	1.2	1	2.9
Fell Asleep	0	0.0	0	0.0	0	0.0	0	0.0
Driver Inexperience/Confusion	6	3.6	1	2.9	3	1.8	0	0.0
Lost Consciousness	0	0.0	0	0.0	0	0.0	0	0.0
Physical Disability	0	0.0	0	0.0	0	0.0	0	0.0
Prescription Medication	0	0.0	0	0.0	0	0.0	0	0.0
Drugs (Illegal)	0	0.0	0	0.0	0	0.0	0	0.0
Illness	0	0.0	0	0.0	0	0.0	0	0.0
Excessive Hours of Service	0	0.0	0	0.0	0	0.0	0	0.0
Use of Electric Device	0	0.0	0	0.0	0	0.0	0	0.0
Failure to Yield Right-of-Way	6	3.6	3	8.6	17	10.1	1	2.9
Traffic Control Device Disregarded	1	0.6	3	8.6	1	0.6	0	0.0
Following Too Closely	6	3.6	0	0.0	2	1.2	0	0.0
Driving too Fast for Road Conditions	0	0.0	0	0.0	0	0.0	0	0.0
Exceeding Speed Limit	2	1.2	1	2.9	0	0.0	0	0.0
Turning Improper	0	0.0	1	2.9	2	1.2	0	0.0
Passing/Lane Usage Improper	3	1.8	2	5.7	0	0.0	0	0.0
Backing Unsafely	0	0.0	0	0.0	1	0.6	0	0.0
Pedestrian Error/Confusion	0	0.0	0	0.0	0	0.0	0	0.0
Failed to Signal	0	0.0	1	2.9	0	0.0	0	0.0
Wrong Way	0	0.0	0	0.0	0	0.0	0	0.0
Taking Avoiding Action	1	0.6	1	2.9	0	0.0	0	0.0
Crossed Centre Line	0	0.0	0	0.0	0	0.0	0	0.0
Defective Brakes	0	0.0	0	0.0	0	0.0	1	2.9
Vision Obstructed/Obscured	0	0.0	0	0.0	2	1.2	2	5.7
Defective Tires	0	0.0	0	0.0	0	0.0	0	0.0
Defective Tow Hitch/Connection	0	0.0	0	0.0	0	0.0	0	0.0
Engine/Power Train	1	0.6	0	0.0	0	0.0	0	0.0
Hood/Door Opening	0	0.0	0	0.0	0	0.0	0	0.0
Load Shift	0	0.0	0	0.0	0	0.0	0	0.0
Defective Headlights	0	0.0	0	0.0	0	0.0	0	0.0
Defective Rearlights	0	0.0	0	0.0	1	0.6	0	0.0
Animal Action (Other)	0	0.0	0	0.0	0	0.0	0	0.0
Surface Slippery	1	0.6	1	2.9	0	0.0	1	2.9
Loose Gravel	0	0.0	0	0.0	0	0.0	0	0.0
Snow Drift	0	0.0	0	0.0	0	0.0	0	0.0
Obstruction/Debris	0	0.0	0	0.0	0	0.0	0	0.0
View Obstructed/Limited	1	0.6	0	0.0	2	1.2	2	5.7
Glare	1	0.6	0	0.0	1	0.6	0	0.0
Construction Zone	0	0.0	0	0.0	1	0.6	0	0.0
Shoulders Defective/Inadequate	0	0.0	0	0.0	0	0.0	0	0.0
Traffic Control Device Not Working	0	0.0	0	0.0	0	0.0	0	0.0
Uninvolved Vehicle	4	2.4	1	2.9	4	2.4	0	0.0
Uninvolved Pedestrian	1	0.6	0	0.0	3	1.8	0	0.0
Presence of Prior Accident	0	0.0	0	0.0	0	0.0	0	0.0
Unknown	75	44.6	10	28.6	71	42.3	21	60.0

To determine any evolving trends of cyclists-related collisions based on the MCF, Figures 4.20 and 4.21 were developed. Firstly, there was a slight drop in the number of pedestrian-related collisions caused by driver inattention over the 22-year period in both urban and rural NB. Additionally, the data revealed a considerable decline in the number of collisions caused by pedestrian confusion or error with two major peaks in 2003 and 2010 in urban areas. In terms of rural collisions caused by pedestrian confusion or error, there was a steep drop in the number of collisions with large peaks in 2001 as well as 2007 and 2010.

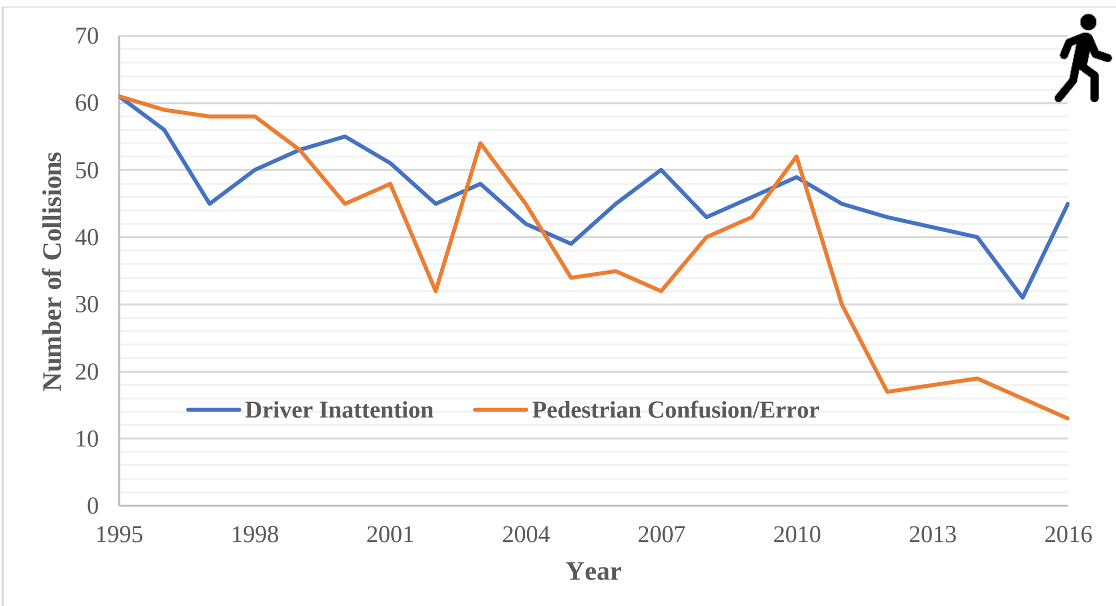

Figure 4.20. Pedestrian-related collisions by major contributing factor (urban)

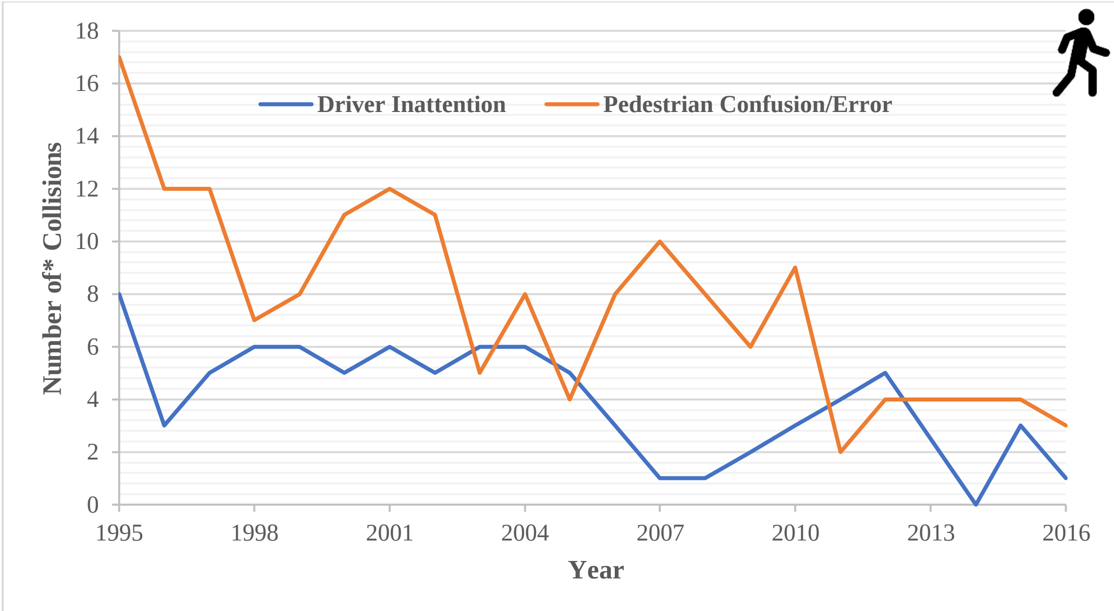

Figure 4.21. Pedestrian-related collisions by major contributing factor (rural)

Figures 4.22 and 4.23 present the number of cyclist-related collisions by MCF over a 25-year period. Cyclist-related collisions caused by driver inattention in urban areas saw a gradual decline between 1993 and 2017. However, in rural areas there was a sharp drop in the number of collisions caused by driver inattention with a major peak in collisions in 2001. In terms of both urban and rural collisions caused by failure for the driver to yield right of way, there was a slow decline over the 25 years. In addition, in rural areas, the number of collisions plummeted between 2012 and 2017 resulting in zero collisions over the period.

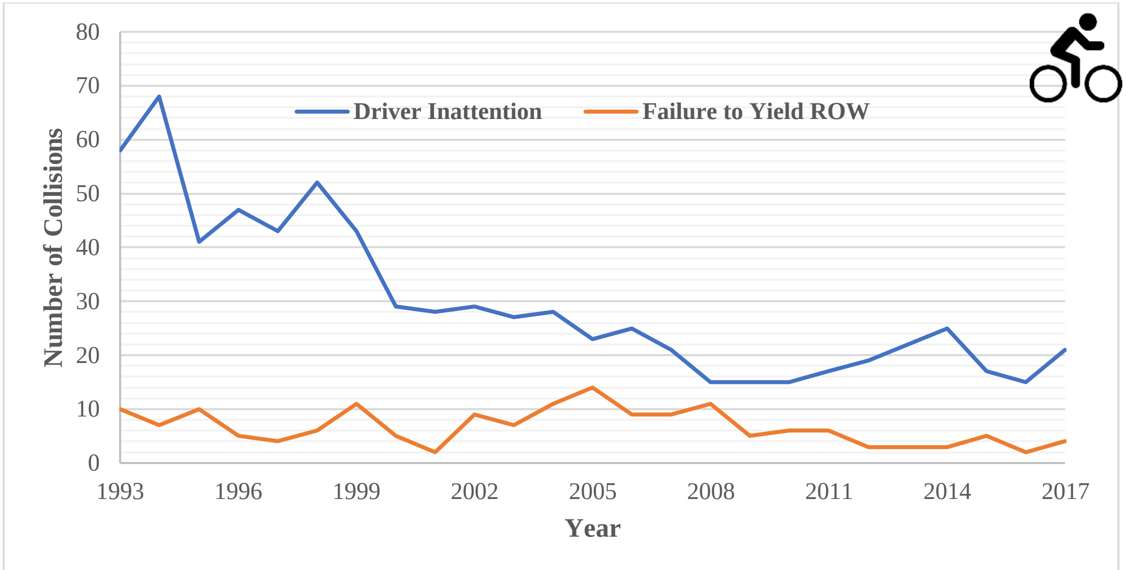

Figure 4.22. Cyclist-related collisions by major contributing factor (urban)

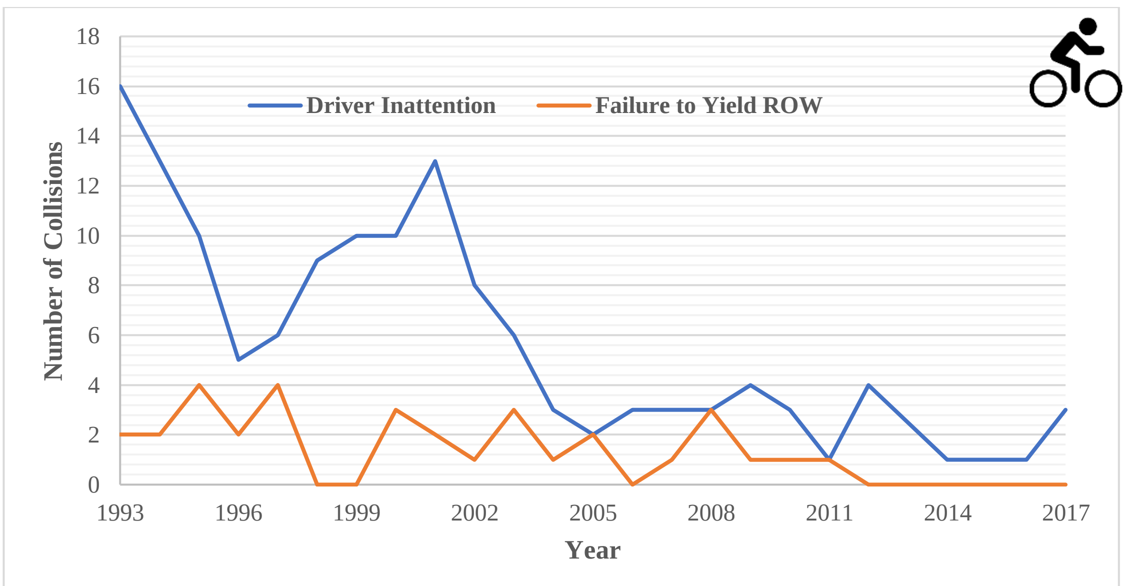

Figure 4.23. Cyclist-related collisions by major contributing factor (rural)

Figure 4.24 presents the number of PABS-related collisions by MCF over a 25-year period. Considering the low number of PABS-related collisions, the urban and rural collisions were grouped together. All the data in the figure reveal a major fluctuation in the number collisions caused by driver inattention and therefore, no conclusions could be drawn from the data.

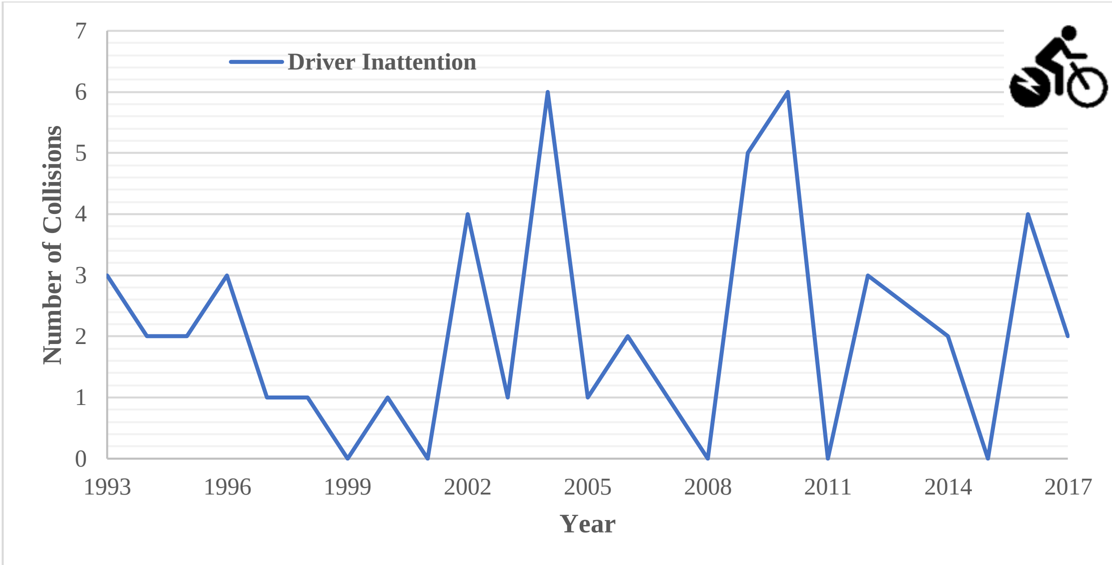

Figure 4.24. Power-assisted bike and scooter-related collisions by major contributing factor (urban and rural)

4.3.3 Pedestrian Action

Similar to the MCF discussed above in section 4.3.2, Table 4.34 presents the frequency of pedestrian collisions based on pedestrian action. In urban areas, three different pedestrian actions were recorded the most: 14.8% (418 collisions) were "at intersection, crossing, marked x-walk, no signal", 13.5% (383 collisions) were "running onto roadway", and 13.0% (367 collisions) were "at intersection, crossing with signal". On the other hand, 20.4% (94 collisions) were "walking on roadway with traffic" and 14.1% (65 collisions) were "running onto roadway" in rural areas.

Table 4.34: Pedestrian-to-Vehicle Collisions by Pedestrian Action

Pedestrian Action	Urban	%	Rural	%
At Intersection, Crossing with Signal	367	13.0	0	0.0
At Intersection, Crossing Against Signal	111	3.9	0	0.0
At Intersection, Crossing, Marked X-Walk, No Signal	418	14.8	1	0.2
At Intersection, Crossing, No X-Walk, No Signal	295	10.4	8	1.7
Mid-Block/Highway Crossing Marked X-Walk	90	3.2	0	0.0
Mid-Block/Highway Crossing No X-Walk	340	12.0	39	8.5
Walking on Roadway with Traffic	182	6.4	93	20.2
Walking on Roadway Against Traffic	125	4.4	56	12.2
Emerging from in Front or Behind Parked Vehicle/Object	112	4.0	26	5.7
Running onto Roadway	383	13.5	65	14.1
Getting On/Off School Bus	4	0.1	9	2.0
Getting On/Off Vehicle other than School Bus	35	1.2	11	2.4
On Sidewalk/Shoulder/Boulevard	140	5.0	48	10.4
Pushing/Working on Vehicle	28	1.0	22	4.8
Playing on Roadway	44	1.6	15	3.3
Lying on Roadway	7	0.2	14	3.0
Hitch Hiking	3	0.1	11	2.4
Working on Roadway	38	1.3	14	3.0
Unknown	105	3.7	28	6.1

4.4 Road and Environmental Factors

4.4.1 Legal Speed Limit

The speed limit recorded for each collision involving a pedestrian, cyclist or PABS driver was analyzed, and the resulting frequencies can be found in Tables 4.35, 4.36, and 4.37, respectively. Not surprisingly, in urban NB, the majority of collisions took place on streets that had a posted speed limit of 50 km/h. Based on the results, 80.4% (2168 collisions) of pedestrian-related collisions, 80.4% (1531 collisions) of cyclist-related collisions, and 74.4% (125 collisions) of PABS-related collisions occurred at a posted speed of 50 km/h in urban areas. These results were consistent with those identified in the literature review, considering the majority of collisions in the studies occurred on urban roads posted at 60 km/h or less. On the other hand, the largest share of rural collisions occurred on roads with a posted speed of 80 km/h. It was revealed that the frequency of rural collisions, occurring on roads posted at 80 km/h, involving pedestrians, cyclists, and PABS drivers was 39.4% (172 collisions), 42.4% (131 collisions), and 51.4% (18 collisions), respectively.

Table 4.35: Pedestrian-to-Vehicle Collisions by Legal Speed Limit

Speed Limit	Urban	%	Rural	%
30 km/h or less	292	10.8	18	4.1
40 km/h	21	0.8	14	3.2
50 km/h	2168	80.4	86	19.7
60 km/h	111	4.1	41	9.4
70 km/h	50	1.9	44	10.1
80 km/h	21	0.8	172	39.4
90 km/h	16	0.6	26	5.9
100 km/h	12	0.4	23	5.3
110 km/h	6	0.2	13	3.0
Unknown	0	0.0	0	0.0

Table 4.36: Cyclist-to-Vehicle Collisions by Legal Speed Limit

Speed Limit	Urban	%	Rural	%
30 km/h or less	39	2.0	3	1.0
40 km/h	26	1.4	2	0.6
50 km/h	1531	80.4	42	13.6
60 km/h	73	3.8	50	16.2
70 km/h	43	2.3	45	14.6
80 km/h	15	0.8	131	42.4
90 km/h	7	0.4	15	4.9
100 km/h	9	0.5	8	2.6
110 km/h	1	0.1	5	1.6
Unknown	161	8.5	8	2.6

Table 4.37: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Legal Speed Limit

Speed Limit	Urban	%	Rural	%
30 km/h or less	1	0.6	0	0.0
40 km/h	0	0.0	0	0.0
50 km/h	125	74.4	3	8.6
60 km/h	15	8.9	1	2.9
70 km/h	10	6.0	3	8.6
80 km/h	3	1.8	18	51.4
90 km/h	1	0.6	4	11.4
100 km/h	1	0.6	4	11.4
110 km/h	0	0.0	1	2.9
Unknown	12	7.1	1	2.9

Figure 4.25 presents the trend of VRU-related collisions occurring on urban roads posted at 50 km/h and on rural roads posted at 80 km/h over a 22-year period. The data included in Figure 4.25 consisted of all pedestrian-, cyclist-, and PABS-related collisions between 1995 and 2016. Ultimately, the data show a significant decrease in the number of collisions occurring on urban roads posted at 50 km/h; however, in 2016, the number of collisions remained relatively high. Additionally, the number of collisions occurring on rural roads posted at 80 km/h slightly decreased over the 22-year period, with a significantly low number of collisions in 2016.

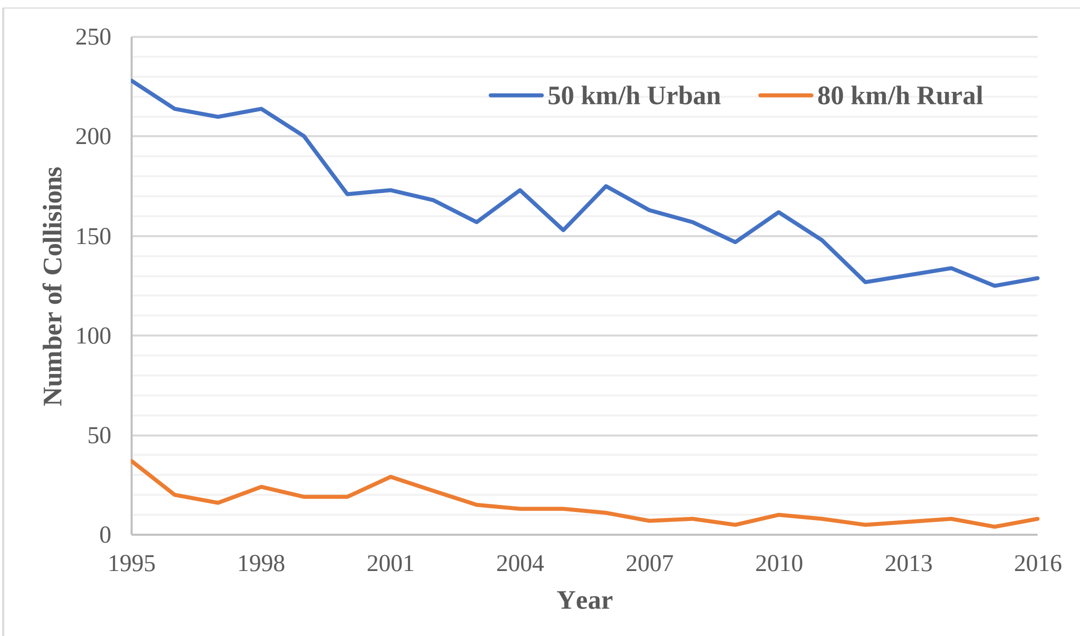

Figure 4.25. Vulnerable road user-related collisions by legal speed limit (urban and rural)

The number of pedestrian-related collisions resulting in a fatality or injury based on the legal speed limit was analyzed and is presented as Figures 4.26 and 4.27 for urban and rural areas, respectively. Both graphs show that the number of pedestrian-to-vehicle collisions resulting in an injury decrease and fatalities significantly increase as the speed limit increases, particularly in urban areas. Fortunately, the number of cyclist- and PABS-related collisions leading to a fatality were very limited and therefore, the analysis of these types of collisions was not advantageous.

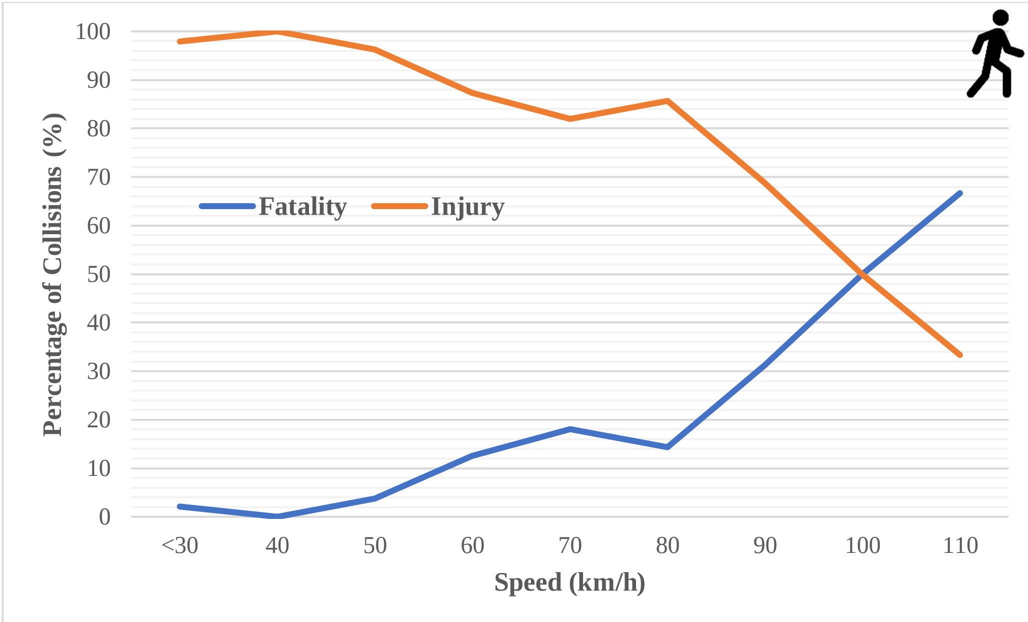

Figure 4.26. Pedestrian-related collision severity by legal speed limit (urban)

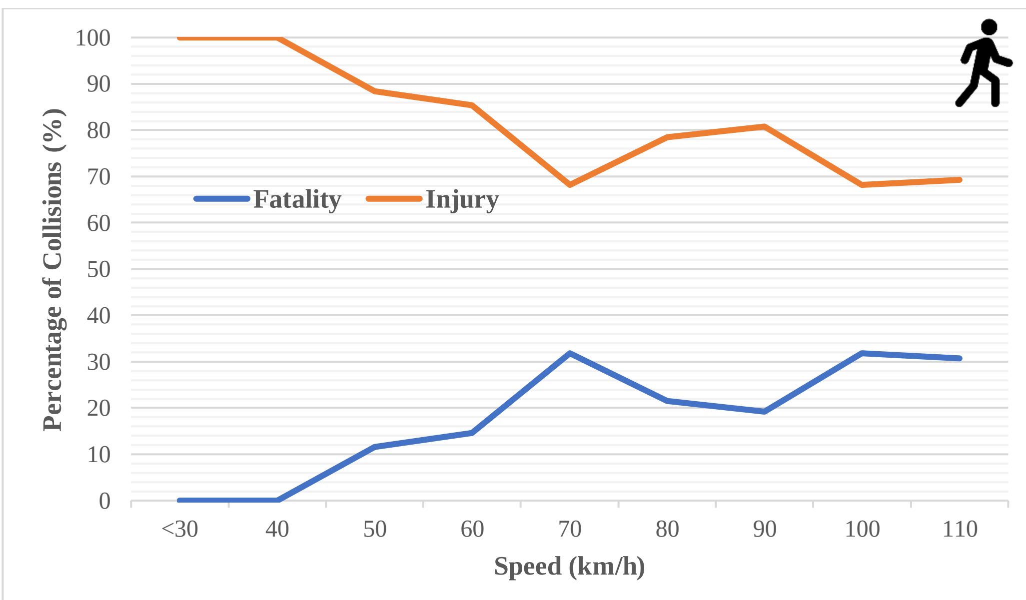

Figure 4.27. Pedestrian-related collision severity by legal speed limit (rural)

4.4.2 Weather Condition

The most prevailing weather condition at the time of a collision involving a VRU was recorded and analyzed. It was determined that, in both urban and rural areas, the majority of collisions involving all three types of VRUs occurred in clear weather conditions. In terms of pedestrian-to-vehicle collisions, Table 4.38 reveals that 1634 (60.6%) and 246 (56.3%) collisions occurred in clear conditions in urban and rural NB, respectively. Further, from Table 4.39, 1373 urban collisions (72.1%) and 226 rural collisions (73.5%) involving a cyclist occurred in identical conditions. Finally, the frequency of PABS-related collisions in clear weather was 123 urban collisions (73.2%) and 25 rural collisions (71.4%) which can be found in Table 4.40. These results were consistent with those found in the literature review, given that the largest frequency of collisions in the studies occurred in clear weather conditions.

Table 4.38: Pedestrian-to-Vehicle Collisions by Weather Condition

Weather Condition	Urban	%	Rural	%
Clear	1634	60.6	246	56.3
Cloudy	534	19.8	92	21.1
Raining	329	12.2	30	6.9
Snowing	99	3.7	45	10.3
Sleet/Hail/Freezing Rain	15	0.6	0	0.0
Fog/Smoke/Smog	21	0.8	6	1.4
Drifting Snow/Dust	3	0.1	9	2.1
Strong Wind	2	0.1	1	0.2
Unknown	63	2.3	8	1.8

Table 4.39: Cyclist-to-Vehicle Collisions by Weather Condition

Weather Condition	Urban	%	Rural	%
Clear	1373	72.1	227	73.5
Cloudy	376	19.7	60	19.4
Raining	120	6.3	13	4.2
Snowing	10	0.5	3	1.0
Sleet/Hail/Freezing Rain	3	0.2	1	0.3
Fog/Smoke/Smog	10	0.5	2	0.6
Drifting Snow/Dust	1	0.1	0	0.0
Strong Wind	2	0.1	0	0.0
Unknown	9	0.5	3	1.0

Table 4.40: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Weather Condition

Weather Condition	Urban	%	Rural	%
Clear	123	73.2	25	71.4
Cloudy	38	22.6	5	14.3
Raining	6	3.6	3	8.6
Snowing	1	0.6	2	5.7
Sleet/Hail/Freezing Rain	0	0.0	0	0.0
Fog/Smoke/Smog	0	0.0	0	0.0
Drifting Snow/Dust	0	0.0	0	0.0
Strong Wind	0	0.0	0	0.0
Unknown	0	0.0	0	0.0

4.4.3 Light Condition

Tables 4.41, 4.42, and 4.43 present the frequency of pedestrian, cyclist, and PABS collisions based on the light condition at the time of the collision. In urban NB, 59.0% (1592 collisions) of pedestrian-related collisions, 80.8% (1539 collisions) of cyclists-vehicle collisions, and 81.5% (137 collisions) of collisions involving PABS drivers occurred during the daylight. Additionally, 77.7% (240 collisions) and 77.1% (26 collisions) of cyclist- and PABS-related collisions took place in the daylight in rural areas. These results were consistent with those identified in the literature review. Alternatively, nearly half of pedestrian-vehicle collisions in rural areas occurred in the dark, 49.0% (214 collisions), whereas 45.3% (198 collisions) occurred in the daylight.

Table 4.41: Pedestrian-to-Vehicle Collisions by Light Condition

Light Condition	Urban	%	Rural	%
Daylight	1592	59.0	198	45.3
Dark	893	33.1	214	49.0
Dusk	80	3.0	14	3.2
Dawn	30	1.1	7	1.6
Artificial Light	102	3.8	4	0.9
Unknown	0	0.0	0	0.0

Table 4.42: Cyclist-to-Vehicle Collisions by Light Condition

Light Condition	Urban	%	Rural	%
Daylight	1539	80.8	240	77.7
Dark	261	13.7	46	14.9
Dusk	71	3.7	17	5.5
Dawn	7	0.4	1	0.3
Artificial Light	27	1.4	5	1.6
Unknown	0	0.0	0	0.0

Table 4.43: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Light Condition

Light Condition	Urban	%	Rural	%
Daylight	137	81.5	27	77.1
Dark	20	11.9	8	22.9
Dusk	5	3.0	0	0.0
Dawn	2	1.2	0	0.0
Artificial Light	4	2.4	0	0.0
Unknown	0	0.0	0	0.0

Figures 4.28 and 4.29 were presented to identify any concerning trends evolving during the most frequently reported light conditions in urban and rural areas, respectively. In terms of urban pedestrian-related collisions, a significant drop in the number of collisions occurring in the daylight was seen over the 22-year period. Similarly, in dark conditions, there was a slight decrease in the number of collisions between 1995 and 2016. In rural areas, Figure 4.29, a sharp decline in pedestrian-related collisions occurring in the daylight was identified from 1995 to 1996. Following 1996, the number of collisions saw a gradual decrease over the 21 years. Finally, a substantial drop in collisions between 1995 and 2000 was observed in dark conditions in rural NB. Subsequently, there was a peak in collisions from 2001 to 2002 and a slight decrease in collisions until 2016.

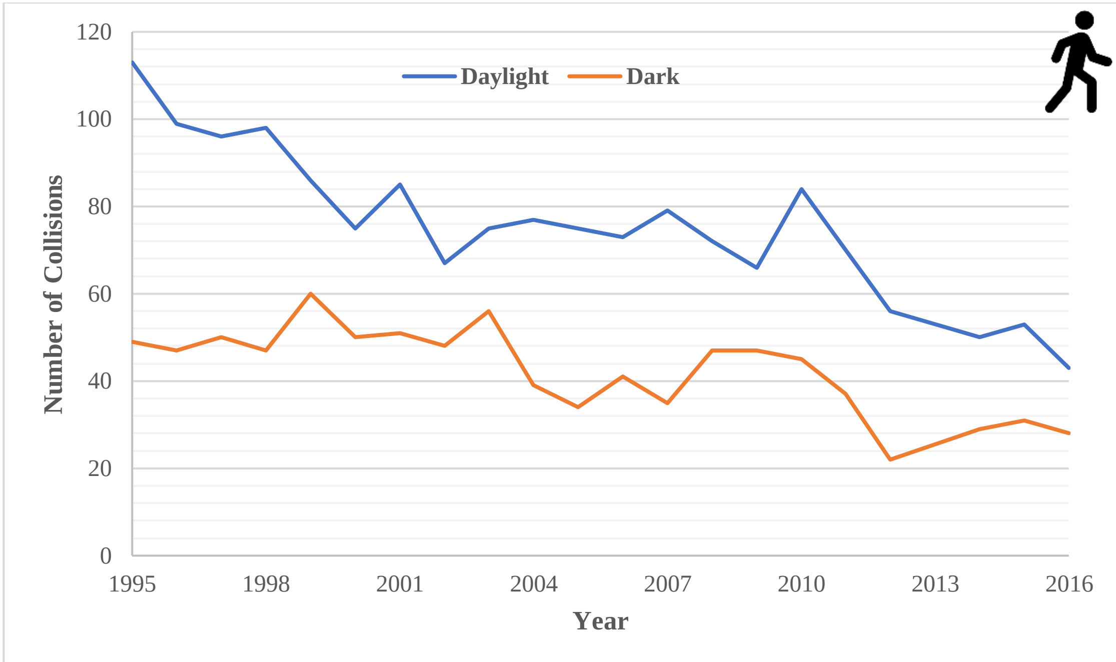

Figure 4.28. Pedestrian-related collisions by light condition (urban)

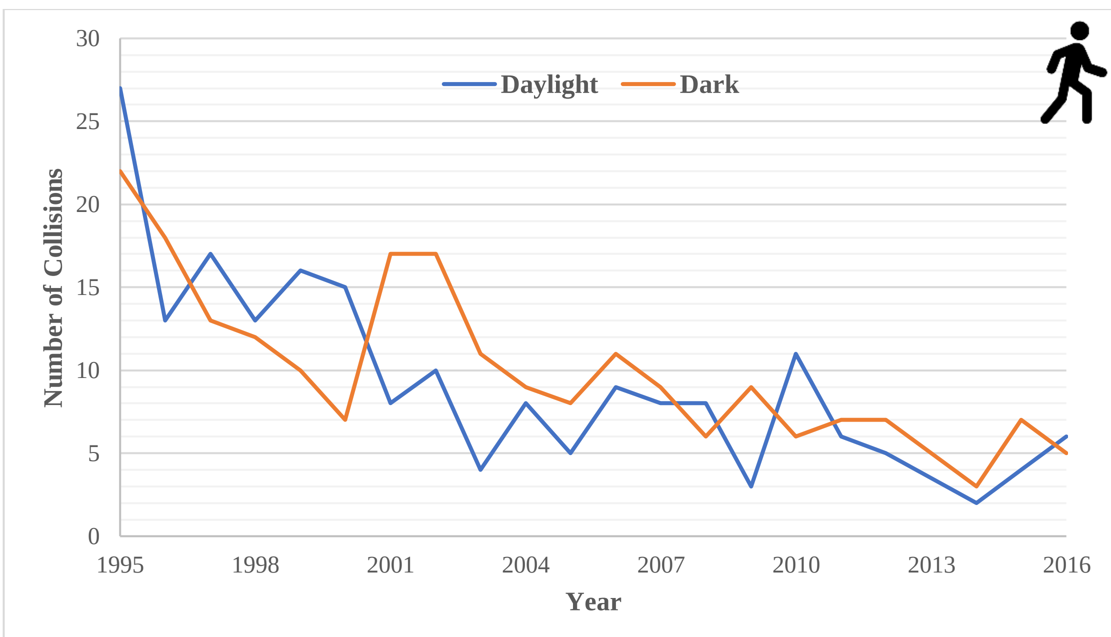

Figure 4.29. Pedestrian-related collisions by light condition (rural)

To determine any evolving trends of cyclists-related collisions based on lighting condition, Figures 4.30 and 4.31 were developed. In both urban and rural areas, there was a considerable decline in the number of cyclists involved in a motor vehicle collision occurring in the daylight over the 25-year period. Moreover, Figure 4.31 revealed a major peak in collisions occurring in the daylight in 2000. In terms of cyclist-related collisions in urban areas, the data show the number of collisions remained relatively constant over the 25-year period. Conversely, the number of cyclist-related collisions in rural areas saw a slight drop over the 25 years, with a small peak in 2001.

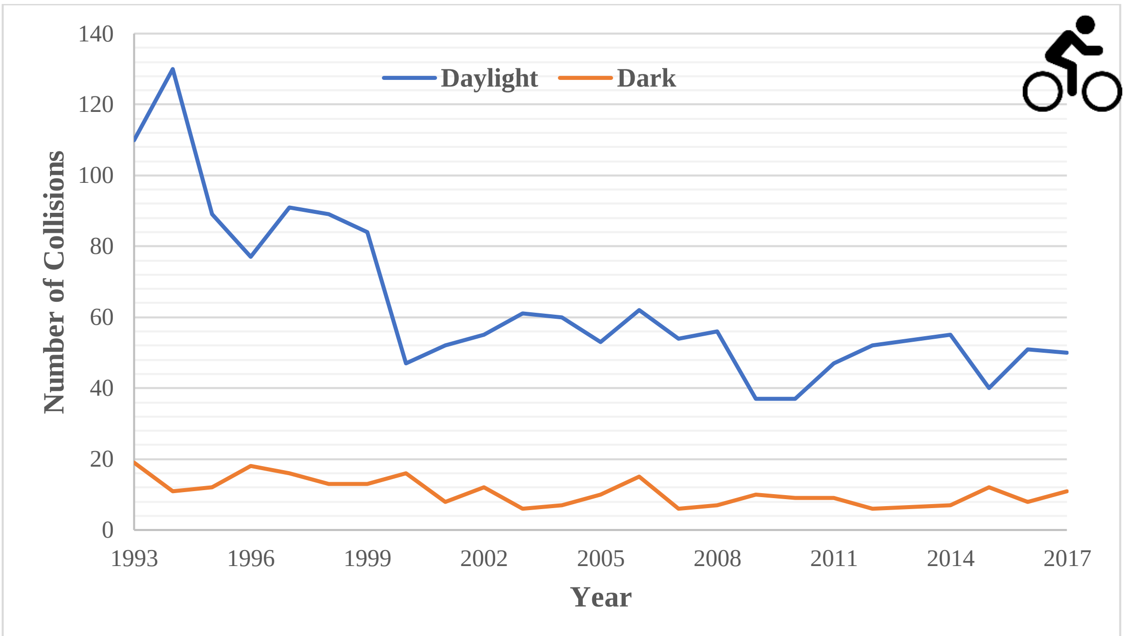

Figure 4.30. Cyclist-related collisions by light condition (urban)

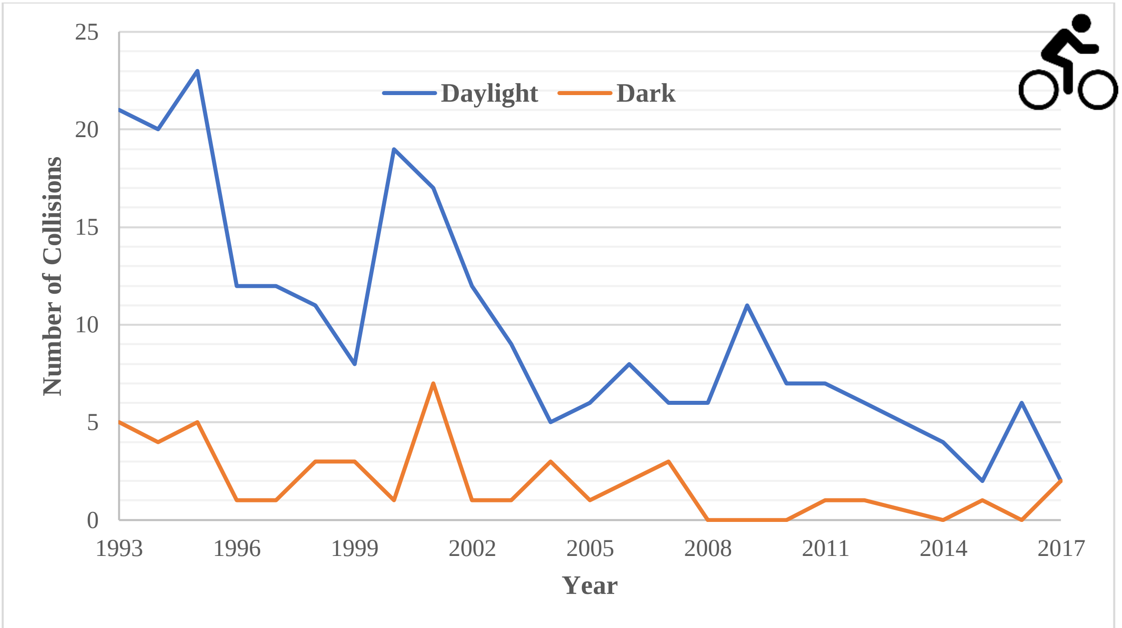

Figure 4.31. Cyclist-related collisions by light condition (rural)

The number of PABS-related collisions based on light conditions over a 25-year period can be found in Figure 4.32. Considering the low number of PABS-related collisions, the urban and rural collisions were grouped together. In terms of collisions occurring in the daylight, there was a fluctuation in the data from 1993 to 2007, followed by a peak in PABS collisions in 2010. Following the peak, the number of collisions hit a plateau until 2017. Ultimately, in dark conditions, the number of PABS-related collisions remained relatively constant over the 25-year period.

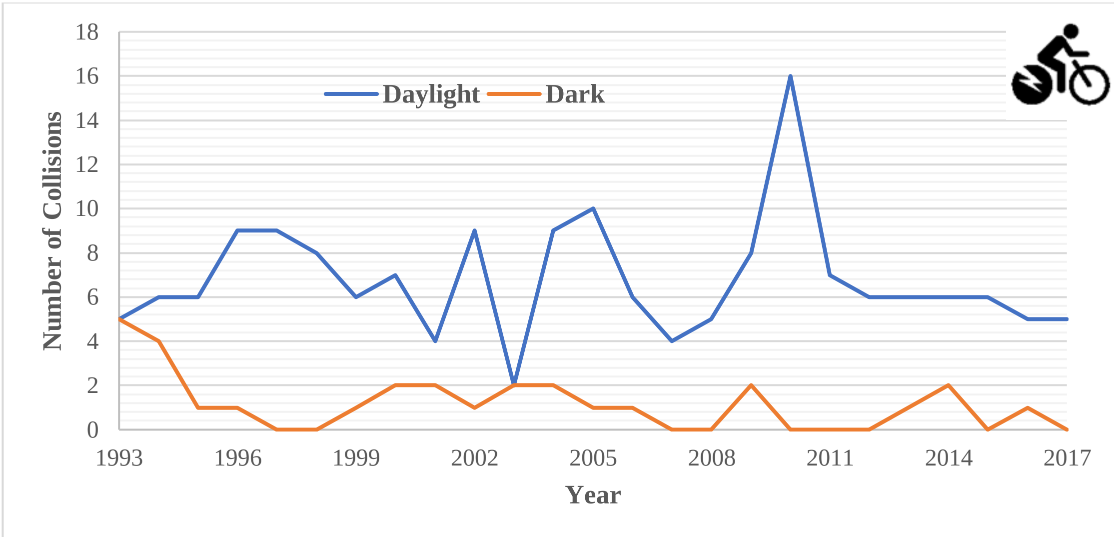

Figure 4.32. Power-assisted bike and scooter-related collisions by light condition (urban and rural)

4.4.4 Road Surface Condition

Similar to the weather condition at the time of a collision, the road surface condition was analyzed. With regard to all three types of VRUs and in both urban and rural areas of NB, the majority of collisions occurred on dry road conditions. These results were consistent with those identified in the literature review. To highlight, Table 4.44 presents a frequency of 2656 pedestrian-vehicle collisions (98.5%) in urban areas and 347 pedestrian-vehicle collisions (78.4%) in rural areas. Interestingly, 16.0% (70 collisions) of pedestrian-related collisions in rural areas occurred on muddy road surfaces. From Table 4.45, dry road conditions were encountered in 1686 urban collisions (88.5%) and 275 rural collisions (89.0%) involving a cyclist. Lastly, the frequency of PABS-to-vehicle collisions that occurred in dry road conditions, displayed in Table 4.46, was 154 urban collisions (91.7%) and 26 rural collisions (74.3%). Additionally, in rural areas, 14.3% (5 collisions) of PABS-related collisions occurred on road surfaces with snow.

Table 4.44: Pedestrian-to-Vehicle Collisions by Road Surface Condition

Surface Condition	Urban	%	Rural	%
Dry	2656	98.5	347	79.4
Snow	12	0.4	11	2.5
Ice	3	0.1	6	1.4
Wet	9	0.3	1	0.2
Muddy	15	0.6	70	16.0
Loose Gravel/Sand	0	0.0	0	0.0
Slush	0	0.0	0	0.0
Fresh Oil	0	0.0	0	0.0
Unknown	2	0.1	2	0.0

Table 4.45: Cyclist-to-Vehicle Collisions by Road Surface Condition

Surface Condition	Urban	%	Rural	%
Dry	1686	88.5	275	89.0
Snow	10	0.5	3	1.0
Ice	5	0.3	1	0.3
Wet	188	9.9	20	6.5
Muddy	0	0.0	0	0.0
Loose Gravel/Sand	4	0.2	8	2.6
Slush	5	0.3	1	0.3
Fresh Oil	1	0.1	0	0.0
Unknown	6	0.3	1	0.3

Table 4.46: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Road Surface Condition

Surface Condition	Urban	%	Rural	%
Dry	154	91.7	26	74.3
Snow	2	1.2	5	14.3
Ice	0	0.0	0	0.0
Wet	10	6.0	3	8.6
Muddy	0	0.0	0	0.0
Loose Gravel/Sand	1	0.6	0	0.0
Slush	1	0.6	1	2.9
Fresh Oil	0	0.0	0	0.0
Unknown	0	0.0	0	0.0

4.4.5 Traffic Control

The number of pedestrian-, cyclist-, and PABS-vehicle collisions based on the traffic control type can be found in Tables 4.47, 4.48, and 4.49, respectively. Based on the results presented in the tables below, the majority of VRU collisions in both urban and rural NB had no traffic control present. Specifically, traffic controls were absent in 52.8% of pedestrian collisions (1425 collisions), 69.1% of cyclist collisions (1316 collisions), and 68.5% of PABS collisions (115 collisions) in urban NB. Additionally, in rural areas, 91.3% (399 collisions), 89.3% (276 collisions), and 80.0% (28 collisions) of pedestrian-, cyclist-, and PABS-related collisions had no traffic control. Further, it is interesting to note that 21.9% (590 collisions) of collisions involving pedestrians occurred at marked pedestrian crossings in urban areas.

Table 4.47: Pedestrian-to-Vehicle Collisions by Traffic Control Type

Traffic Control	Urban	%	Rural	%
No Control Present	1425	52.8	399	91.3
Traffic Signal	438	16.2	1	0.2
Flashing Traffic Signal	9	0.3	0	0.0
Stop Sign	145	5.4	5	1.1
Yield Sign	14	0.5	0	0.0
Marked Pedestrian Crossing	590	21.9	0	0.0
Reduced Speed Zone	21	0.8	6	1.4
Flagman/Police Officer	22	0.8	8	1.8
No Passing Zone	27	1.0	13	3.0
School Bus Exhibiting Flashing Red Light	2	0.1	4	0.9
Unknown	4	0.1	1	0.2

Table 4.48: Cyclist-to-Vehicle Collisions by Traffic Control Type

Traffic Control	Urban	%	Rural	%
No Control Present	1316	69.1	276	89.3
Traffic Signal	258	13.5	1	0.3
Flashing Traffic Signal	5	0.3	0	0.0
Stop Sign	183	9.6	17	5.5
Yield Sign	8	0.4	0	0.0
Marked Pedestrian Crossing	97	5.1	0	0.0
Reduced Speed Zone	10	0.5	1	0.3
Flagman/Police Officer	2	0.1	1	0.3
No Passing Zone	17	0.9	12	3.9
School Bus Exhibiting Flashing Red Light	0	0.0	0	0.0
Unknown	9	0.5	1	0.3

Table 4.49: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Traffic Control Type

Traffic Control	Urban	%	Rural	%
No Control Present	115	68.5	28	80.0
Traffic Signal	24	14.3	0	0.0
Flashing Traffic Signal	1	0.6	1	2.9
Stop Sign	11	6.5	4	11.4
Yield Sign	1	0.6	0	0.0
Marked Pedestrian Crossing	4	2.4	0	0.0
Reduced Speed Zone	2	1.2	0	0.0
Flagman/Police Officer	2	1.2	0	0.0
No Passing Zone	7	4.2	2	5.7
School Bus Exhibiting Flashing Red Light	1	0.6	0	0.0
Unknown	0	0.0	0	0.0

4.4.6 Roadway Alignment

The tables shown below present the results of the frequency of pedestrian, cyclist, and PABS collisions based on the roadway alignment. The results indicate that the alignment that was recorded the most frequent was a level and straight road, which was consistent with the results found in the literature review. In terms of pedestrian-vehicle collisions, Table 4.50 reveals that 74.9% (2019 collisions) of collisions in urban areas and 64.5% (282 collisions) of collisions in rural areas occurred on a level and straight alignment. Further, Table 4.51, which presents cyclist-vehicle collisions, confirms that a level and straight road was reported the most with 73.0% (1390 collisions) and 66.3% (205 collisions) in urban and rural NB, respectively. Finally, PABS-vehicle collision data, found in Table 4.52, reveals that 75.6% (127 collisions) of urban collisions and 60.0% (21 collisions) of rural collisions took place on a level and straight roadway. Further, it should be noted that between 20.9% and 30.6% of VRU-related collisions occurred on curved road sections in both urban and rural NB.

Table 4.50: Pedestrian-to-Vehicle Collisions by Roadway Alignment

Road Alignment	Urban	%	Rural	%
Level and Straight	2019	74.9	282	64.5
Level and Curve	101	3.7	29	6.6
Straight with a Curve	402	14.9	83	19.0
Curve with a Grade	70	2.6	22	5.0
Top of Hill	51	1.9	9	2.1
Bottom of Hill	35	1.3	9	2.1
Unknown	19	0.7	3	0.7

Table 4.51: Cyclist-to-Vehicle Collisions by Roadway Alignment

Road Alignment	Urban	%	Rural	%
Level and Straight	1390	73.0	205	66.3
Level and Curve	59	3.1	17	5.5
Straight with a Curve	341	17.9	56	18.1
Curve with a Grade	43	2.3	11	3.6
Top of Hill	18	0.9	6	1.9
Bottom of Hill	46	2.4	10	3.2
Unknown	8	0.4	4	1.3

Table 4.52: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Roadway Alignment

Road Alignment	Urban	%	Rural	%
Level and Straight	127	75.6	21	60.0
Level and Curve	4	2.4	3	8.6
Straight with a Curve	25	14.9	6	17.1
Curve with a Grade	6	3.6	1	2.9
Top of Hill	2	1.2	1	2.9
Bottom of Hill	4	2.4	3	8.6
Unknown	0	0.0	0	0.0

4.4.7 Surface Type

The surface type was analyzed for pedestrian-, cyclist-, and PABS-related collisions and are presented in Tables 4.53, 4.54, and 4.55, respectively. In both urban and rural NB, the largest frequency of collisions occurred on asphalt roads. Specifically, 98.4% (2654 collisions) of pedestrian-related collisions, 95.3% (1815 collisions) of cyclist-related collisions, and 95.8% (161 collisions) of PABS-related collisions took place on asphalt in urban areas. Additionally, in rural areas, between 74.0% and 80.0% of collisions involving a VRU transpired on an asphalt surface. Rural NB results further indicated that a significant frequency of collisions occurred on chip seal type roads. Based on the tables below, approximately 16.0% to 20.0% of collisions involving pedestrians, cyclists, and PABSs took place on a chip seal surface.

Table 4.50: Pedestrian-to-Vehicle Collisions by Surface Type

Surface Type	Urban	%	Rural	%
Asphalt	2654	98.4	350	80.1
Gravel	12	0.4	10	2.3
Dirt/Earth	3	0.1	4	0.9
Concrete	10	0.4	1	0.2
Chip Seal	15	0.6	70	16.0
Unknown	3	0.1	2	0.5

Table 4.51: Cyclist-to-Vehicle Collisions by Surface Type

Surface Type	Urban	%	Rural	%
Asphalt	1815	95.3	235	76.1
Gravel	17	0.9	10	3.2
Dirt/Earth	3	0.2	5	1.6
Concrete	58	3.0	0	0.0
Chip Seal	8	0.4	59	19.1
Unknown	4	0.2	0	0.0

Table 4.52: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Surface Type

Surface Type	Urban	%	Rural	%
Asphalt	161	95.8	26	74.3
Gravel	2	1.2	1	2.9
Dirt/Earth	2	1.2	0	0.0
Concrete	0	0.0	1	2.9
Chip Seal	3	1.8	7	20.0
Unknown	0	0.0	0	0.0

4.4.8 Roadway Character

Tables 4.56, 4.57, and 4.58 present the roadway character results for collisions involving pedestrians, cyclists, and PABSs, respectively. It was revealed that the largest frequency of collisions in both urban and rural NB occurred on undivided – 2-way, 2 lane roadways. Particularly, in urban areas, 69.9% (1884 collisions) of pedestrian-related collisions, 71.5% (1362 collisions) of cyclist-related collisions, and 73.2% (123 collisions) of PABS-related collisions occurred on undivided – 2-way, 2 lane roads. Additionally, approximately 20.0% of all three VRU-related collisions took place on undivided – 2-way, multi-lane roads. In terms of rural NB, 91.5% (400 collisions), 90.9% (281 collisions), and 94.3% (33 collisions) of collisions involving pedestrians, cyclists, and PABSs, respectively, occurred on undivided - 2-way, 2 lane roads.

Table 4.53: Pedestrian-to-Vehicle Collisions by Roadway Character

Roadway Character	Urban	%	Rural	%
Undivided – 1-way	155	5.7	7	1.6
Undivided – 2-way, 2 lane	1884	69.9	400	91.5
Undivided – 2-way, multilane	546	20.2	7	1.6
Divided – barrier	41	1.5	4	0.9
Divided – Median – No Barrier	30	1.1	14	3.2
Unknown	41	1.5	5	1.1

Table 4.54: Cyclist-to-Vehicle Collisions by Roadway Character

Roadway Character	Urban	%	Rural	%
Undivided – 1-way	58	3.0	7	2.3
Undivided – 2-way, 2 lane	1362	71.5	281	90.9
Undivided – 2-way, multilane	355	18.6	2	0.6
Divided – barrier	20	1.0	2	0.6
Divided – Median – No Barrier	19	1.0	6	1.9
Unknown	91	4.8	11	3.6

Table 4.55: Power-Assisted Bike and Scooter-to-Vehicle Collisions by Roadway Character

Roadway Character	Urban	%	Rural	%
Undivided – 1-way	7	4.2	0	0.0
Undivided – 2-way, 2 lane	123	73.2	33	94.3
Undivided – 2-way, multilane	34	20.2	1	2.9
Divided – barrier	0	0.0	0	0.0
Divided – Median – No Barrier	1	0.6	1	2.9
Unknown	3	1.8	0	0.0

5. DISCUSSION

The following chapter addresses all the major concerns associated with VRU-related collisions that were unusual or unexpected based on the frequency and trend analysis results. Further, the section discusses significant collision attribute results that were anticipated or common and the rationale behind it. Finally, the chapter provides several cost-effective safety countermeasures that could be implemented to reduce the severity and frequency of VRU-to-vehicle collisions in NB.

5.1 Temporal Factors

The first collision attribute that was analyzed was the year in which VRU-related collisions occurred. As stated, there was concern that the push to promote active transportation had increased the number of collisions involving VRUs; however, the analysis revealed the contrary. Over the 25-year period, collisions had significantly decreased in both urban and rural NB. In terms of the month in which VRU-related collisions occurred, the highest frequency was in the summer months for cyclists and PABSs. The results were unsurprising considering individuals are more likely to bike or ride a PABS during warmer seasons. On the other hand, the larger occurrence of pedestrian-related collisions that took place during the winter months was unexpected. Similar to cyclists and PABSs, it would be assumed that higher pedestrian traffic would have occurred during warmer months and thus resulting in more collisions. Ultimately, the larger frequency of collisions involving a pedestrian in winter months was assumed to be due to more dangerous driving and walking conditions. Regarding the day in which a collision occurred, it was anticipated that VRU collisions would increase throughout the week; however, the decline in collisions over the weekend was unexpected. In other studies, it was found that collisions most frequently occurred on weekends, specifically on Saturdays. Lastly, the time of day when a VRU-related collision took place was analyzed and the results were as expected. Specifically, it was predicted that the larger number of collisions would occur during peak traffic periods, typically around 6:00-10:00 AM and 3:00-7:00 PM. Generally, VRUs and motor vehicle drivers are traveling to and from work during these periods, which results in an increased risk of a collision due to greater exposure.

5.2 Road User Characteristics

The road user characteristics that were considered the most significant were the age of VRUs, driver experience, and the safety equipment utilized. Firstly, it was revealed that VRUs between the ages of 0 and 29 are significantly overrepresented in the data; however, the recent drop in collisions among this age group suggests that there were potentially less young VRUs walking or biking. In the past, the major concern surrounding VRU-related collisions was children, for instance the safe routes to school initiative. That being said, VRUs over the age of 40 are most recently emerging as a problem and therefore, it was important that safety countermeasures were focused on the two age groups discussed. Further, given that road users that identified as male were involved in the majority of collisions, countermeasures need to be directed towards that demographic.

The results concerning the number of years of experience of a motor vehicle driver, cyclist, or PABS driver were expected. In all cases, the largest frequency of collisions occurred between VRUs and motor vehicles driven by those with only 0 to 9 years of experience. Consequently, it was crucial to recommend specific safety countermeasures that target drivers with limited experience.

The findings associated with the safety equipment utilized by VRUs was particularly concerning. Unlike the results presented in the literature review, a large number of cyclists and PABS drivers were reported not wearing a helmet or other protective equipment when travelling. Essentially, collisions involving VRUs that do not wear the recommended safety equipment are more likely to result in a fatality.

5.3 Collision Factors

The severity of a collision, MCF, and pedestrian action were three important collision attributes. Considering pedestrians, cyclists, and PABS drivers are the most at risk in the event of a collision with a motor vehicle, it could be assumed that there would be a large number of collisions resulting in a personal injury or fatality. However, the results revealed a low percentage of fatal collisions involving a VRU in urban areas. Conversely, in rural areas, a fatal collision was more likely to occur, which could be due to several different factors including small shoulder widths, limited illumination during dark hours, higher speeds, etc.

The MCF was an important collision attribute that aided in determining safety countermeasures. Recurring MCFs associated with VRU collisions were driver inattention, pedestrian error/confusion, and failure to yield right-of-way. More specifically, the pedestrian action was critical considering it gives an indication of the location of the collision as well as the pedestrians movement. In urban areas, collisions typically occurred at an intersection whereas in rural areas, collisions generally took place while the pedestrian was walking on the roadway.

5.4 Road and Environmental Factors

Road characteristics that were considered significant to address were the posted speed limit, light condition, road surface condition, traffic control, and roadway alignment. Firstly, the legal speed limit results revealed that a large number of VRU-related collisions occur at 50 km/h speeds in urban areas and 80 km/h speeds in rural areas. This is expected given that the vast majority of urban roads are posted at 50 km/h and many rural roads are posted at 80 km/h. On another note, the severity of a collision generally increases as the posted speed limit increases, thus resulting in more fatalities. This was revealed in the pedestrian analysis, given that the number of collisions resulting in a pedestrian fatality significantly increased as the posted speed limit rose. Next, the light condition results were expected since the majority of collisions involving a VRU occurred in the daylight. Despite that, between 12.0% and 49.0% of VRU-related collisions occurred during the dark, with the highest frequencies in rural areas. These outcomes could be a result of inadequate illumination, narrow shoulders in rural areas, or driver inattention.

The number of collisions based on the road surface condition were expected as well, considering over 74.0% occurred on dry surfaces. Although, the frequency of collisions occurring on muddy surfaces stood out in the pedestrian analysis. Interestingly, under 2.5% of pedestrian- and cyclist-related collisions and approximately 14.0% of PABS-related collisions in rural areas occurred on surface conditions with snow. Considering the dangerous driving conditions in the winter season, a low frequency of collisions involving pedestrians was not anticipated.

The traffic control present during a collision involving a VRU was a considerable attribute to discuss. Though it was anticipated that the majority of VRU-related collisions would occur with no traffic control present, there were additional traffic control types that were surprising. For instance, 22.0% of pedestrian-related collisions occurred at a marked pedestrian crossing in urban areas of NB. A few reasons could be that pedestrians were assuming they were safe to cross and became less alert, the crossings could have potentially been poorly signed or marked, and/or pedestrians were more concentrated in these areas. In terms of cyclists and PABS-related collisions, a reasonable number of collisions took place at a traffic signal in urban areas and at a stop sign in rural areas. To determine the major cause of collisions occurring at traffic signals and stop signs, it would be beneficial to look at the MCFs. These collisions could likely be due to driver inattention or a disregard for the traffic control by the VRU or motor vehicle driver.

Finally, the roadway alignment analysis presented some interesting results. Although many VRU-related collisions occurred on level and straight roads, as high as 23.3% and 30.6% occurred on roadways with a curve in urban and rural NB, respectively. Several causes of collisions occurring on these types of roads could be connected to drivers taking the turn too quickly, low VRU visibility if the curve is sharp, or inadequate signage to warn drivers.

5.5 VRU Safety Countermeasures

5.5.1 Safety Equipment

Wearing safety equipment, especially while riding a bike or a PABS, is critical in reducing the severity of a collision. In several studies it was revealed that wearing a certified approved helmet can reduce the risk of severe head injury or fatality by over 60.0% (Olivier and Creighton 2016, Hagel *et al.* 2020). Alarmingly, only 1 in 4 cyclists in NB reported wearing a helmet and nearly 40.0% did not have safety equipment available to them or was available but did not use. Additionally, only about half of PABS drivers reported wearing a helmet when travelling in both urban and rural NB. Nonetheless, in order to increase the usage of helmets and protective equipment among cyclists and PABS drivers in NB, two major countermeasures are recommended. These safety countermeasures include developing education and enforcement programs to promote helmet use and target specific age groups. Specifically, cyclists and PABS drivers between the ages of 10 and 29 in urban areas and 29 years and under in rural areas, considering these age groups were considerably overrepresented in the data. Education programs may include education for younger users on helmet safety at schools or utilizing social marketing campaigns to increase helmet use and safety in older users. Additionally, more stringent helmet enforcement by police could be developed to increase helmet usage and compliance in the province. Currently in NB, the use of helmets for either cyclists or PABS drivers is compulsory in all ages; however even with the existing legislations helmet use remains relatively low. Further, these laws should enforce the usage of helmets that meet a specific safety standard.

Considering helmet laws and educational programs would likely be implemented province-wide, the countermeasures discussed could be utilized in both urban and rural NB. Ultimately, there has been compelling research and evidence revealing that helmet legislations increase helmet use as well as reduce the risk of head injuries (Hagel *et al.* 2020). However, there has not been significant indication that education programs increase the utilization of safety equipment in cyclists or PABS drivers given that it is very difficult to measure and given the lack of studies to prove it.

5.5.2 Training and Education

The implementation of road safety training initiatives and educational programs were the most common age-related safety countermeasures recommended in the literature. These programs aim to emphasize and increase awareness to the safety of VRUs and driver behavior. In terms of educational initiatives, classroom-based programs highlighting road safety could be implemented in elementary, middle, and high schools. A large frequency of cyclists and PABSs involved in a motor vehicle collision in this research were between the ages of 15 and 19 and had low driver experience years. Therefore, more emphasis on VRU safety at driver training centres could be beneficial in raising awareness to young VRUs. Considering a high frequency of drivers involved in a VRU-related collision were over the age of 20, media campaigns and public education could be enforced. These programs would put a spotlight on safe crossing behaviours, bicycle and PABS safety, increase visibility, and understanding signals, signs, and road rules. Other topics that should be considered based on the pattern and trend results of this report include MCFs, correlation between speed and collision severity, environmental conditions, traveling at night, and rural road safety.

A less common educational training countermeasure was the use of virtual reality to simulate road environments, specifically for cyclists. The virtual reality technology is most commonly utilized to simulate cyclist behavior and performance through various conditions. The results that are presented from these simulations can then be used to determine additional countermeasures to improve bicycle safety.

Ultimately, there are a lack of studies that provide evidence to support the effectiveness of training and education countermeasures in reducing VRU-related collisions. This is due to the fact that the efficiency of these countermeasures is very difficult to measure. It is recommended that, if training and education programs are implemented, they be highly targeted to VRUs and motor vehicle drivers that are commonly involved in a collision. More specifically, these initiatives should consider the age and driver experience of VRUs and motor vehicle drivers.

5.5.3 VRU Infrastructure

Based on the concerns identified through the analysis of VRU-to-vehicle collisions, there are a significant number of VRU infrastructure improvements that could be implemented in NB. It should be noted that the following countermeasures would only be utilized on a site-specific basis following a detailed review of VRU collision histories, as opposed to a mass province-wide implementation. Infrastructure improvements to reduce VRU-related collisions include:

- **Median Refuge Islands** are protected spaces along a multilane roadway that pedestrian and cyclists can take refuge in while crossing. Generally, it is recommended that median refuge islands are installed at midblock locations on a road with four lanes or more where there is a high volume of VRU activity. These islands are especially beneficial when the posted speed limit along a road is greater than 50 km/h. Considering a significant number of VRU-related collisions in NB occurred on multilane highway midblock locations with no crosswalk present as well as due to pedestrian error, refuge islands installed at targeted locations could be extremely advantageous. In addition to reducing pedestrian collisions by 32.0%, median refuge islands reduce the number of conflict points between pedestrians and motorists, reduce vehicle speeds, decrease exposure time for pedestrians and cyclists, and increase driver awareness (Hall *et al.* 2004).

- **Raised Pedestrian Crossings** are similar to marked crosswalks; however, the crosswalk is raised to meet the same elevation as the sidewalk, creating a ramped speed table across the width of the road. It is recommended that these crossings are installed along two or three lane roads, at midblock crossing locations, along roads that are posted at 50 km/h or less, and where there is a high volume of VRU activity (Hall *et al.* 2004). Given that a significant number of collisions in NB occurred at midblock locations with no marked crosswalk and due to drivers failing to yield right-of-way to VRUs, raised crossings placed at select locations could be beneficial. In addition to reducing pedestrian crashes by 45.0%, raised pedestrian crossings reduce vehicle speeds and increase the visibility of pedestrians and cyclists (Hall *et al.* 2004). Further, a study concluded that before a raised pedestrian crossing was installed, motorists only yielded to 10.0% of pedestrians; however, after the crossing was implemented, drivers yielded to 55.0% of pedestrians (Hall *et al.* 2004). It is important to note that these crossings in urban areas can impact the operation of buses, emergency vehicles, and snow plowing.
- **Wider Shoulders** and wider white edge lines to delineate shoulders in rural areas where there is significant pedestrian and vehicle volumes. Generally, narrow, and unpaved shoulders on rural roads force pedestrians to walk along the roadway with or against traffic. This became evident in the analysis considering nearly 33.0% of pedestrian collisions occurred as a result of pedestrians “walking on roadway with or against traffic” in rural areas. In addition to reducing collisions where VRUs travel

along the roadway by up to 71.0%, wider, paved shoulders provide a stable surface to travel on and increases the level of comfort for VRUs (Lagerwey *et al.* 2013). It is recommended that shoulders are paved and are a minimum width of 4 feet along both sides of high pedestrian and cyclist volume rural roads and highways (Lagerwey *et al.* 2013).

- **Curved Section Modifications** should be implemented at select locations considering between 20.9% and 30.6% of VRU-related collisions occurred on curved road sections. Improvements could include wider lanes and shoulders, improved delineation, and curve warning signs in target areas where pedestrian activity is high.
- **Bicycle Lanes** are sections of roadway that are designated to cyclists only and are distinguished by white pavement markings, symbols, and signage. These lanes can be applied on streets in both an urban and rural setting, with an ADT greater than 3,000, posted speed greater than 40 km/h, and on transit vehicle routes (NACTO 2013). In the case that traffic volumes are significantly high, posted speeds are high, and there is significant parking turnover, bicycle lanes with physical separation may be required (NACTO 2013). Some of the major benefits of implementing designated bike lanes are to provide a buffer between cyclists and motor vehicles, increase cyclist activity, provide a low stress experience for cyclists, increase driver attention to cyclists, and reduce conflicts with pedestrians on sidewalks (FHWA 2016, NACTO 2013). Although there are currently numerous bike lanes in the province, it is critical that these lanes are adequately connected to provide cyclists with a reliable bike route and are properly maintained. It is recommended that bike lane widths are a minimum of 4 feet; however, a desirable width is between 5 and 7 feet (ASHTO 2012, FHWA 2019).

The width will depend on the design feature adjacent to the bike lane including the curb, gutter, on-street parking lane, or guiderail. It is important to note that bicycle lanes that lack a physical buffer should not be greater than 7 feet, as reckless drivers may use the lane to pass other vehicles.

- **Leading Pedestrian Interval (LPI)** is a pedestrian signal timing that gives pedestrians 3 to 7 seconds to cross the roadway before vehicles are given a green indication. This type of pedestrian signal was recommended given that nearly 15% of VRU-related collisions occurred at an intersection with a traffic signal and a large number of collisions occurred due to driver inattention and pedestrian error. The LPI is typically utilized at signalized intersections with a high volume of turning vehicles as well as high pedestrian volumes. In addition to reducing pedestrian-vehicle collisions by up to 60%, LPIs increase the visibility of pedestrians crossing the roadway, give priority to pedestrians, reduce conflict points between VRUs and motor vehicles, and increase likelihood of drivers yielding to pedestrians (NACTO 2013). Based on several studies, it is recommended that the LPI is at least 3 seconds and up to 10 seconds if pedestrian volume is high and/or the crossing distance is long (NACTO 2013).
- **Exclusive Pedestrian Phase (EPP)** or a pedestrian scramble is a pedestrian signal timing that allows VRUs to cross any direction of roadway, even diagonally, at an intersection while all motor vehicles are stopped. Similar to LPI's, this type of pedestrian signal was recommended given that nearly 15% of VRU-related collisions occurred at an intersection with a traffic signal and a large number of collisions occurred as a result of driver inattention and pedestrian error. This type of phasing is

typically applied at signalized intersections with a high pedestrian volume, low speeds, and high conflicting turning vehicles (Hall *et al.* 2004). In addition to reducing pedestrian-vehicle collisions by approximately 50.0%, pedestrian scrambles reduce the number of pedestrian and vehicle conflicts, and pedestrians are able to cross both streets in one phase (Hall *et al*. 2004). However, the main disadvantage of EPPs is the loss of vehicle capacity at an intersection and therefore, can only be implemented in select locations.

5.5.4 Speed

A safety countermeasure that has become increasingly popular in several municipalities across Canada is the reduction of the legal speed limit from 50 km/h to 40 km/h. Recently, Calgary, Edmonton, Toronto, and Halifax have begun incorporating reduced speed limits on nearly all residential and high VRU traffic roads to 40 km/h, unless posted otherwise. In order to implement this countermeasure, municipalities are required to develop and post new speed limit signs to appropriate roads as well as promote a public education campaign to inform and enforce the speed limit change (City of Edmonton 2021). Alternative approaches to reducing speeds on high VRU traffic roads include traffic calming measures such as corner curb extensions, speed humps, chicanes, traffic circles, etc.

Implementing traffic calming measures and reduced speeds have numerous benefits to VRUs and have proved to be effective safety countermeasures. Firstly, the change from 50 km/h to 40 km/h provides drivers with more reaction time, which in turn reduces the breaking distance of a vehicle. Based on Edmonton’s speed reduction initiative, pedestrian survival rate at 40 km/hr (40.0%) is twice the rate of survival than at a speed of 50 km/hr (20.0%). Further, through countless studies, including this report, it has been established that collision severity significantly decreases as the impact speed decreases (City of Edmonton 2021). Ultimately, speed reduction measures create calmer and quieter roads as well as improve safety for all road users, including motor vehicle drivers.

5.5.5 Lighting

Pedestrians and cyclists travelling during dark conditions are more vulnerable and are at a higher risk of being involved in a collision with a motor vehicle. As shown in the frequency analysis, between 11.9% and 49.0% of collisions involving a VRU occurred at night. Generally, lighting along streets and at intersections are designed for motorists instead of for VRU movement. As a result, a study concluded that pedestrian fatalities are 3 to 6.75 times more likely to occur at night due to decreased visibility (Markowitz and Smith 2017). It is critical that illumination improvements are implemented and designed to meet the safety requirements for both motorists and VRUs. Streetlights in urban areas should be strategically and consistently installed to illuminate both sides of the street/road to provide appropriate illumination along the roadway (Lagerwey *et al.* 2013). Additionally, lighting designs should include adequate illumination along pedestrian crosswalks and at the approaches to the crosswalk instead of the traditional placement of one luminaire over the intersection (Lagerwey *et al.* 2021). Unlike urban areas, it is not practical to install illumination along long sections of rural roads as the benefit is reduced. Preferably, the use of lighting in rural areas should be targeted and only implemented for special circumstances. Two cases that were mentioned in the literature were at complex horizontal or vertical roadway geometry or in a concentrated area where the ratio of nighttime collisions is greater than daytime collisions (Field and Solomon 2011, Hall *et* *al.* 2004). Overall, implementing adequate lighting design has proven effective in reducing the severity and frequency of VRU-to-vehicle collisions.

Another important measure that would improve pedestrian, cyclist, and even PABS driver safety during dark conditions is the enforcement of retroreflective gear. In the event that adequate illumination is not provided, VRUs can be more visible to motor vehicle drivers when wearing reflective clothing and lights.

5.5.6 Autonomous Emergency Braking (AEB)

Presently, autonomous vehicle technology is undergoing major developments to reduce the frequency of fatal collisions. One major development that is highly discussed is an in-vehicle Autonomous Emergency Braking (AEB) system, which aims to avoid or reduce the risk of a collision with a pedestrian or cyclist by automatically applying the vehicles brakes. Typically, the AEB system will first provide a warning to the driver that a VRU is traveling in front of the vehicle. If the driver does not react in a certain amount of time, the system will automatically apply the brakes to avoid the collision. This type of system can be extremely valuable in urban areas when motor vehicle drivers are not alert, considering a large frequency of VRU-related occurred due to driver inattention. It is important to note that AEB systems do not work on high-speed roads, and therefore it is currently not beneficial in a rural setting to reduce collisions with VRUs.

Considering the AEB system has only recently been widely implemented, studies to determine the effectiveness of AEB is limited. However, based on several studies that simulated the effect of the system on a collisions outcome, effectiveness of the countermeasure was found to vary between 2.2% and 84.0% (Saadé 2017). Ultimately, AEB systems show promise of being proficient in reducing the frequency and severity of collisions involving VRUs in urban areas through reduced impact speeds.

6. CONCLUSION AND RECOMMENDATIONS

Vulnerable road users, including pedestrians, cyclists, and PABS drivers, are considered most at risk when involved in a collision with a motor vehicle. Through this study, the major patterns and trends were identified and investigated to better understand the causes and concerns associated with VRU-related collisions in NB. Research included developing a dataset of all VRU collisions in NB, analyzing the collision data through frequency and trend analysis, and recommending cost-effective countermeasures that road authorities can implement to improve VRU safety.

6.1 Conclusions

This research presented an analysis of VRU-to-motor vehicle collision data in NB between 1993 and 2017, through frequency and trend analysis. Specifically, common patterns and trends were identified in order to recommend safety countermeasures to reduce the frequency of pedestrian-, cyclist-, and PABS-related collisions in the province. Given the limited research on this topic, this study provided a better understanding of the factors influencing VRU-related collisions as well as measures that can be implemented by road authorities to improve pedestrian, cyclist, and PABS driver safety within NB.

Several collision attributes were investigated in this research including temporal, environmental, behavioural, demographic, and road characteristics. Some of the key findings in the analysis were:

- Vulnerable road user collisions have significantly decreased over the 25-year period,
- The frequency of VRU collisions peaked on Friday,

- VRU's under the age of 30 were significantly over-represented in the collision data,
- A low proportion of cyclists and PABS drivers were reported wearing helmet or safety equipment (22.7% to 54.7%),
- Male VRU's were involved in the majority of collisions (74.8% to 91.4%),
- Recurring major contributing factors were driver inattention (16.7% to 44.3%) and pedestrian error/confusion (30.3% to 32.9%),
- Severity of a collision increased as the speed of a vehicle increased,
- A fatality is more likely to occur in rural areas,
- A high frequency of collisions occurred during dark conditions (11.9% to 49.0%); and
- The majority of collisions occurred under ideal conditions (clear weather, dry road surface, daylight).

Finally, extensive research was completed to identify and support the effectiveness of the recommended safety countermeasures. The major countermeasures that were discussed were related to training and education initiatives to emphasize road safety for VRUs, VRU infrastructure improvements, speed reduction measures, improved illumination, and AEB systems for pedestrians and cyclists.

6.2 Recommendations for Further Research

This research serves as a baseline for future analysis of VRU-to-motor vehicle collisions in NB. The following section summarizes recommendations for analyzing VRU-related collisions through this research as well as for future research.

- In order to reduce the number of VRU fatalities, it is critical that all collisions resulting in a fatality are analyzed separately. From the frequency and trend analysis results of fatal collisions, relevant safety countermeasures could be recommended. Collision attributes that would be advantageous to analyze are time of day, age, safety equipment used, driver experience, vehicle type, MCF, pedestrian action, speed limit, light condition, environmental conditions, and road conditions.
- Considering there has been low reporting of helmet use in cyclist- and PABS-related collisions in NB, investigating further attributes associated with the safety equipment worn would be useful. Specifically, analyzing attributes like VRU age, speed limit, and severity of a collision when safety equipment is worn and when it is not.
- Generally, in rural areas of NB the road shoulders are unpaved and fairly narrow for VRUs to travel along. These conditions, along with higher speeds, can be particularly hazardous for pedestrians and cyclists. Recording the width and condition of shoulders in rural NB, specifically along a road where a collision occurred is a critical measure in determining the safety of VRUs and establishing safety countermeasures.
- Throughout the literature, the common method used to analyze VRU patterns and trends was regression models. Generally, the binomial and multivariable models were used to identify predictors of severe injury and fatal collisions, the significance of trends, and predict the odds of a fatal collision. Based on the analysis, collision attributes such as VRU and driver characteristics, time of day,

day of week, vehicle type, severity, speed, etc. could be investigated using a regression model to better understand their significance.

- It may be beneficial to analyze further collision attributes that are considered significant to identify patterns and trends and recommend other cost-effective safety countermeasures. For example, the accident configuration, pre-collision vehicle action, sequence of events, and other MCFs.
- A study could be conducted that provides estimates of the effectiveness of certain safety countermeasures discussed within this report. Similar to the Federal Highway Administration's Proven Safety Countermeasure initiative, the study would identify the effectiveness of specific countermeasures to reduce the severity of VRU-to-vehicle collisions through Collision Modification Factors (CMF) (FHWA 2017).
- In order to gain a better understanding of the influence of speed and injury severity of VRU-to-vehicle collisions, impact speed is important. In addition to recording the speed limit along the road where a collision occurred, it is recommended that the Report of Motor Vehicle Accident Form include an estimate of impact speed where possible.

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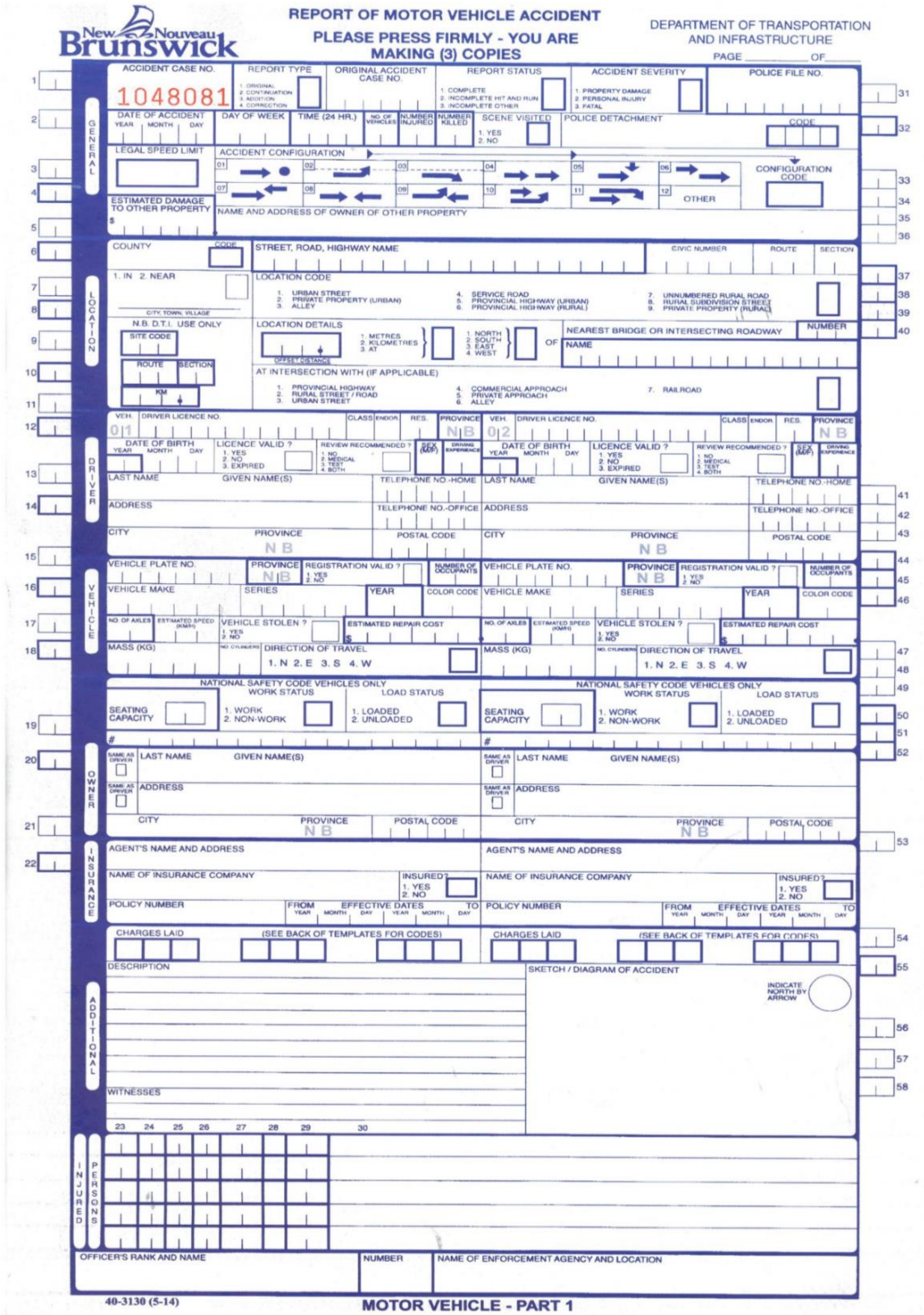
A. APPENDIX A – REPORT OF MOTOR VEHICLE ACCIDENT FORM


New Nouveau Brunswick

REPORT OF MOTOR VEHICLE ACCIDENT

PLEASE PRESS FIRMLY - YOU ARE MAKING (3) COPIES

DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE

PAGE ____ OF ____

GENERAL

ACCIDENT CASE NO. 1048081

REPORT TYPE: 1. ORIGINAL 2. CONTINUATION 3. ADDITION 4. CORRECTION

ORIGINAL ACCIDENT CASE NO.

REPORT STATUS: 1. COMPLETE 2. INCOMPLETE HIT AND RUN 3. INCOMPLETE OTHER

ACCIDENT SEVERITY: 1. PROPERTY DAMAGE 2. PERSONAL INJURY 3. FATAL

POLICE FILE NO.

DATE OF ACCIDENT (YEAR, MONTH, DAY) | DAY OF WEEK | TIME (24 HR.) | NO. OF VEHICLES | NUMBER INJURED | NUMBER KILLED | SCENE VISITED 1. YES 2. NO | POLICE DETACHMENT | CODE

LEGAL SPEED LIMIT

ACCIDENT CONFIGURATION: 01 02 03 04 05 06 07 08 09 10 11 12 OTHER | CONFIGURATION CODE

ESTIMATED DAMAGE TO OTHER PROPERTY $

NAME AND ADDRESS OF OWNER OF OTHER PROPERTY

LOCATION

COUNTY | CODE | STREET, ROAD, HIGHWAY NAME | CIVIC NUMBER | ROUTE | SECTION

1. IN 2. NEAR | CITY, TOWN, VILLAGE

LOCATION CODE: 1. URBAN STREET 2. PRIVATE PROPERTY (URBAN) 3. ALLEY 4. SERVICE ROAD 5. PROVINCIAL HIGHWAY (URBAN) 6. PROVINCIAL HIGHWAY (RURAL) 7. UNNUMBERED RURAL ROAD 8. RURAL SUBDIVISION STREET 9. PRIVATE PROPERTY (RURAL)

N.B. D.T.I. USE ONLY: SITE CODE | ROUTE | SECTION | KM

LOCATION DETAILS: OFFSET DISTANCE | 1. METRES 2. KILOMETRES 3. AT | 1. NORTH 2. SOUTH 3. EAST 4. WEST | OF | NEAREST BRIDGE OR INTERSECTING ROADWAY | NAME | NUMBER

AT INTERSECTION WITH (IF APPLICABLE): 1. PROVINCIAL HIGHWAY 2. RURAL STREET / ROAD 3. URBAN STREET 4. COMMERCIAL APPROACH 5. PRIVATE APPROACH 6. ALLEY 7. RAILROAD

DRIVER

VEH. 01 | DRIVER LICENCE NO. | CLASS | ENDOR. | RES. | PROVINCE N B

VEH. 02 | DRIVER LICENCE NO. | CLASS | ENDOR. | RES. | PROVINCE N B

DATE OF BIRTH (YEAR, MONTH, DAY) | LICENCE VALID ? 1. YES 2. NO 3. EXPIRED | REVIEW RECOMMENDED ? 1. NO 2. MEDICAL 3. TEST 4. BOTH | SEX (M/F) | DRIVING EXPERIENCE

LAST NAME | GIVEN NAME(S) | TELEPHONE NO.-HOME

ADDRESS | TELEPHONE NO.-OFFICE

CITY | PROVINCE N B | POSTAL CODE

VEHICLE

VEHICLE PLATE NO. | PROVINCE N B | REGISTRATION VALID ? 1. YES 2. NO | NUMBER OF OCCUPANTS

VEHICLE MAKE | SERIES | YEAR | COLOR CODE

NO. OF AXLES | ESTIMATED SPEED (KM/H) | VEHICLE STOLEN ? 1. YES 2. NO | ESTIMATED REPAIR COST $

MASS (KG) | NO. CYLINDERS | DIRECTION OF TRAVEL 1. N 2. E 3. S 4. W

NATIONAL SAFETY CODE VEHICLES ONLY

SEATING CAPACITY | WORK STATUS 1. WORK 2. NON-WORK | LOAD STATUS 1. LOADED 2. UNLOADED

OWNER

SAME AS DRIVER | LAST NAME | GIVEN NAME(S)

SAME AS DRIVER | ADDRESS

CITY | PROVINCE N B | POSTAL CODE

INSURANCE

AGENT'S NAME AND ADDRESS

NAME OF INSURANCE COMPANY | INSURED? 1. YES 2. NO

POLICY NUMBER | EFFECTIVE DATES FROM (YEAR, MONTH, DAY) TO (YEAR, MONTH, DAY)

ADDITIONAL

CHARGES LAID (SEE BACK OF TEMPLATES FOR CODES)

DESCRIPTION

SKETCH / DIAGRAM OF ACCIDENT | INDICATE NORTH BY ARROW

WITNESSES

INJURED PERSONS

23 24 25 26 27 28 29 30

OFFICER'S RANK AND NAME | NUMBER | NAME OF ENFORCEMENT AGENCY AND LOCATION

40-3130 (5-14)

MOTOR VEHICLE - PART 1

New Brunswick Nouveau-Brunswick

REPORT OF MOTOR VEHICLE ACCIDENT

PLEASE PRESS FIRMLY - YOU ARE MAKING (3) COPIES

DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE

1 LIGHT CONDITION
01. Daylight
02. Dark
03. Dusk
04. Dawn
05. Artificial Light

2 WEATHER CONDITION
01. Clear
02. Cloudy
03. Raining
04. Snowing
05. Sleet / Hail / Freezing Rain
06. Fog / Smoke / Smog
07. Drifting Snow / Dust
08. Strong Wind

3 V1 / 4 V2 ROAD SURFACE TYPE
01. Asphalt
02. Gravel
03. Dirt / Earth
04. Concrete
05. Chip Seal

5 V1 / 6 V2 ROAD SURFACE CONDITION
01. Dry
02. Snow
03. Ice
04. Wet
05. Muddy
06. Loose Gravel or Sand
07. Slush
08. Fresh Oil

7 V1 / 8 V2 UNUSUAL ROAD CONDITION
01. Under Construction
02. Under Repair
03. Holes, Ruts, Bumps
04. Changing Road Width
05. Flooded

9 V1 / 10 V2 ROADWAY ALIGNMENT
01. Level and Straight
02. Level and Curve
03. Straight with Grade
04. Curve with Grade
05. Top of Hill
06. Bottom of Hill

11 V1 / 12 V2 ROADWAY CHARACTER
01. Undivided - 1 Way
02. Undivided - 2 Way, 2 Lane
03. Undivided - 2 Way, Multi-Lane
04. Divided - Barrier
05. Divided - Median - No Barrier

13 V1 / 14 V2 TRAFFIC CONTROL
01. No Control Present
02. Traffic Signal
03. Flashing Traffic Signal
04. Stop Sign
05. Yield Sign
06. Marked Pedestrian Crossing
07. Reduced Speed Zone
08. Flagman / Police Officer
09. RR Crossing - No Control
10. RR Crossing - Signs, Crossbuck
11. RR Crossing - Signal
12. RR Crossing - Gates
13. RR Crossing - Watchman
14. No Passing Zone
15. School Bus Exhibiting Flashing Red Light

15 V1 / 16 V2 TRAFFIC CONTROL CONDITION
01. Functioning
02. Not Functioning
03. Missing
04. Vandalized

GENERAL CODES
97. Not Applicable
98. Unknown
99. Other, Specify in Comments

17 V1 / 18 V2 SPECIAL FACILITY
01. Interchange - Through Lane
02. Traffic Circle
03. Entrance Ramp
04. Exit Ramp
05. Overpass - Bridge
06. Underpass, Tunnel, Subway
07. Climbing Lane
08. Parking Lot
09. Dock / Wharf
10. Ferry

19 V1 / 20 V2 VEHICLE IDENTIFICATION
01. Passenger Car
21. Multi Purpose Veh / Passenger Van
02. Pickup Trucks under 4500 Kg
03. Panel / Cargo Van under 4500 Kg
04. Trucks 4500 Kg and over
05. Truck Tractor (Bobtail)
55. Truck Tractor with Towed Unit
06. Motorcycle
07. Motor Driven Cycle
08. Bicycle
09. Transit Bus
10. Inter-City Bus
11. School Bus
12. Other Bus
13. Ambulance / Police / Fire
14. Motorhome
15. Motorized Snow Vehicle
16. Construction and Maintenance - Equip
17. Farm Equipment
18. Off Highway Vehicle

21 V1 / 22 V2 TOWED UNIT
01. Tent Trailer
02. Travel Trailer
03. Boat Trailer
04. Utility Trailer
05. Farm Equipment
06. Towed Motor Vehicle
07. Low / High Bed (Semi)
08. Single Trailer (Semi)
09. Double Trailer (Semi)
10. Petroleum or Other Tanker (Semi)
11. Over-Dimensioned Vehicle No Pilot Vehicle
12. Over-Dimensioned Vehicle with Pilot Vehicle

POSITION IN / ON VEHICLE
01. Driver
02-10. Passenger
11. Riding or Hanging On
12. Pedestrian

EJECTION FROM VEHICLE
01. Not Ejected
02. Ejected
03. Partially Ejected

SAFETY EQUIPMENT USED
01. Lap & Shoulder Belt
02. Lap Belt
03. Seatbelts and Air Bag Deployed
04. Air Bag Deployed
05. Passive Seatbelts
06. Child Restraint
07. Helmets
08. Protective Clothing
09. None Available
10. Available Not Used

INJURY CODE
02. Minor - No Treatment
03. Moderate - Treated and Released
04. Major - Hospitalized
05. Fatal - At Scene or DOA
06. Fatal - Within 48 Hours
07. Fatal - Within 30 Days

23 Which Vehicle Occupied | 24 Position In / On Vehicle | 25 | 26 | 27 AGE | 28 | 29 | 30 NAME & ADDRESS

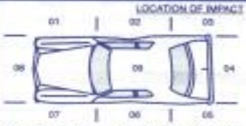
INJURED PERSONS

31 V1 / 32 V2 PRE-COLLISION VEHICLE ACTION
01. Going Straight Ahead
02. Turning Right
03. Turning Left
04. Making U-Turn
05. Starting From Parked Position
06. Entering Parked Position
07. Starting in Traffic
08. Slowing or Stopping
09. Stopped in Traffic
10. Parked Legally
11. Parked Illegally
12. Changing Lanes
13. Overtaking
14. Merging
15. Backing

MAJOR CONTRIBUTING FACTORS (V1: 33, 34, 35, 36; V2: 37, 38, 39, 40)
01. Driver Inattention
02. Driver Distraction
03. Had Been Drinking
04. Driving While Impaired
05. Extreme Fatigue
06. Fell Asleep
07. Driver Inexperience / Confusion
08. Lost Consciousness
09. Physical Disability
10. Prescription Medication
11. Drugs (Illegal)
12. Illness
13. Excessive Hours of Service
14. Use of Electronic Device
21. Failure to Yield Right-of-Way
22. Traffic Control Device Disregarded
23. Following Too Closely
24. Driving Too Fast for Road Conditions
25. Exceeding Speed Limit
26. Turning Improper
27. Passing or Lane Usage Improper
28. Backing Unsafely
29. Pedestrian Error / Confusion
30. Failed to Signal
31. Wrong Way
32. Taking Avoiding Action
33. Crossed Centre Line
40. Defective Brakes
42. Vision Obstruction / Obscured
43. Defective Steering
44. Suspension / Wheel Failure
45. Defective Tires
46. Defective Tow Hitch / Connection
47. Engine / Power Train
48. Hood / Door Opening
49. Vehicle Color / Dirty / Snow Covered
50. Jackknife / Trailer Swing
51. Vehicle Modifications
52. Exhaust
53. Load Shift
54. Over Dimensioned Vehicle
55. Electrical
56. Defective Headlights
57. Defective Rearlights
60. Animal Action (Deer)
61. Animal Action (Moose)
62. Animal Action (Other)
63. Surface Slippery
64. Loose Gravel
65. Snow Drift
66. Obstruction / Debris
67. View Obstructed / Limited
68. Glare
69. Construction Zone
70. Defective Driving Surface
71. Shoulders Defective / Inadequate
72. Lane Markings Inadequate
73. Traffic Control Device Not Working
74. Crosswind
75. Hydroplaning
76. Uninvolved Vehicle
77. Uninvolved Pedestrian
78. Presence of Prior Accident

SEQUENCE OF EVENTS (V1: 1ST EVENT 41, 2ND EVENT 42, 3RD EVENT 43; V2: 1ST EVENT 44, 2ND EVENT 45, 3RD EVENT 46)
01. Another Vehicle
02. Animal
03. Pedestrian
04. Bicyclist
05. Farm Machinery
06. Maintenance Machinery
07. Construction Machinery
08. Railroad Train
09. Other Movable Object
10. Debris
20. Ditch Bottom / Back Slope
21. Approach
22. Traffic Barricade
23. Sign Post
24. Traffic Signal Standard
25. Street Light Standard
26. Telephone / Power Pole
27. Guide Rail
28. Bridge Structure
29. Tree / Bush
30. Parking Meter
31. Building / Wall
32. Curbing
33. Fence
34. Culvert
35. Snow Embankment / Drift
36. Rock Cut
37. Delineator Posts
38. Fire Hydrant
39. Median / Barrier
40. Crash Cushion
41. Gravel Pile
42. Mail Box
43. Low Hanging Wires
49. Other Fixed Object
50. Ran Off Road
51. Overturned
52. Fire / Explosion
53. Submersion
54. Skidding / Sliding
55. Load Spilled

LOCATION OF IMPACT



10. Undercarriage
11. Interior
12. More Than Three Areas
13. Towed Unit

V1: PRIMARY IMPACT 47, OTHER DAMAGE 48, OTHER DAMAGE 49
V2: PRIMARY IMPACT 50, OTHER DAMAGE 51, OTHER DAMAGE 52

53 PEDESTRIAN ACTION
01. At Intersection, Crossing With Signal
02. At Intersection, Crossing Against Signal
03. At Intersection, Crossing, Marked X-Walk, No Signal
04. At Intersection, Crossing, No X-Walk, No Signal
05. Mid Block / Highway Crossing Marked X-Walk
06. Mid Block / Highway Crossing No X-Walk
07. Walking on Roadway with Traffic
08. Walking on Roadway Against Traffic
09. Emerging From in Front or Behind Parked Vehicle / Object
10. Running into Roadway
11. Getting On / Off School Bus
12. Getting On / Off Vehicle Other Than School Bus
13. On Sidewalk / Shoulder / Boulevard (Not on Roadway)
14. Pushing / Working On Vehicle
15. Playing on Roadway
16. Lying on Roadway
17. Hitch Hiking
18. Working on Roadway

DANGEROUS GOODS (V1 54, V2 55)
01. Explosives
02. Gases
03. Flammable Liquids
04. Flammable Solids
05. Oxidizing Substances
06. Poisonous and Infectious Substances
07. Radioactive Materials
08. Corrosive Substances
09. Miscellaneous Dangerous Substances or Articles

SPECIAL STUDIES (56, 57, 58)

OFFICER'S RANK AND NAME	NUMBER	NAME OF ENFORCEMENT AGENCY AND LOCATION

40-3130 (5-14)

Province / State Codes

Alberta	AB	Hawaii	HI	Ohio	OH
British Columbia	BC	Idaho	ID	Oklahoma	OK
Manitoba	MB	Illinois	IL	Oregon	OR
New Brunswick	NB	Indiana	IN	Pennsylvania	PA
Newfoundland	NL	Iowa	IA	Rhode Island	RI
Nova Scotia	NS	Kansas	KS	South Carolina	SC
Ontario	ON	Kentucky	KY	South Dakota	SD
Prince Edward Island	PE	Louisiana	LA	Tennessee	TN
Quebec	QC	Maine	ME	Texas	TX
Saskatchewan	SK	Maryland	MD	Utah	UT
Yukon Territory	YT	Massachusetts	MA	Vermont	VT
North West Territories	NT	Michigan	MI	Virginia	VA
		Minnesota	MN	Washington	WA
Alabama	AL	Mississippi	MS	West Virginia	WV
Alaska	AK	Missouri	MO	Wisconsin	WI
Arizona	AZ	Montana	MT	Wyoming	WY
Arkansas	AR	Nebraska	NE	Puerto Rico	PR
California	CA	Nevada	NV	Mexico	MX
Colorado	CO	New Hampshire	NH		
Connecticut	CT	New Jersey	NJ	Canadian Armed Forces	CF
Delaware	DE	New Mexico	NM	International Licence	IR
District of Columbia	DC	New York	NY	Other Foreign Licence	FE
Florida	FL	North Carolina	NC		
Georgia	GA	North Dakota	ND		

Colour Codes

White	01	Purple	08
Black	02	Brown	09
Red	03	Grey	10
Green	04	Gold	11
Blue	05	Silver	12
Yellow	06	Bronze	13
Orange	07		

Two-Tone Vehicle use most
Predominant Color

Other Codes

The following codes are to be utilized on the form where conditions warrant.

97- Not Applicable

98- Unknown

99- Other (Specify under Description)

CODES FOR CHARGES LAID

CODE	DEFINITION
600	Unregistered vehicle
608	Disobey stop sign
614	Fail to signal
628	Speed too fast for conditions
630	Drive without due care and attention
631	Following too closely
634	Fail to drive right of center
636	Improper lane change
638	Improper turn
641	Fail to yield right-of-way
646	Fail to yield to pedestrian
656	Disobey traffic signal
680	Inadequate brakes
721	Unsafe backing
723	No driver's licence
725	Operator not using seatbelt
708	Dangerous driving
709	Drive while suspended
711	Criminal negligence
712	Fail to remain
713	Impaired driving (includes 80 mg. offences)
714	Refuse breath test
900	Other offence (Specify under Description)

CURRICULUM VITAE

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Fredericton, New Brunswick
Bachelor of Science in Civil Engineering (2015-2020)

Publications:

Wood, T.M. 2020. Safety Implications Associated with Implementing Road Diets and Shared Spaces in Urban Communities. Published in the proceedings of the 2021 CTRF Annual Conference, Canadian Transportation Research Forum, Fredericton, NB, May 16, 2021.