A STUDY OF AGE DIFFERENCES IN ACCIDENT RATES AT INTERSECTIONS IN BRITISH COLUMBIA

by

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Bachelor of Science, University of Victoria, 2000

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

In the

Gerontology

Program

SIMON FRASER UNIVERSITY

August 2003

APPROVAL

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Abstract

The automobile has become the predominant form of transportation in Western society. With population aging, the proportion of older drivers will increase. This study's objective is to examine trends in accident rates by age utilizing aggregate data of passenger vehicle collisions for British Columbia from January 1st, 1996 to December 31st, 2000. The second objective is to examine accidents that occurred October 1st, 1996 to October 1st, 2001 at 39 Greater Vancouver Regional District intersections to test hypotheses pertaining to behavioral and environmental factors. Person-environment fit theory is used as a theoretical framework to determine the influence of the driving environment on accident risk as a person ages.

The results confirm that older drivers are more likely to have accidents at intersections than other locations. Interestingly, older female drivers were less likely to have accidents at intersections. Two older driver groups were more likely to have accidents when turning at an intersection. Fewer prior offenders had accidents. Of those who did, younger and older drivers were more likely to have accidents than were middle-aged drivers. Older and younger drivers were more likely to be assigned a contributing factor compared to middle-aged drivers. Older drivers were more likely to have accidents in daytime hours, in daylight and in clear/dry weather than the middle-aged group. Younger and three older age group categories were more likely to have accidents at intersections with fewer turning treatments compared to middle-aged drivers. The oldest drivers were more likely to have accidents at intersections with entrances/exists, and less likely at intersections with medians/dividers than middle-aged drivers. Older drivers were also more likely to have accidents at intersections with high visual environmental complexity than middle-aged drivers. However, for the 75-79 year age group accidents were more likely to occur at lower complexity intersections.

Overall, results of the study lend strong support that older drivers have higher adjusted accident rates at intersections. Various environmental factors within the intersection influence the proportion of accidents that occur across ages. Future road design should be performed with these factors kept in mind as the proportion of elderly drivers continues to grow.

Acknowledgement

I would like to take this opportunity to acknowledge several individuals who assisted and supported my efforts in the completion of this thesis. First, to my husband, Kevin, for his encouragement and words of motivation, that guided my achievements in the Master's Degree. To my family, Jane, Jim, Ann, and David, who have lent support and love through these endeavors. I am indebted to my sister, Ann, for her unfaltering friendship and assistance.

I would also like to affirm my gratitude to all members of my thesis committee Dr. Andrew Wister, Dr. Barbara Mitchell, Dr. Habib Chaudhury, and Dr. Robert Horsfall, for their provision of time and scholarly advice. Particular credit should go to my senior supervisor, Dr. Andrew Wister, for all of his guidance.

To Solicitor General Rich Coleman who substantiated my plea for assistance by promoting a corroboration with the "E" Division Traffic Services, Camera Unit of the Royal Canadian Mounted Police. A special thank you, to Constable Timothy Boynton, who advocated on my behalf for access to information through the Insurance Corporation of British Columbia and the Traffic Management Department of the City of Vancouver. Finally, I sincerely appreciate all of the assistance from the following people: Atiya Mahmood, Kathy Montgomery, John McCracken, John Ratel, Jack Lisman, and Wayne Meckle.

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CHAPTER 1: INTRODUCTION

1.1 Statement of the Problem

In Western society, the automobile has become the predominant form of transportation. The elderly driver now makes up an increasing proportion of the driving population. Yet, based on absolute number of accidents, the elderly have the lowest number of accidents (Motor Vehicle Branch, 2001). Indeed, there is a well known 'U'-shaped relationship between age and accident rates when hours and distance driven, termed the "corrected accident rate", are taken into account indicating that younger and older drivers have the highest corrected accident rate (Cobb & Coughlin, 1998; Millar, 1999; Retchin & Anapolle, 1993). For these reasons, the literature and research in this area has grown over recent years. One of the main questions that remains is: why do these accidents occur? Some have hypothesized that declines in the older driver's functional ability have increased the corrected accident rate (Ball & Owsley, 2000; Burns, 1999; Millar, 1999; Rothe, Cooper, & de Vries, 1990; Staplin & Lyles, 1991; Willis, 2000).

In addition, the intersection is one of the highest risk areas for older drivers with a higher proportion of accidents occurring at intersections than at any other location (Garber & Srinivasan, 1991a; Garber & Srinivasan 1991b; Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998; Staplin, Lococo, & Byington, 1998). Until recently roads and vehicles have been designed primarily for the use of younger drivers, while little consideration has gone into accommodating the needs of the older driver (Alicandri, Robinson, & Penney, 1999; Straight & Jackson, 1999; Tuokko & Hunter, 2002; Wister, Carriere, Sauter, & McWhirter, 2000). Little research exists regarding why intersections are so dangerous for the older driver.

Causes of accidents can be grouped into environmental (i.e., road design) and behavioral (i.e., driver pre-actions) elements. These components can be altered to increase safety on the roads for all age groups. However, it is unclear from the existing literature to what extent specific elements such as behavioral factors and environmental components individually or in combination compromise safe driving in older age groups. This highlights the need to examine declining function and increased environmental challenge, that is, it is necessary to combine person and environment in the context of accident rates among older drivers. The person-environment fit theory can be used to examine accidents that occur to determine if associated risk is related to an imbalance between the level of environmental demand and the driver's functional ability. A mismatch of these two variables may lead to a traffic accident.

1.2 Purpose of the Study

The primary purpose of this study is to examine accident rates at intersections for older and younger drivers in British Columbia who are operating passenger vehicles. It will also investigate trends in accident rates by age. The thesis first utilizes aggregate data on all accident rates for British Columbia from January 1st, 1996 through to December 31st, 2000 to accomplish this goal.

A second objective is to examine the level of complexity of intersections and determine if accident rates increase with rising environmental complexity. Accident rates obtained from a sample of 39 four-way light operated intersections in the Greater

Vancouver district are used to analyze the impact of intersection complexity and other contributing factors on the number of accidents by age groups during a five year time period (October 1st, 1996 to October 1st, 2001). Person-environment fit theory is used as a theoretical framework to understand the increasing importance of the driving environment on accident risk as a person ages.

1.3 Thesis Overview

This thesis presents an overview of the problems surrounding older drivers on the road through the examination of the implications that aging of the Canadian population have on the transformation of the driving population's demographics. Chapter Two, the Literature Review, is divided into six main parts. It commences (Section 2.2) with a detailed description of the influence population aging in British Columbia has on members of the older driving segment. It also reviews how prior research examined and evaluated the risks associated with driving for the general public. The research on older driver's safety is also reviewed because it influences future research objectives and informs policy makers.

Person-environment fit theory is outlined in Section 2.3. In Section 2.4, the intersection is discussed as an appropriate site to evaluate accident rates due to the greater prevalence of collisions that occur at this location. Elements of the intersection environment are examined for their influence on accident rates for older drivers. Possible environmental factors that may result in causal implications for accidents in older drivers are also reviewed. Section 2.5 briefly describes some of the terms utilized throughout the thesis. Statements of the hypotheses for this thesis are outlined in Section 2.6.

Chapter Three outlines the research methods used for this study as well as a description of aggregate and intersection data. The data source, the units of analysis, and the statistical techniques for data analysis are also discussed in detail. The variables are then analyzed using percentage differentials to determine if the results are significant, these findings are presented in Chapter Four, Results. A discussion, which summarizes the relevant findings and links them to the theoretical orientation and the proposed hypotheses, is presented in Chapter Five.

Finally, Chapter Six presents a discussion of the implications that the results may have on the older drivers' ability to retain his/her license. The chapter concludes with recommendations regarding future directions for both policy and research in the area of driving safety and older drivers.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter consists of four main parts. The first section provides an overview of aging and driving with an examination of the statistical methods used to evaluate risk to driving safety and a description of the issues surrounding these findings. It also introduces contributing variables influencing driving patterns of older persons. An overview of the person-environment fit theory is presented in the second section to provide a framework for understanding how attributes of the individual and person interact and influence driving. In the third section, intersections are considered as a form of environmental complexity. The final part of this chapter states the hypotheses of the thesis.

2.2 Overview: Aging and Driving

Driving safety has progressed since British Columbia's first regulation of drivers and motor vehicles in 1904, at which time legal speed limits were implemented (Office of the Superintendent of Motor Vehicles, 1999). However, it was not until 1920 that the Motor Vehicle Act was put into effect and four years later lifetime driver's licenses were first issued. In 1932 these licenses were to be reviewed annually (Office of the Superintendent of Motor Vehicles, 1999). The automobile as a mode of transportation has also advanced as the primary choice for mobility in the Western world (Rosenbloom, 1993). An automobile enables mobility, the ability to perform purposeful movement from one point to another through the environment (Ball & Owsley, 2000; Patla & Shumway-Cook, 1999). As a tool for mobility, the automobile is essential for independence and maintaining quality of life, as it may be the only available form of transportation for the older adult.

Issues regarding older drivers will assume even greater importance as Canada's population ages. The proportion of persons 65 years and older in British Columbia is expected to increase from 13.3% in 2001 to about 21% by 2025 (BC Statistics, 2002) (see Table 2.1). There are a number of reasons for the projected increase in the elderly population. As the baby boom generation ages, we will experience the fastest rate of population aging because of the relative size of this age group. Canada has experienced substantial declines in fertility rates with diminishing numbers in the younger age groups along with increased life expectancy (Gutman, Wister, Carriere, & Tredwell, 2000; Wister et al., 2000).

This rapid growth will result in an increase in the number of elderly who retain a valid driver's license (Cobb & Coughlin, 1998; McGwin & Brown, 1999; Millar, 1999; Waller, 1991). Chronological age has been found to be an insufficient indicator of safe driving ability for such a heterogeneous group partly due to the diversity of individuals of age 65 years and over (Alicandri et al., 1999; Rothe et al., 1990; Planek & Fowler, 1969; Tuokko & Hunter, 2002; Waller, 1991). Moreover, future older adults are unlikely to accept a society that treats them as a homogeneous group. This segment of our population will likely demand the development and creation of policies that enable them to actively participate and retain his/her independence by maintaining his/her ability to drive. Research is necessary to ascertain if this demographic transformation will have implications for older adults and society with respect to driving and road safety.

Research from the past indicates that the typical older driver is a male with many years of driving experience (Planek & Fowler, 1969). Population aging statistics along with changes in the roles of women over time indicate that older women may eventually represent the majority of older drivers (Rosenberg & Moore, 1997). Not only are women more likely to live longer, they are more likely to live alone and require independent mobility (Gutman et al., 2000; Rosenberg & Moore, 1997). There is a limited amount of research on driving safety for older adults that stratifies those 65 years and over into smaller age categories or separates them by gender to capture the unique characteristics of these different age groups.

Table 2.1: Projections for Percentage of British Columbia's Population Who Will Be 65 Years and Over in 2001, 2015, and 2025

Age Group	2001 (%)	2015 (%)	2025 (%)
65-69	3.7	5.6	6.5
70-74	3.3	3.9	5.4
75-79	2.8	2.8	4.2
80-84	1.9	2.0	2.5
85+	1.6	2.2	2.4
Total (65+)	13.3	16.5	21.0

** Data compiled from BC Population Forecast 02/05, British Columbia Statistics, Ministry of Finance and Corporate Relations, Victoria, B.C. (BC Statistics, 2002).*

2.2.1 Accident Patterns

Accident data as an outcome measure has provided the predominant way to examine driver and road safety. One of the primary issues for the assessment of driving safety is how to calculate risk. There are two conflicting techniques used in the analysis of statistical information to determine which segment of the driving population is most at risk with respect to safety on the road.

In the first technique, researchers have developed an accident index, where the actual number of accidents is expressed for each age group. These counts indicate that older drivers are relatively safe drivers, and younger drivers have the greatest number of accidents (Cobb & Coughlin, 1998; Motor Vehicle Branch, 2001; Rothe et al., 1990). However, many other researchers have statistically controlled for the distance traveled by different age groups to calculate risk of collision by exposure, because this varies by age (Gunderson, 1989; McCracken, Beattie, Strang, & Gauthier, 1998; McGwin & Brown, 1999; Millar, 1999; Park & Smith, 1991; Planek & Fowler, 1969; Reuben, Silliman, & Traines, 1988; Rothe et al., 1990; Simpson, Klein, Brennan, Krahn, Yee, & Skanes, 2000; Waller, 1991). Exposure to accident risk can be controlled by including distance traveled, mean hours driven, traffic volume, and number of licensed drivers per age group. These data create a U-shaped graph representing higher accident rates for those in the youngest and oldest segments of our driving population. This research indicates that when exposure is correlated with accident rate to calculate collision risk for older drivers, this segment of the population represents the highest risk group with accident rates increasing from the age of 55 years old (McCracken et al., 1998; Millar, 1999; Park &

Smith, 1991; Reuben et al., 1988). These studies controlled for the fact that older drivers reduced his/her risk exposure by decreasing driving time and distance traveled.

Recent literature indicates that gender may also be an issue. Statistical information on accident rates that are adjusted for risk exposure reveal that women 80 years and over have the highest incidence of accidents and are the fastest growing proportion of the driving population (Simpson et al., 2000; Straight & Jackson, 1999; Tuokko & Hunter, 2002).

Studies indicate that older age groups represent the greatest proportion of drivers involved in fatal accidents per mile driven (Cobb & Coughlin, 1998; Garber & Srinivasan, 1991a; Gunderson, 1989). Regardless of the decrease in mileage and time accrued behind the wheel, crash statistics on older drivers demonstrate that a greater proportion of accidents involve more serious consequences resulting in fatality or severe injury (Alicandri et al., 1999; Bedard, Stones, Guyatt, & Hirdes, 2001; Cobb & Coughlin, 1998; O'Neill, 1996; Peek-Asa, Dean, & Halbert, 1998; Zhang, Lindsay, Clarke, Robbins, & Mao, 2000). Recovery time from accidents is longer for elderly and traffic accidents are the leading cause of fatality by unintended injury for those 65 to 74 years old in the United States, probably due to greater fragility of the older age groups. In fact, death related to traffic accidents is second only to falls as a cause of death for those 75 years and older (Reuben et al., 1988; Sterns & Camp, 1998).

Interestingly, over the years, a substantial decline has occurred in mortality and morbidity rates from driving accidents in general for the total population. However, the proportion of older drivers involved in traffic accidents has increased (McGwin & Brown, 1999; Zhang et al., 2000). Older drivers are also more likely to be at fault in an accident (Cooper, Tallman, Tuokko, & Beattie, 1993; Garber & Srinivasan, 1991a; Gunderson, 1989; Planek & Fowler, 1969; Sosnowski, 2000).

In summary, this body of research has found that there are important age-related patterns in driving risk. Furthermore, friction exists in the dilemma between enabling people to drive as long as possible without risk to themselves, and the general public's right to a safe driving environment. These age-related patterns in accidents have heightened the awareness for the competing issues surrounding policy issues pertaining to older drivers.

2.2.2 The Policy Dilemma

Issues arise when there is a discrepancy between individuals ability to drive safely and his/her perception of his/her ability to drive safely. The primary problem is how to balance the interests of the older individual and the welfare of society. The responsibility to create a safe environment for all citizens is weighed against the responsibility to ensure that individual's rights to independence and freedom are not impinged.

Research has examined the importance of retaining a license for the older individual. In the United States, the loss of a driver's license in some states may mean more than limitations to mobility but also include consequences for other motorized vehicles such as motorbikes and motorboats (Doty, Heilman, Stewart, Bowers, & Rothi, 1993). Unfortunately, if driving privileges are revoked, there are limited options for alternative transportation for those who cannot drive. Some communities, especially rural communities, lack affordable and accessible public transportation (Coughlin & Cobb, 1998). Driving is seen by many as crucial to active participation in society, allowing older adults to incorporate a sense of continuity of freedom, independence and control of his/her lives through meaningful activities.

The retention of a license reflects not only social status, but also competency. A person's ability to accomplish activities of daily living is commonly used as a measure of abilities necessary to reside in independent living situations (Hare, 1992). The decision to stop driving is a life-altering event that is often made with great reluctance on the part of the older driver because it creates isolation and dependency on others for survival (Persson, 1993; Yassuda, Wilson, & von Mering, 1997). This infringement on the older adults autonomy and life space may decrease his/her quality of life (Ball & Owsley, 2000).

Many researchers have shown that there can be negative influences on an older person's well being and health when there are restrictions to his/her mobility (Hare, 1992; Johnson, 1999; Marottoli, Mendes de Leon, Glass, Williams, Cooney, Berkman, & Tinetti, 1997; O'Neill, 1996; Rittner & Kirk, 1995; Rogers, Meyer, Walker, & Fisk, 1998; Rowe & Kahn, 1997; Sosnowski, 2000; Straight & Jackson, 1999; Waller, 1991; Yassuda et al., 1997). Findings from the latter research have shown that increased loneliness, lower activity levels, depression, and lower general life satisfaction are all associated with driving cessation in the elderly.

Society can also be negatively influenced by the isolation of its older adult population by the creation of physical dependency through restriction of mobility (Yassuda et al., 1997). Instead of actively participating in society, older adults who no longer drive are often no longer able to contribute valuable financial and public services within his/her communities. The dependency created by driving cessation puts additional strain on family members who often are required to fill the transportation gap (Coughlin & Cobb, 1998; Sterns & Camp, 1998; Waller, 1991). Eisenhandler (1990) has argued that the importance of a driver's license is deeper than a functional asset utilized in everyday living, but that it is capable of creating a sense of personal and social identity.

As a symbol, the driver's license demonstrates universally that the individual is 'fit' to drive, therefore retaining competence and the ability to function within society. The driver's license symbolizes continuity of self and activity across a lifetime without restricting the person's social and personal identity through the use of chronological age or assigned categories (Eisenhandler, 1990; Gillins, 1990). From this perspective, the cessation of driving is a much more complex decision that may mean more than a loss of independence to many older adults, but perhaps is seen by some as a loss of his/her social identity.

Society also must have the assurance of safety within the traffic environment. The predominant method utilized to assess driving ability is a measure of 'fitness-to-drive'. In British Columbia, fitness to drive is determined primarily by a medical examination from a physician. The British Columbia Motor Vehicle Act requires a mandatory medical examination at the age of 80 years and every two years thereafter to ensure that an individual is capable to drive (British Columbia Medical Association, 1982; British Columbia Medical Association, 1997; Canadian Medical Association, 2000; Office of the Superintendent of Motor Vehicles, 1999; Tuokko & Hunter, 2002). If requirements and criteria outlined on the medical fitness form completed by a physician are not met, which is rare, further investigation is required such as a road test. This age-based testing originates from the common assumption that as a person ages, they can expect to experience some declines in both physical and cognitive performance. There is an increased prevalence of disease and chronic conditions with age (Hebert, 1997; Rosenberg & Moore, 1997; Waller, 1991). Much of the present research indicates that higher accident rates among seniors are linked to the presence of medical illness.

Age-related changes can be a result of normal physiological processes or abnormal pathological patterns (Schroots, 1996). Natural aging happens to everyone with gradual changes in both physical and cognitive abilities. The speed and timing of symptom onset, and extent of functional impairment is also varied. For example, vision loss may begin at age 50 years for some people whereas others may not experience vision loss until the age of 75 years. Medical examinations for fitness-to-drive have been supported through the vast literature on pathological related changes indicating that with age comes a greater propensity for certain diseases. These diseases often lead to chronic co-morbidity that adversely affect an individual's ability to drive safely (Gillins, 1990; Gunderson, 1989; O'Neill, 1996; Owsley, 1997; Reuben et al., 1988; Wallace, 1997). Prior research indicates that people 65 years and older have a higher prevalence of chronic diseases and are more likely to experience co-morbidity, as well as side effects from medications that may pose complications for driving safety. More specifically, the ability to drive safely can be encumbered by declines in sensory, motor, and cognitive function that can compromise manual dexterity, reaction time, and decision making skills (Alicandri et al., 1999; Canadian Ophthalmological Society Working Group on Driving Standards, 2000; Kaszniak, Keyl, & Albert, 1991; Sosnowski, 2000; Staplin & Lytes, 1991). Unfortunately, these declines in function are difficult to properly test due to the diversity of conditions, and their interaction with drug treatments, not to mention the individuality of response to the various situations.

Many researchers have argued that medical exams are not an adequate measure by which to assess ability to drive safely (Marshall, Spasoff, Nair, & van Walraven, 2002; McGwin & Brown, 1999; Supreme Court of Canada, 1999; Tuokko & Hunter, 2002; Waller, 1991). The latter literature indicates that medical professionals are not equipped to be arbitrators of fitness-to-drive because they are not able to test functional driving capabilities, but rather they can only form diagnostic labels that may have no relevance to that individual's actual ability to drive safely on the road (Gunderson, 1989).

Some researchers have specifically tested the ability of the medical exam to test actual danger as opposed to potential risk (Hakamies-Blomqvist, Johansson, & Lundberg, 1996; Johansson, Bronge, Lundberg, Persson, Seideman, & Viitanen, 1996; Reuben et al., 1988). This research compared accident data (a measure of actual danger) for countries that used medical exams as a screening tool for potential risk versus those who did not, and discovered no benefit to reducing actual crash rates. It is presumed that people can compensate for their deficiencies in driving by altering many variables such as avoiding high crash risk areas, driving slower, and driving only in good weather. Thus, although a vast amount of research has investigated the risk that diseases and normal aging pose for driving ability among older persons, causal associations are difficult to establish (Gunderson, 1989; Owsley, 1997; Reuben et al., 1988; Wallace, 1997).

To enable a clearer measure of fitness to drive, an assessment of the complete picture is necessary. Unfortunately, research to date has focused primarily on the person's physical limitations in the driving situation and has neglected to address the complete traffic environment and its role in restricting functioning. The traffic environment is made up of many different elements encompassing signage, design, and traffic flow. The traffic environment can also be referred to as a physical environment that is made up of nonsocial and non-personal aspects (Lawton, 1982). Researchers have recently begun to investigate environmental factors or dimensions that constrain mobility (Patla & Shumway-Cook, 1999; Shumway-Cook, Patla, Stewart, Ferrucci, Ciol, & Guralnik, 2002). However, there is a lack of research on the extent to which factors in the traffic environment that are extrinsic to the person are potentially reducing that individual's ability to drive.

Current literature regarding the influence of the traffic environment has focused primarily on younger males as the average test profile (Staplin et al., 1998; Waller, 1991). Accident rates have clearly indicated a need to examine the complex relationships that create the 'U'-shaped curve. Not only do accident rates enable examination of multiple variables, they are a more cost effective, less time consuming, and less risky method of determining driving safety, as opposed to alternative measures such as road or simulator tests (Dobbs, Heller, & Schopflocher, 1998; Willis, 2000). Utilizing accident rates is a more reliable method due to its non-subjective nature relative to medical examinations and self-graduation at predicting those who pose an actual danger to the general public (Cooper et al., 1993; Cox & Cox, 1998; Marottoli, 1997; Marshall et al., 2002; O'Neill, 1996; Waller, 1991). Accident rates also allow cross-data comparisons while controlling for extraneous variables such as number of licensed individuals per age group and volume of traffic at any given area. This approach is necessary to enable research to focus on specific elements within the traffic environment that may pose a higher risk to older drivers.

The imbalance between the environment and personal need will result in reducing the older driver's ability to drive safely, creating a handicap for that individual. A handicap has been defined as the result of an inadequacy of environmental circumstances limiting the individual's ability to function (World Health Organization, 1980; Wister et al., 2000). When an older driver interacts with a complex traffic environment, the dimensions of this external environment may constrain his/her ability to drive safely. It is this interaction between the factors extrinsic to the older driver, such as the traffic environment, and the resulting behavior of the person that can be used to evaluate the outcome measure (accident rates) that this thesis will investigate.

2.3 Theoretical framework: Person-Environment Fit

Some researchers argue that the focus of attention in the driving literature has been on how to modify habits and lifestyles of the individual rather than how to provide interventions and resources in the traffic environment (Lawton, 1982; Stokols, 1992; Wahl, Oswald, & Zimprich, 1999; Willis, 2000). Given that the focus of research has been to examine declines in age-related driver characteristics, consideration of the environmental and contextual demands of driving has only been given secondary consideration. This is unfortunate in light of the importance of environmental elements for their direct influence on driving safety. As an adjunct to the growing empirical evidence focusing on a driver's characteristics, it is important that the environmental complexity of the traffic system be brought into the equation since behavior cannot be studied in absence of its context. This requires consideration of theory.

The person-environment fit framework came from the examination of the interactions between organisms and their environments at a broad level referred to as the study of ecology (Stokols, 1992). Concepts such as environmental press and competence arose from earlier attempts at theorizing (Lawton, 1970; Lawton & Nahemow, 1973; Lawton & Simon, 1968). This early research applied the theoretical concepts to social relationships and housing. In 1980, Lawton integrated previous work as he developed the person-environment fit framework. Research has used this framework to continue the examination of environmental modifications for housing and institutions and expanded by using the theory to measure competency levels for those who are impaired physically (Messecar, 2000; Wahl et al., 1999).

The person-environment fit model enables an examination of the interaction between the environment and individual. This model is appropriate for several reasons; it assumes that deficits in function are not only associated with the interaction between chronological age and behavior, but that environments can be the underlying factor limiting the person's ability to function (Lawton, 1982). The person-environment fit model investigates the dynamic interplay between individuals and his/her contextual environment but with a focus on the built environment (Lawton, 1980; Lawton, 1982; Messecar, 2000; Willis, 2000). There is the assumption that the congruence or fit between the traffic environment and the older driver will result in positive outcomes such as reduction in the consequences of collisions and accident rates. It is believed that a person's behavior is influenced by a combination of physical environment and level of ability. In this way, the demands or press of the traffic environment influence the older driver's capabilities. If the environmental demand is too great, then drivers ability to adapt to the elements in the traffic environment may be jeopardized, thus reducing his/her safety on the road. An alternative explanation is that the driver has inadequate skills for that environment. A balance must be sought between the driver's abilities and the traffic environment to alleviate the risk to driving safety.

The physical and structural elements of this traffic environment are believed to create behavioral demands on the individual producing what is referred to as environmental press. Lawton (1980) proposed that the individual copes with this environmental press through a set of competencies made up of domains that include sensory-motor functioning, biological health, ego strength, and cognition. All of these domains are relevant to behaviors necessary for safe driving. Older drivers may experience deficits in certain areas that will have varied influences on his/her driving behavior. The outcome depends on his/her ability to adapt to the changing environments and the complexity of these environmental contexts.

In order to deal with demanding traffic environments such as intersections, drivers must have adequate executive functioning. Executive functioning, a form of higher level decision making, enables a person to perform dual tasks or simultaneously utilize multiple sources of information (Willis, 2000). Due to the increased prevalence of chronic disease and disability in older adults, this segment of the population is subject to more reductions in the domains of competence than younger age groups. Reduced competency can be countered through environmental adaptation by viewing the environment as a form of resource. By utilizing the person-environment fit framework, an evaluation of what environmental factors create an imbalance for older drivers can be identified. Changes at the environmental level can be made to structural elements in the driving context to mitigate the negative effects experienced by those of all ages with lower driving skills.

There is a linear relationship between environmental press and an individual's level of competence (Lawton, 1980; Wallace & Bergeman, 1997; Willis, 2000). When there is too much environmental press for the given level of competence, a stress threshold is surpassed. The result is a reduction in the ability to compensate and perform appropriately. But when the level of competence matches the environmental press, a balance is achieved producing the desired outcomes such as reduction in accident rates.

For the older driver, where certain competencies may be reduced, the impact of the environmental components will have a greater influence on the ability to drive safely. This is supported by the 'environmental docility hypothesis', which argues that more complex environments are expected to negatively influence those with lower competence (Lawton, 1980; Wahl et al., 1999). It is not the reduced driving capabilities in groups such as older drivers or the increased environmental press in certain contexts such as intersections that individually lead to variability in outcomes. Rather, it is the fit or lack of fit between these two components (Kahana, 1982). For these reasons the person-environment fit framework is useful in analyzing outcome measures such as accident rates, and can be used to evaluate the balance between the complexity of the traffic environment and the older driver's capabilities in specific contextual settings.

2.4 Intersections as a Form of Environmental Complexity

The intersection is a specific physical environment that is made up of many elements. These components create a complex traffic environment that is ideal for testing the person-environment fit theory. Notably, the intersection is a traffic location with a high concentration of traffic and increased structural complexity. As such, it represents a specific context that has presented a greater risk for older drivers. Indeed, research indicates that intersections in comparison to other locations produce one of the highest accident rates for older drivers when controlling for risk exposure (Garber & Srinivasan, 1991a; Garber & Srinivasan, 1991b; Preusser et al., 1998; Staplin et al., 1998). Statistics from British Columbia police reported accidents indicates that 44.1% of collisions occur at intersections (Motor Vehicle Branch, 2001). Driver errors that are intersection-related, such as turning across traffic and ignoring traffic control devices, increase with age (Rothe et al., 1990). This suggests that accident causation is the result of the interaction between aspects of the driver's behavior and the elements of the environmental context. The intersection is thus a good location to test the importance and contribution that different components of this environment have on accident occurrence in older drivers.

Focusing on a specific environment with a high propensity for accidents in all age groups, such as the intersection, enables a more focused evaluation of the person-environment fit theory. Factors in this traffic environment can be categorized and tested for their individual contribution towards accident risk. Intersections can be classified by type such as cross or T intersections allowing researchers to perform comparative analysis on the influences of different environmental factors while controlling for intersection design. There are three categories commonly used in the literature to examine the interaction between the elements of the traffic environment and the driver (Organization for Economic Co-operation & Development, 1976). These encompass both subjective and objective components including demographic factors, behavioral elements, natural environmental characteristics, and visual complexity, including road characteristics, as summarized in Figure 2.1.

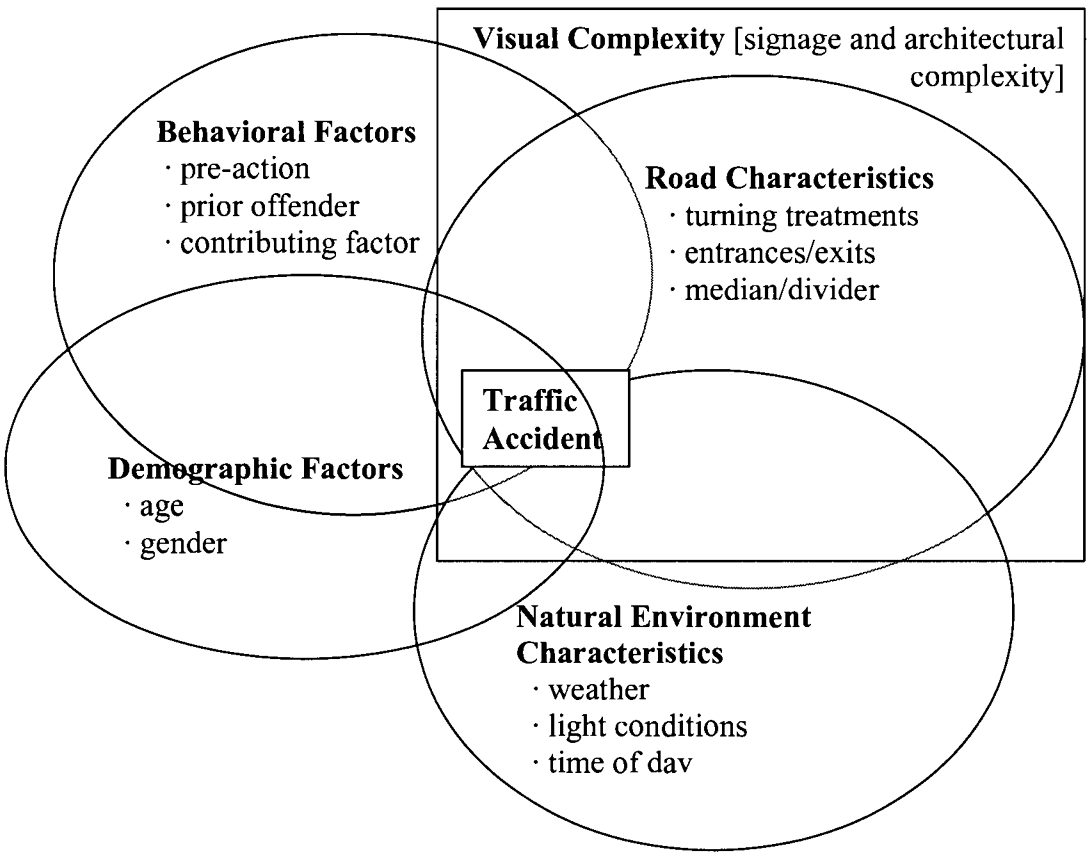


Figure 2.1. Interactions Between Elements of the Traffic Environment and the Driver in a Traffic Accident.

Literature from the social sciences has focused almost exclusively on the behavioral factors that contribute to the increased risk of accidents for the older driver (Ball & Owsley, 2000; Burns, 1999; Millar, 1999; Rothe et al., 1990; Staplin & Lytes, 1991; Willis, 2000). As noted earlier, this work has linked age-related deficiencies to accident risk in older adults. A study by Preusser et al. (1998) focused on older drivers and investigated fatal crash risk at intersections. This study supported the theory that certain behaviors such as failure to yield are common in older age groups and lead to increased accidents at intersections. Some researchers who utilize data from police accident reports have also examined the driver's actions before the accident occurred (i.e., pre-actions such as turning or proceeding straight) along with other contributing factors such as ignoring traffic control devices or driving without due care (Rothe et al., 1990; Garber & Srinivasan, 1991a). The latter literature found that these behaviors did relate to risk of accidents in older drivers. However, these studies focused on only one dimension of the traffic accident.

The most basic environment to test is the natural environment (i.e., weather and light). Both engineers and behavioral scientists have examined the influence of the natural environment on mobility (Appleyard, 1973; Patla & Shumway-Cook, 1999). The influence of the natural environment on driving has been examined by using police post-accident reports that include measures of weather, time of day, and lighting. Interestingly, the statistics from these police reports indicate that most accidents occur in daylight (62.7%) when visibility is good with clear weather (48.3%) and when the roads are dry (61.8%) (Motor Vehicle Branch, 2001). However, these data do not control for distance traveled or volume nor are they examined specifically for occurrence at intersections. Further, none of these analyses were differentiated by age groups. Rothe et al. (1990) were able to demonstrate that older adults are more likely to avoid the less than ideal driving conditions. For example, they avoid peak traffic hours, poor road conditions, and night driving. However, this study also found that older drivers are more likely to have an accident when there is a combined effect of poor road conditions and visibility such as a rainy night (Rothe et al., 1990). Unfortunately, these environmental factors are neither predictable nor can they be controlled by the driver rendering their effectiveness as a possible level for intervention insufficient. Although we may not be able to manipulate or change weather conditions, older drivers can use the information from studies on the influence of weather to self-regulate his/her driving behavior.

From the perspective of prevention, it is the road characteristics of the intersection that are of greatest interest because we have the ability to change these environmental elements. The road characteristics are the structural traffic-related components of the traffic environment (Appleyard, 1973; Organization for Economic Co-operation & Development, 1976; Willis, 2000). The road environment is made up of structural elements that influence the traffic flow.

With continuously changing traffic patterns that increase the risk of accidents for all drivers, the intersection is the most complex traffic environment. Components of the intersection environment have been studied for their relevance to accident risk in older drivers. The driving behavior that presents the greatest risk for older drivers at an intersection is the left-turn action. This action requires the ability to multitask, which can be limited in those experiencing reductions in physical functions.

Garber and Srinivasan (1991b) found that older drivers had more accidents at intersections with an increased volume of left-turn traffic. So, not only do older drivers have difficulty with this operation, but also they seem to be at higher risk in intersections with a high volume of left-turn behavior. Left-turn treatments at intersections include the creation of separate turn-lanes, signalized turning lights, lane markings, and traffic signs that range from no turning to specifying the direction in which to turn. This clearly indicates the importance of studying more than one aspect of the collision since structural elements can influence behavior.

Researchers have discovered that the creation of separate left-turn lanes and signalized turning lights results in reduced accident rates for older drivers at intersections (Garber & Srinivasan, 1991b; Marottoli, 1997; Pline, 1996; Staplin et al., 1998). However, the influences of these turning treatments were not tested in conjunction with other components but separately. For example, the presence or absence of left-turn lanes at intersections is evaluated for associated risk. The latter literature also indicates that other road treatments such as directional signage both posted and in the form of road markings also decreases the accident risk for older adults. In addition, this research has shown that some structural elements, such as medians, can change the physical design of an intersection to prevent accidents and reduce the impact on surrounding traffic when an accident does occur. The influence of these structural factors at an intersection has not been measured across age while controlling for exposure and volume.

Unfortunately, environmental components are not always used when safety measures indicate that their construction would be beneficial in reducing accident rates. Often structural limitations to high-density areas that reduce the ability to expand the road width restrict the use of medians and left-turn lanes. Traffic flow (i.e., traffic volume and delay) is also given priority in determining if these structural elements should be implemented. However, this thesis will investigate the importance of structural components such as turning treatments, and medians/dividers in reducing accident rates for older drivers. It will evaluate the importance of structural factors for different age groups while controlling for exposure and volume. It also will examine structural elements such as entrances and exits at intersections that may influence the flow of traffic increasing the risk of accidents for older drivers. This part of the traffic environment can be manipulated to fit the older driver's ability to prolong the retention of a driver's license and reduce the risk of accidents. For example, separate turning lanes or traffic signs can be implemented at intersections to alter the flow and direction of traffic. Changes can range from small changes in signage to large changes in the design of the intersection.

The traffic flow is also of great importance to the safety of the traffic environment. High-volume intersections are sometimes selected as the focus for risk assessment because of the increased risk of accidents (Pline, 1996). The measure of volume is based on traffic counts representing the number of cars traveling in each direction within certain time periods. For example, peak time periods often are referred to as rush hour. The analysis of traffic flow has not included the difference in zoning of different areas such as residential or commercial areas. This differentiation could help account for distinguishing characteristics of various intersections such as pedestrian traffic and visual complexity (i.e., signage and architectural complexity).

Research has begun to assess the elements of the traffic environment individually for their importance in reducing the risk of accidents for older drivers. However, little attention has been given to a number of these environmental factors. Although each of the elements making up the traffic environment at an intersection may have an individual influence on accident rates in older drivers, it is the interaction of all of these different components that creates the perceived or visual traffic environment. The visual traffic environment is what is actually experienced by the driver, including everything in the driver's visual field. Research on the older driver has not examined the complexity of the visual traffic environment as a separate entity. As mentioned earlier, older drivers may experience difficulty with situations that require multitasking and in complex environments, such as the intersection.

2.5 Definitions

It is important to clarify some of the terminology utilized in this thesis and to identify any differences from the existing literature in the area of driving and the older adult. This will enable the utilization of information found in this thesis for future research.

The most common definition of the older driver is a person 65 years and older. However, the literature in the area of driving and older adults has sometimes utilized varying ages as the cut off for defining older drivers, ranging from 50 to 70 years old. Declines in physical and cognitive performance can begin around 50 years of age. Although the experience of age related declines vary from one person to the next, the influence of age related declines begin to appear to varying extents after the age of 50 in the majority of people. Unfortunately, these classifications are misleading because they create the assumption that a 60 year old driver has a similar level of function and associated risk as a 90 year old driver.

The specific traffic environment of interest in this thesis is the intersection. This location has been chosen not only because of the risks associated with it for older drivers, but to control for different intersection designs enabling a comparative analysis. For this thesis, the cross-intersection design has been chosen because it is the most common design. The cross intersection has four different directions that enter and emerge from the intersection (see Figure 2.2). This thesis focuses on those four-way intersections that are light operated.

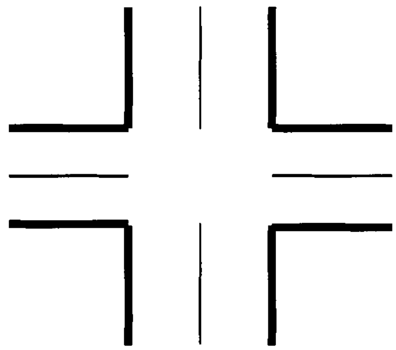


Figure 2.2. **The Cross Intersection**

The formal definition of an intersection is the area beyond the crosswalk called the quadrangle. In this definition, an accident would have to occur after the cars have crossed the pedestrian crosswalk into the center of an intersection to be classified as an intersection accident. However, the working definition of an intersection utilized by a police officer can encompass a much larger area. In police attended accidents, the location of an accident is determined by the attending police officer post accident. The definition of the location (i.e., intersection) is dependent on that officer's training, employment district, and subjective assessment. For the purpose of this study, the intersection is defined by the attending police officer in the post accident report.

As a traffic environment, the intersection is a location where the behavioral factors, natural environmental factors, and factors of the road environment interact with each other resulting in a combined influence on the older driver's accident risk. This complexity is what the driver experiences. The level of complexity at the intersection is comprised of visual stimuli presented to the driver including signage and architectural complexity. Signage complexity is based on the evaluation of all traffic and commercial signs within the visual parameters of the intersection that the driver may divert some of his/her attention. The number of signs, size, color, and location may influence signage complexity. Architectural complexity is an evaluation of the structural features surrounding the intersection. These structures not only can increase the complexity of the intersection through the number of structures increasing the density of objects in the visual field, but through their height, variation of form, and complexity. The creation of a scale to rate the complexity of intersections would enable the development of guidelines that were age sensitive.

2.6 Hypotheses

Based upon the previous review of empirical and theoretical literature, a number of hypotheses can be identified for testing. The age patterns comprised in the hypotheses pertain to the U-shape distribution found in the literature. Specifically, the following six hypotheses will be tested in this thesis:

1) The proportion of intersection accidents increases with age.
2) The oldest drivers have more accidents at intersections than other age groups after controlling for the number of licensed drivers.

3) Behavioral factors (i.e., pre-action, prior offender, and contributing factors) will be associated with age patterns in adjusted accident rates at intersections.

4) Natural environment factors (i.e., time of day, illumination, and weather) will be associated with age patterns in adjusted accident rates at intersections.

5) Road environment factors (i.e., turning treatments, entrances/exits, and medians/dividers) will be associated with age patterns in adjusted accident rates at intersections.

6) Visual environmental complexity (i.e., signage and architectural complexity) will be associated with age patterns in adjusted accident rates at intersections.

Hypothesis three through six do not provide the direction of association because of the complexity of the different variables but elaboration can be found in the results section in Chapter Four.

2.7 Summary

While automobiles were once used as a leisure form of transportation, they are now essential for mobility. Driving is essential for an older adult's independence because mobility is required for the acquisition of basic resources. Unfortunately, alternative transportation is often lacking or insufficient. The increase in the proportion of Canada's elderly population has lead researchers to investigate the safety of the older driver. Previous research indicates that older drivers are one of the lowest risk segments of the driving population because as a group they have the least number of accidents per age group. However, recent evaluations of accident risk have adjusted for exposure (i.e., distance or hours traveled) and have discovered that older drivers, along with the younger drivers, present the highest risk to themselves and others.

Research has found an association in older drivers of increased accident risk to physical and cognitive declines associated with the aging process. There is variation between individuals, but age related declines in driving ability may increase the accident risk in this segment of the population. The ideal objective for researchers is to increase safety on the road and enable older adults to retain his/her mobility for longer. Unfortunately, declines associated with aging are often not reversible and no remedies have been discovered to stop this aging process. An alternative approach to this situation is to examine the environmental factors that could be creating a demand that exceeds the older driver's level of competence or ability. The person-environment fit theory enables an evaluation of the congruency or fit between the older driver and the traffic environment. If the environment is too demanding, the accident risk is expected to increase. However, if a balance is created between the older driver's abilities and the demand of the environment, the risk is reduced.

The intersection is a traffic environment that is good for testing the person-environment fit theory. This location has a high accident risk and comparative research can evaluate the impact specific components of the traffic environment have on accident rates. There are three dimensions of the intersection environment that have been studied. These relate to the driver's behavior, elements of the natural environment, and road characteristics (see Figure 2.1).

The majority of the literature has focused on the influence the older driver's behavior has on accident risk, supporting the belief that functional declines and diseases associated with aging increase this risk. Research investigating the influence that the natural environment has on the older driver has indicated that older drivers avoid driving under less desirable conditions (Motor Vehicle Branch, 2001; Rothe et al., 1990). However, when there is a combination of factors from the natural environment that interact with the older driver, this segment of the driving population has a greater risk of accidents. Researchers have also discovered that some of the elements of the road environment including left-turn treatments, signage treatments, and other design factors that relate to traffic flow can influence the accident risk for older drivers at intersections. Unfortunately, the research evaluating the combined influence of physical components in the traffic environment that could benefit older drivers is limited. The combined influence of elements in the traffic environment (i.e., signage and architectural complexity) on the older driver has not yet been examined. These structures are what the older driver is exposed to when navigating through an intersection and can be referred to as the perceived environment. The multiple stimuli at an intersection may increase the level of visual complexity or demand that the environment has on the driver.

This thesis hypothesizes that the oldest drivers have more accidents at intersections than other age groups when controlling for the number of licensed drivers. It will evaluate this hypothesis by stratifying data into five-year age groups, and not just lump drivers 65 years old and above into one large age group. It also hypothesizes that behavior (pre-action, prior offender, contributing factors), natural environment (time of day, illumination, weather), road environment (turning treatments, entrances/exits, median/divider), in combination with visual environmental complexity (signage and architectural complexity) will be associated with age patterns in adjusted accident rates at intersections. Specifics regarding the direction of the latter associations are presented in Chapter Four, Results, because of the complexity of the different variables. These hypotheses will be examined by comparing a cross-section of the younger (16 to 19 years) and the older (80 years and over) age groups to a control middle-age group (40 to 44 years) for each category in a variable. The reconstruction of intersections to reduce accident rates for older drivers would not only benefit older age groups by enabling them to retain mobility for a longer period, but structural changes would create a safer traffic environment for all.

CHAPTER 3: METHODS

3.1 Data Collection and Source

This thesis utilizes data in British Columbia's Traffic Accident System for a five-year time frame from the Road Safety Research Department of the Insurance Corporation of British Columbia (ICBC). The information was requested through the 'E' Division Traffic Services, Camera Unit of the Royal Canadian Mounted Police (RCMP). The data requested include collision information from police reports where accidents involved death, personal injury, or vehicle material damage over $1,000, and were attended by a police officer. Information on unattended collisions was not obtained because the data collected on these accidents were self reported, less inclusive, subjective, and less accurate. The attending police officer completes the Traffic Accident Police Investigation Report (MV6020) form from which the information for this thesis is collected. Data collected in these police reports were obtained for each driver at the scene of the accident. The attending police officer collected information on the driver's demographic data, the events surrounding the collision, the driver's behavior and natural environment variables. Further data were requested from the ICBC driver records and insurance files, on prior offences of each driver involved in an accident and the number of licensed drivers by age and gender.

A number of different data sets are acquired from ICBC. The first part of this thesis analyzes the data files containing collision data in aggregate form for all police attended accidents across British Columbia and at intersections in British Columbia as well as the number of licensed drivers in British Columbia. The aggregate data files called 'all accidents' and 'intersection accidents' include British Columbia driver counts and accidents by age and gender from January 1st, 1996 to December 1st, 2001. The data file on the number of 'licensed drivers' in British Columbia contains license counts by age and gender for January 1st, 1996 through December 31st, 2000. Not all of the data for 2001 had been entered into the aggregate database at ICBC at the time of data acquisition. Therefore, not all cases in the year 2001 are included in the analysis of aggregate data (Part One) in this thesis.

The second part of this thesis uses data that are derived from police reports and driver records from ICBC. Information on collisions related to passenger vehicles from October 1, 1996 through October 1, 2001 is acquired for 39 different traffic intersections in the Greater Vancouver District of Vancouver, British Columbia, Canada. The police reported collision information is considered the best source by ICBC of detailed data for driver traffic accident data. Information on the specifics of each collision is contained in the databank including demographic factors, timing, crash characteristics, environmental conditions, and other contributing factors. Further information was gathered to supplement the existing data set from the Traffic Management Department of the City of Vancouver. The information acquired through this source is 'manual traffic counts' in the form of intersection flow diagrams generated for the selected 39 intersections in 1995 (see Appendix A for an example). These traffic flow charts include peak hour manual traffic counts in all directions at the specific intersections. This information is used to control for the volume of traffic that travels through each intersection.

Data in the second part of the thesis are also supplemented with collected information about the traffic environment at the selected intersections by the author. This information was collected between August 11th and August 18th, 2002. Data on the traffic environment are manually collected by the author to assess the importance of median/divider presence, turn treatments, and entrance/exit presence for older drivers at intersections. In addition, digital photos were acquired at the same time using a Kodak DC280, two-mega pixel digital camera for each direction at the intersections for the purpose of creating a visual environmental complexity scale. Photographs were taken at 45 to 100 feet from the edge of the intersection in each of the four directions. Photos were obtained at roughly the same height and direction as a driver approaching the intersection to simulate the environment that the driver sees approaching the intersection.

British Columbia population data are also used in Part Two to develop the license rates used in the development of the dependent variable. The total number of individuals in the British Columbia population by age are obtained from the Statistics Canada website and are based on census data for the year 1998 (BC Statistics, 2002). Five-year age groups are represented in the data from Statistics Canada that matched the present study's data with the exception of the 15 to 19 year age group. The latter five-year age group still approximates rates for the 16-19 year age group and is used in calculations for the related selected intersection data.

3.2 Sample Description

A population-based cross-sectional study is conducted using traffic accidents in British Columbia. The thesis subjects in both data sets include collisions related to drivers of passenger vehicles only. The aggregate British Columbia data for Part One of the thesis use police attended accidents that occurred on public roads between January 1st, 1996 and December 31st, 2000. Information on the number of total collisions (n=228,008) and the number of collisions at intersections (n=133,107) in British Columbia by passenger vehicle drivers for the years 1996 through 2001 are presented by year, age and gender of the driver. The number of accidents occurring at non-intersection locations in British Columbia is derived by combining the above two data sets. Data related to the number of licensed drivers in British Columbia (n=13,310,545) also includes the age and gender of the person and the relevant year ranging from 1996 to 2000. Information for the year 2001 was not available for the number of licensed drivers at the time of data acquisition. Accident cases are omitted from the analysis if the accident occurred in the year 2001, if the driver is under the legal licensing age of 16, and if the gender is unknown. The number of cases omitted from each data file includes: 816 from license driver (unknown gender), 35,767 from all accidents (35,731 cases occur in the year 2001 and are omitted, six drivers are less than 16 years old and are omitted, and 30 cases have drivers of unknown gender and are omitted), and 18,455 from intersection accidents (18,438 cases occur in 2001 and are omitted, three drivers are less than 16 years old and are omitted, and 14 drivers have unknown gender and are omitted). The final data set for Part One of this thesis encompasses 192,241 collisions in British Columbia for the years 1996 through 2000, with 114,652 occurring at intersections and 77,593 occurring at non-intersection locations.

Table 3.1: Accidents and Licensed Drivers, B.C. (1996-2000)

Gender	All Accidents n (%)	Intersection Accidents n (%)	Non-Intersection Accidents n (%)	Licensed Drivers n (%)
Males	124,238 (64.6%)	72,606 (63.3%)	51,632 (66.5%)	6,956,526 (52.3%)
Females	68,003 (35.4%)	42,046 (36.7%)	25,961 (33.5%)	6,353,203 (47.7%)
Total	**192,241 (100%)**	**114,652 (100%)**	**77,593 (100%)**	**13,309,729 (100%)**

Note: Non-intersection accidents is derived from the difference between the all accidents and intersection accidents.

In the second data set, subjects include passenger vehicle collisions relating to 39 selected intersections in the Greater Vancouver District of Vancouver, British Columbia, Canada. To be selected, the intersections within this district had to have automated lights in all four directions. A map was used to randomly select from the intersections with these selection criteria. The intersections are chosen in close proximity to one another to try to control for variations in demographic characteristics of different districts. The selection of the traffic intersections creates a non-randomized convenience sample. Collisions are included in the data sets that occur at the 39 different intersections within the time period of October 1, 1996 through October 1, 2001 (n=1395). A small number of collisions (n=3) possess a non-existent intersection label so they are removed from the data set. These data are incorrectly entered as being intersection-based accidents, however, when reviewing the data, it was discovered that the accident site is not an existing location since the labeled streets never converge. The sample for the analysis consists of 1,392 individuals involved in police reported accidents at the 39 selected intersections.

In this second data set, there is an age range from 16 to 93 years of age (M= 36.6; SD± 15.2). The sample consists of a greater percentage of younger drivers with 51.9% (n=723) within 16 to 34 years of age, 35.6% (496) between 35 to 54 years of age, and 12.4% (n=173) who are 55 years and older. Gender is also disproportionate, with males involved in 65.7% (n=914) and females involved in 34.3% (n=478) of police reported accidents.

3.3 Measures

This section outlines the measurement of variables used in both Part One and Two of this thesis for descriptive purposes and for the bivariate analysis. In this thesis, five-year age groups have been used with the very old classified as those 90 years and over for Part One, and 80 years and older for Part Two, to try to capture some of the unique characteristics of these older drivers. With the aggregate data used in Part One, there are greater numbers per category so the five-year age groups are made up to 90 years. For Part Two, and 80 years is used as the cut off for the oldest category. Those who are 60 years and over will be considered as part of the older population of drivers to allow for cross comparison with other research. Data are also divided by gender because males generally have higher accident rates than females.

Standard procedures that are typically used to analyze data based on linear assumptions are not used in this thesis because of the expectation of curvilinear associations across the age groups. Correlation coefficients would not expose a U-shaped distribution of the data. Therefore, relative percentage differences are used to compare age groups with respect to accident rates in both Part One and Two of the analysis. This approach allows for identification of anticipated non-linear trends, and allows for comparisons between targeted age groups.

The behavioral variables encompass driver pre-action, prior offences, and contributing factors. The environmental elements in the traffic environment at an intersection can be categorized into the natural environmental factors and the road environment components. The natural environmental elements include the weather, light, and time of day. The factors of the road environment consist of turning treatments, median/divider presence, and entrance/exit presence.

3.3.1 Part One:

The initial part of the data analysis encompasses descriptive information obtained from the aggregate data for British Columbia. The all accidents and intersection accidents data files are used to calculate non-intersection accidents. Accidents at non-intersection locations, **Acc_nonInt**, are a function of the number of total accidents, **Acc_Total**, minus the number of intersection accidents in British Columbia, **Acc_Int**:

$$Acc\_nonInt = (Acc\_Total) - (Acc\_Int)$$

The number of licensed drivers in British Columbia by age is used to calculate accident rates per licensed drivers by age.

3.3.2 Part Two:

This section describes the variables that are used in the development of the dependent variable and the independent variables used in the bivariate analyses. The unit of analysis for this data set is the intersection. Thirty-nine intersections in the Greater Vancouver District are evaluated. The dependent variable (adjusted accident rate) will be described below along with the variables used to create this variable (traffic volume, intersections, and license rates). A description of the independent variables (demographic, behavioral, natural environment, road environment, and visual complexity) and the adjustments to these measures will follow. Table 3.2 shows frequency distributions for the dependent and independent variables used in the bivariate analysis.

Dependent Variable:

The dependent variable used in this study is the interval variable, 'adjusted accident rate'. A number of separate variables are developed to create this adjusted accident rate variable. First, the volume of traffic is calculated for each intersection using the 'manual traffic count intersection flow diagrams' for the peak one hour time period of 7:45-8:45am (1998). A total for the intersections is developed by summing the total volume of traffic from every direction (North, East, South, and West). The total daily volume by intersections, **Vol_T**, is a function of the sum of volume at each intersection, **Vol_Int**, by the number of days in a year (365), and the number of years that data are collected (5) (see Table 3.3):

$$Vol\_T = Vol\_Int * 365 * 5$$

Table 3.2: Frequency Distributions for the Dependent Variable and Independent Variables Used in the Bivariate Analysis

Variables	Coding	Frequency	Valid %
Dependent Variable:			
Adjusted Accident Rate*	275.73	38	2.7
	281.01	125	9.0
	281.22	200	14.4
	281.84	162	11.6
	282.26	90	6.5
	282.33	169	12.1
	295.52	119	8.5
	300.68	54	3.9
	317.98	24	1.7
	327.93	219	15.7
	346.00	19	1.4
	390.47	20	1.4
	494.87	135	9.7
	495.32	18	1.3
Total Valid %			99.9
Independent Variables:			
Demographic Variables			
Age, at time of accident	0=16-19	135	9.7
	1=20-24	219	15.7
	2=25-29	200	14.4
	3=30-34	169	12.1
	4=35-39	162	11.6
	5=40-44	125	9.0
	6=45-49	119	8.5
	7=50-54	90	6.5
	8=55-59	54	3.9
	9=60-64	38	2.7
	10=65-69	24	1.7
	11=70-74	19	1.4
	12=75-79	20	1.4
	13=80+	18	1.3
Total Valid %			99.9
Gender	1=Males	914	65.7
	2=Females	478	34.3
Total Valid %			100.0

Table 3.2 (cont.): Frequency Distributions for the Dependent Variable and Independent Variables Used in the Bivariate Analysis

Variables	Coding	Frequency	Valid %
Behavioral Variables (cont.)			
Driver Pre-action	0=Going Straight	783	56.3
	1=Turning	399	28.7
	2=Stopping	159	11.4
	3=Other	51	3.7
Total Valid %			100.1
Prior Offender	0=Not Prior Offender	1039	74.6
	1=Prior Offender	353	25.4
Total Valid %			100.0
Contributing Factors	1=Without Due Care	75	5.4
	2=Inexperience	27	1.9
	3=Failing to Yield	233	16.7
	4=Ignoring Control Device	130	9.3
	5=Other	316	22.7
	6=Unknown/Not Applicable	611	43.9
Total Valid %			99.9
Natural Environmental Variables			
Time of Day	0=6am-12:59pm	429	30.8
	1=1pm-7:59pm	499	35.8
	2=8pm-5:59am	464	33.3
Total Valid %			99.9
Illumination	1=Daylight	699	50.2
	2=Other Illumination	693	49.8
Total Valid %			100.0
Weather	1=Clear/dry	1019	73.2
	2=Other	373	26.8
Total Valid %			100.0
Road Environment Variables			
Turning Treatments	1=Less Treatment	760	54.6
	2=More Treatment	632	45.4
Total Valid %			100.0
Entrances/Exits	1=No Entrances/Exits	663	47.6
	2=Entrances/Exits	729	52.4
Total Valid %			100.0
Medians/Dividers	1=No Median/Divider	617	44.3
	2=Median/Divider	775	55.7
Total Valid %			100.0

Table 3.2 (cont.): Frequency Distributions for the Dependent Variable and Independent Variables Used in the Bivariate Analysis

Variables	Coding	Frequency	Valid %
Visual Environmental Complexity			
Visual Environmental Complexity Scale	1=1-2.74 (Low Complexity) 2=2.75+ (High Complexity)	614 778	44.1 55.9
Total Valid %			100.0

* *Adjusted Accident Rate is coded by age groups but the order does not coincide with the order of the age variable since it presents the rate from greater to lesser values.*

These variables are used to create an accident rate per 100 million cars per intersection, **Acc_Rate**. Therefore, the total accidents per intersection from the frequency distribution of the intersection variable (**Acc_Int**), are divided by the total daily volume by intersection (**Vol_Daily**), per 100 million cars:

$$Acc\_Rate = \frac{Acc\_Int}{Vol\_Daily/100{,}000{,}000}$$

This denominator (100,000,000) is selected because of the large volume of cars per accident. The accident rate variable (**Acc_Rate**), is adjusted by volume at intersections.

Table 3.3: Intersection Variable

Variable	Coding	Frequency	Valid %
Intersections	1=Arbutus at W 12th Ave	16	1.1
	2=Arbutus at King Edward	6	0.4
	3=Arbutus at W 33rd Ave	13	0.9
	4=W Boulevard at W 41st Ave	2	0.1
	5=Burrard at W Broadway	30	2.2
	6=Burrard at Davie	50	3.6
	7=Burrard at Georgia	61	4.4
	8=Burrard at Pacific	68	4.9
	9=Burrard at Pender	21	1.5
	10=Burrard at Robson	16	1.1
	11=Cambie at W 12th Ave	41	2.9
	12=Cambie at W Broadway	50	3.6
	13=Cambie at King Edward	33	2.4
	14=Cambie at W 41st Ave	57	4.1
	15=Cambie at W 49th Ave	49	3.5
	16=Cambie at SW Marine Dr	122	8.8
	17=Denman at Davie	13	0.9
	18=Denman at Robson	13	0.9
	19=Georgia at Bute	14	1.0
	20=Granville at W 12th Ave	39	2.8
	21=Granville at King Edward	69	5.0
	22=Granville at W 41st Ave	48	3.4
	23=Granville at W 49th Ave	87	6.3
	24=Granville at W 70th Ave	25	1.8
	25=MacDonald at W Broadway	13	0.9
	26=MacDonald at King Edward	23	1.7
	27=Oak at W 12th Ave	35	2.5
	28=Oak at W Broadway	25	1.8
	29=Oak at King Edward	32	2.3
	30=Oak at W 41st Ave	28	2.0
	31=Oak at W 49th Ave	66	4.7
	32=Oak at W 70th Ave	30	2.2
	33=W 10th Ave at Alma	17	1.2
	34=W 16th Ave at Granville	58	4.2
	35=W 16th Ave at MacDonald	14	1.0
	36=W 4th Ave at Alma	38	2.7
	37=W 4th Ave at Burrard	32	2.3
	38=W 4th Ave at Fir	23	1.7
	39=W 4th Ave at MacDonald	15	1.1
Total Valid %			99.9

Further adjustments are needed to create a dependent variable adjusted for license rates by age groups to make age comparisons. The accident rate (**Acc_Rate**), is totaled for each age group and divided by the frequency of accidents for each age group (**Acc_Rate**$_{\mathbf{age\_group}}$). The dependent variable is then adjusted for the number of possible drivers per age group in order to identify persons at risk. This is done by creating license rates using the license information from the data set of Part One. The percentage of licensed drivers per age group (**Lic%_AgeGrp**), is simply a function of the number of licensed drivers per age group (**Num_LicAge**), divided by the number of people in the British Columbia population per age group (**Pop_SizeAgeGrp**):

$$Lic\%\_AgeGrp = \frac{Num\_LicAge}{Pop\_SizeAgeGrp}$$

The percentage of licensed drivers is averaged (**Mean%**) by summing the percentage of licensed drivers by age group for a total license drivers group (**Lic%_AgeGrp**$_{\mathbf{Total}}$), and dividing by the number of age groups (14):

$$Mean\% = \frac{\text{Lic\%\_AgeGrp}_{\text{Total}}}{14}$$

Thus, the adjusted accident rate (**Adjusted_AccRate**), is a function of the accident rate per 100 million cars per intersection by age group (**$\text{Acc\_Rate}_{\text{age\_group}}$**), divided by the percentage of licensed drivers per age group (**Lic%_AgeGrp**), all multiplied by the mean percentage of licensed drivers (**Mean%**):

$$Adjusted\_AccRate = \frac{\text{Acc\_Rate}_{\text{age\_group}}}{\text{Lic\%\_AgeGrp}} * Mean\%$$

This represents the number of collisions per 100 million cars, per selected intersection, and per percentage licensed drivers by age group. It is calculated in this manner in order to create a comparable accident rate by age that adjusts for age differences in licensed drivers and different volumes by intersection. Adjusted accident rate comprises the dependent variable for Part Two of the analysis.

Independent Variables:

Demographic Variables

Age. Age at the time of accident is calculated by the subtraction of the date of the accident by the date of birth. Age groups spanning five years are created with the exception of the 16-19 years (four years) and the 80 years and over age groups for the reasons explained earlier.

Gender. Data are separated by gender as past literature found males have been more likely to be involved in accidents (when exposure is not controlled) and have a driver's license than females.

Behavioral Variables

There are three behavioral variables that are hypothesized to have an important influence on the accident rate outcome measure and include: driver pre-action, prior offender, and contributing factors. Two of these variables (driving pre-action and contributing factors) are derived from the police reports, and the other from driving records (prior offender).

Driver Pre-action. Driver pre-action originally encompassed sixteen categories that are aggregated into four categories [going straight (n=783, 56.3%), turning (n=399, 28.7%), stopping (n=159, 11.4%), other (n=51, 3.7%)] because of the small numbers in some of the original categories. The literature indicates that there is a greater incidence of accidents for those going straight.

Prior Offender. Prior offender is determined by the driver's involvement in collisions prior to the accident within the study data set (not prior offender= 1,039, 74.6%; prior offender= 353, 25.4%). According to the literature, drivers with a prior offence are more likely to be involved in further collisions.

Contributing Factors. Contributing factors are determined by the attending police officer post-accident. The officer can enter up to three contributing factors in priority sequence. Only the first group of factors is included because most of the reports only list one contributing factor (the primary factor) for the accident. Contributing factors originally consisted of 28 categories that are recoded into six categories [driving without due care (n=75, 5.4%), driving inexperience (n=27, 1.9%), failing to yield right of way (n=233, 16.7%), ignoring traffic control device (n=130, 9.3%), other (n=316, 22.7%), and unknown/not applicable (n=611, 43.9%)] because of the small numbers in some categories.

Natural Environmental Variables

Three variables are used to test the impact that the natural environment has on car accidents: time of day, illumination, and weather. These variables are derived from the police post-accident reports.

Time of Day. Time of day is an interval variable with a range of 24 hours that is recoded into three categories including: morning [6am-12:59pm (n=429, 30.8%)], afternoon/evening [1pm-7:59pm (n=499, 35.8%)], and night [8pm-5:59am (n=464, 33.3%)]. Research indicates that older adults are more likely to travel during daylight time periods with optimal light and reduced traffic flow. Time of day is not indicated in 39 (2.8%) police post-accident reports. To compensate for the small number of missing cases, median substitution is used and the data are recoded into the modal category (afternoon/evening: 1pm-7:59pm).

Illumination. The illumination level variable originally consisted of seven categories that are recoded into two categories because of the small numbers in some categories. The two categories encompass: daylight (n=699, 50.2%) and other illumination levels (n=693, 49.8%). The literature reveals that older drivers travel mostly during daylight hours.

Weather. Weather originally included five categories that are recoded into two categories because of the small numbers in some of the categories. Prior literature indicates that older drivers tend to avoid less desirable driving conditions choosing to drive during more ideal weather (i.e., clear/dry). The weather variable is composed of two categories: clear/dry (n=1,019, 73.2%) and other (n=373, 26.8%).

Road Environmental Variables

The impact of the road environment on accident rates is tested using three variables: turning treatment scale, presence of entrances/exits, and presence of median/divider. These variables are derived from the manually collected data on the selected intersections.

Turning Treatments. The turning treatment scale is created from two variables that are based on the number of directions in the intersections that each of these two different treatments occur. These variables encompass: left turn lanes and left turn light (see Table 3.4). A five point rating scale is used in each of these variables ranging from zero, no turning treatment present, to four, four directions with turning treatment. The original turning treatment variables, left turn lanes and left turn lights are combined and divided by the total number of variables to create the turning treatment scale. Intersections with a turning treatment frequency of 0-1.50 are recoded into the 'less treatment' category (n=711, 51.1%) and those with a frequency of 1.51 and over are recoded into the 'more treatment' category (n=681, 48.9%). The Alpha reliability for turning treatments is 0.79.

Table 3.4: Turning Treatment Variable

Variable	Coding	Frequency	Valid %
Left Turn Lane	0	363	26.1
	1	153	11.0
	2	296	21.3
	3	38	2.7
	4	542	38.9
Total Valid %			100.0
Left Turn Light	0	454	32.6
	1	350	25.1
	2	399	28.7
	3	6	0.4
	4	183	13.1
Total Valid %			99.9

Entrances/exits. The entrances/exits variable is dichotomized into no entrances/exits (n=663, 47.6%) and entrances/exits into intersection (n=729, 52.4%). One would expect that intersections with entrances/exits would be more likely to increase the accident rate for older drivers.

Median/divider. The median/divider variable is coded into two categories: no median/divider (n=617, 44.3%) and median/divider present (n=775, 55.7%). The literature suggests that the presence of a median decreases the accident rate for older drivers. Each direction in an intersection is given a score of zero or one for the presence of a median, divider, or boulevard.

Visual Environmental Complexity

The visual environmental complexity scale is also hypothesized to have an impact on accident rates for older drivers. This variable is derived from the digital-photo information collected at the selected intersections.

Visual Environmental Complexity. The visual environmental complexity scale is created by rating intersections on their level of signage complexity (i.e., size, color, location, and degree of signage presence) and architectural complexity (i.e., structure height, variation of forms, elevation complexity, and number of structures) to measure the visual environment or the environment that is experienced by the driver. Two raters with backgrounds in the built environment field rated the digital-photos on a scale of one (very little complexity) to five (greater complexity) separately for signage and architectural complexity for each direction in the selected intersections (see Figures 3.1 and 3.2). The criteria used for rating signage complexity include: degree of signage present, size, color, and location. For architectural complexity the criteria encompass: structural height, elevation complexity, variation of forms, and number of structures. The totals for signage and architectural complexity at each direction of the specific intersection are combined and averaged. The combination creates a scale ranging from 1 (very little complexity) to 10 (greater complexity). The total scores from each rater are then averaged for each intersection. The inter-rater reliability for visual environmental complexity is extremely high, with a Pearson r of 0.94. For the bivariate analysis this variable is recoded into two categories including: low complexity that ranges from 1-2.74 (n=614, 44.1%) and high complexity that ranges from 2.75 and over (n=778, 55.9%).

Figure 3.1: Low Visual Environmental Complexity (Arbutus at W.33rd Ave.)

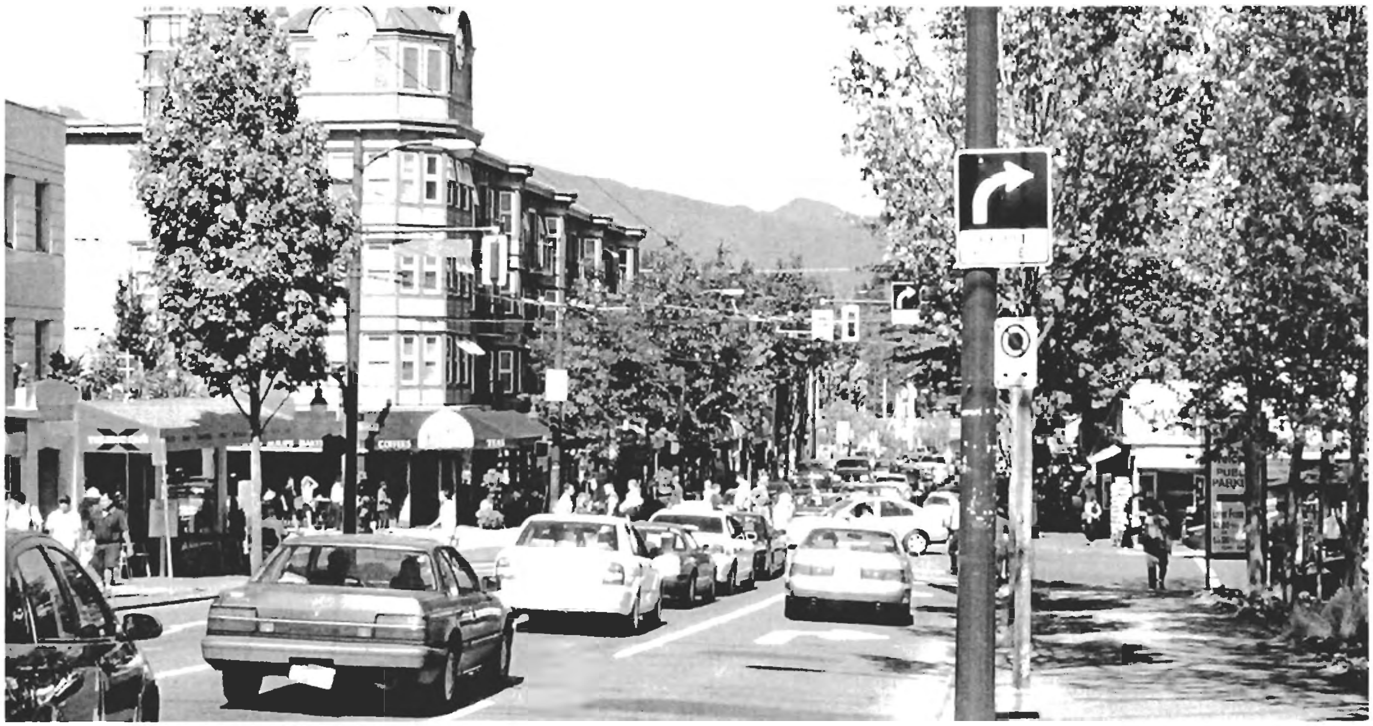


Figure 3.2: High Visual Environmental Complexity (Denman at Robson)

CHAPTER 4: RESULTS

4.1 Introduction

This chapter presents the results as they relate to the hypotheses stated in Chapter Two. The aggregate results in Section 4.2 show the accident rate information as an outcome measure for population-level risk and the trends in collisions at intersection versus non-intersection locations. In Section 4.3, the guidelines used in the bivariate analysis conducted to test the hypotheses for the data on the intersections are outlined and followed by the presentation of the results.

For the analysis of aggregate data, the percentage of intersection accidents by licensed drivers for three comparison age groups are provided separately for males and females in addition to examination of trends across all age groups. The extreme age groups are used to represent the younger and older drivers and are compared to a reference middle-age group (40-44 years) to evaluate across age patterns in Part One and Two. The reference age group used is consistent with prior literature (Preusser et al., 1998). In Part Two, there are too few accidents beyond the age of 80 years to separate into smaller categories. For Part One, the 90 years and over age group is used as the oldest category because of the greater sample size in this data set with the exception of the female 90 years and over age group.

The total percentages of accidents for each category are assessed to indicate the importance of total risk for that category. Percentage differentials are also calculated across age categories to make relative comparisons of accident rates in Part Two. With respect to percentage differentials across targeted age groups, a correspondence rule is followed to determine the strength of the differential (see Table 4.1). An association of less than 10.0% is considered non-significant.

Table 4.1: Predetermined Levels for Strength of Association

Strength of Association	Percentage (%)
Weak	**10.0-19.9**
Moderate	**20.0-39.9**
High	**>=40.0**

In Part Two, a positive score for the across age groups comparisons represents a positive relationship with adjusted accident rates for the focus group whereas, a negative association indicates an inverse relationship. For example, a positive association for high visual environmental complexity would mean that the age group examined would be more likely to have accidents at intersections with higher complexity. Percentage differentials are used instead of percentage change because they represent a relative statistical difference between age groups rather than a descriptive assessment.

4.2 Aggregate Data

From 1996 through 2000, about 60% of all accidents are at intersection locations. For specific age groups, the data reveal that the number of accidents decreased with age (see Tables 4.2 and 4.3, for males and females respectively). Data also demonstrate that the number of licensed drivers on the road decreases as age increases (see Tables 4.2 and

Table 4.2: Accidents and Licensed Drivers for Males by Age Groups, B.C. (1996-2000)

Age Groups (years)	All Accidents n (%)	Intersection Accidents n (%)	Non-Intersection Accidents n (%)	Licensed Drivers n (%)
16-19	16,078 (12.9)	9,268 (12.8)	6,810 (13.2)	364,135 (5.2)
20-24	17,279 (13.9)	9,918 (13.7)	7,361 (14.3)	542,478 (7.8)
25-29	14,368 (11.6)	8,228 (11.3)	6,140 (11.9)	624,010 (9.0)
30-34	14,499 (11.7)	8,291 (11.4)	6,208 (12.0)	710,621 (10.2)
35-39	13,759 (11.1)	7,953 (11.0)	5,806 (11.2)	805,276 (11.6)
40-44	11,787 (9.5)	6,768 (9.3)	5,019 (9.7)	790,384 (11.4)
45-49	9,805 (7.9)	5,755 (7.9)	4,050 (7.8)	730,472 (10.5)
50-54	7,574 (6.1)	4,401 (6.1)	3,173 (6.1)	618,640 (8.9)
55-59	5,436 (4.4)	3,203 (4.4)	2,233 (4.3)	459,413 (6.6)
60-64	3,932 (3.2)	2,438 (3.4)	1,494 (2.9)	372,592 (5.4)
65-69	3,261 (2.6)	2,100 (2.9)	1,161 (2.2)	335,548 (4.8)
70-74	2,583 (2.1)	1,654 (2.3)	929 (1.8)	269,993 (3.9)
75-79	2,138 (1.7)	1,432 (2.0)	706 (1.4)	193,085 (2.8)
80-84	1,214 (1.0)	845 (1.2)	369 (0.7)	96,892 (1.4)
85-89	418 (0.3)	279 (0.4)	139 (0.3)	35,790 (0.5)
90+	107 (0.1)	73 (0.1)	34 (0.1)	7,197 (0.1)
Totals (Valid%)	124,238 (100.1)	72,606 (100.2)	51,632 (99.9)	6,956,526 (100.1)

Note: Percentage of accidents represents the proportion of accidents for that category (i.e., all, intersection, or non-intersection categories).

Table 4.3: Accidents and Licensed Drivers for Females by Age Groups, B.C. (1996-2000)

Age Groups (years)	All Accidents n (%)	Intersection Accidents n (%)	Non-Intersection Accidents n (%)	Licensed Drivers n (%)
16-19	8,230 (12.1)	5,160 (12.3)	3,070 (11.8)	323,000 (5.1)
20-24	8,979 (13.2)	5,459 (13.0)	3,520 (13.6)	514,165 (8.1)
25-29	7,730 (11.4)	4,575 (10.9)	3,155 (12.2)	606,211 (9.5)
30-34	7,630 (11.2)	4,531 (10.8)	3,099 (11.9)	680,360 (10.7)
35-39	7,818 (11.5)	4,766 (11.3)	3,052 (11.8)	777,275 (12.2)
40-44	7,562 (11.1)	4,762 (11.3)	2,800 (10.8)	768,158 (12.1)
45-49	5,929 (8.7)	3,717 (8.8)	2,212 (8.5)	682,793 (10.8)
50-54	4,118 (6.1)	2,568 (6.1)	1,550 (6.0)	555,108 (8.7)
55-59	2,590 (3.8)	1,597 (3.8)	993 (3.8)	396,317 (6.2)
60-64	1,872 (2.8)	1,204 (2.9)	668 (2.6)	304,956 (4.8)
65-69	1,606 (2.4)	1,040 (2.5)	566 (2.2)	260,090 (4.1)
70-74	1,584 (2.3)	1,091 (2.6)	493 (1.9)	220,348 (3.5)
75-79	1,365 (2.0)	907 (2.2)	458 (1.8)	164,686 (2.6)
80-84	733 (1.1)	500 (1.2)	233 (0.9)	74,987 (1.2)
85-89	223 (0.3)	150 (0.4)	73 (0.3)	21,875 (0.3)
90+	34 (0.1)	19 (0.0)	15 (0.1)	2,874 (0.1)
Totals (Valid%)	68,003 (100.1)	42,046 (100.1)	25,957 (100.2)	6,353,203 (100)

Note: Percentage of accidents represents the proportion of accidents for that category (i.e., all, intersection, or non-intersection categories).

4.3). Noteworthy is the finding that 81.2% of drivers in British Columbia are younger than 60 years of age.

Hypothesis 1

The proportion of intersection accidents increases with age.

This hypothesis is examined separately for males and females. Specifically, more of the accidents occur at intersections in comparison to non-intersection locations and this association is greater as age increases, especially for males (see Tables 4.4). This is consistent with the hypothesized relationship. For example, the oldest-old age group of 90 years and over male drivers has 68.22% of his accidents at intersections, compared to 57.42% for those aged 40-44. Those males aged 16-19 only experience 57.64% of his accidents at intersections.

Females also experienced more accidents at intersections than non-intersections (see Table 4.5). For example, the second oldest female age group of 85-89 years has 67.26% of her accidents at intersections, compared to 62.97% for those aged 40-44 years. The oldest female age group of 90 years and over has 55.88% and the 16-19 year age group has 62.70% of her accidents at intersections.

Table 4.4: Percentage of Accidents for Males at Intersections and Non-Intersection Locations, B.C. (1996-2000)

Age Groups (years)	Intersection Accidents (%)	Accidents At Non-Intersection Locations (%)	Total (%)
16-19	57.64	42.36	100
20-24	57.40	42.60	100
25-29	57.27	42.73	100
30-34	57.18	42.82	100
35-39	57.80	42.20	100
40-44	57.42	42.58	100
45-49	58.69	41.31	100
50-54	58.11	41.89	100
55-59	58.92	41.08	100
60-64	62.00	38.00	100
65-69	64.40	35.60	100
70-74	64.03	35.97	100
75-79	66.98	33.02	100
80-84	69.60	30.40	100
85-89	66.75	33.25	100
90+	68.22	31.78	100

Note: Accident percentages represent the proportion of all accidents occurring at intersections and non-intersections.

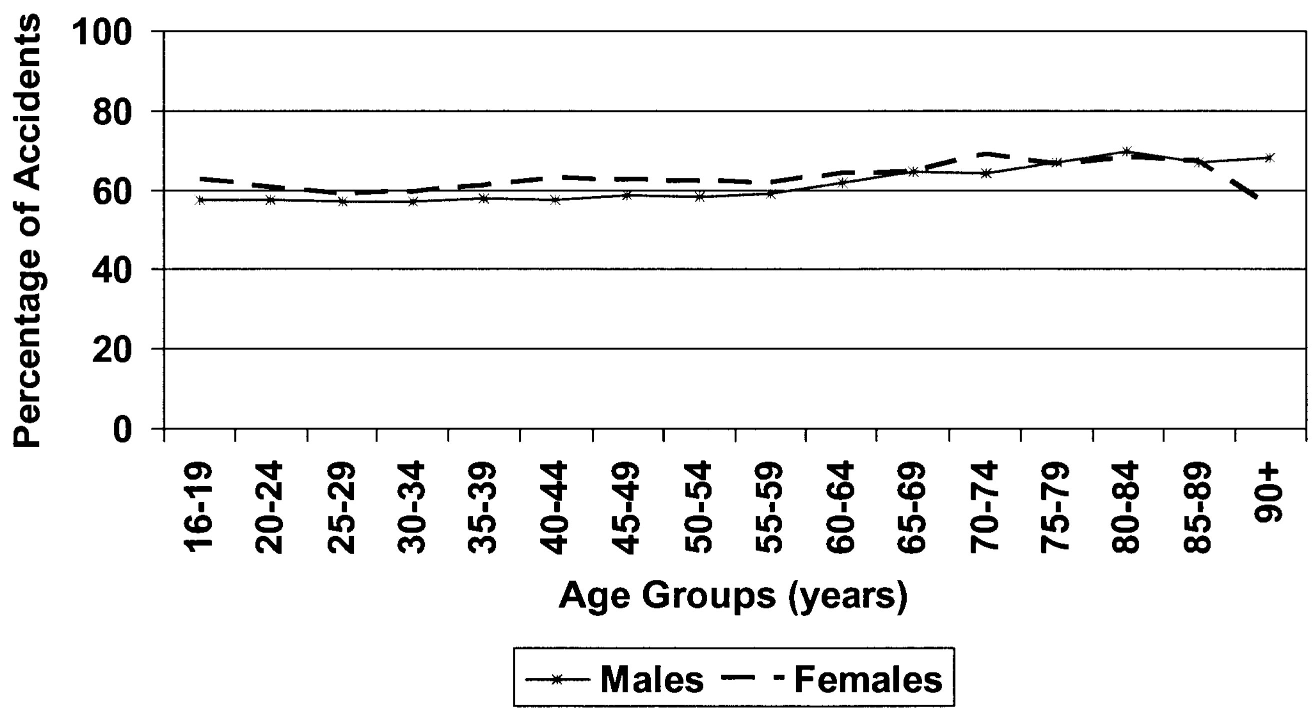
Table 4.5: Percentage of Accidents for Females at Intersections and Non-Intersection Locations, B.C. (1996-2000)

Age Groups (years)	Intersection Accidents (%)	Accidents At Non-Intersection Locations (%)	Total (%)
16-19	62.70	37.30	100
20-24	60.80	39.20	100
25-29	59.18	40.82	100
30-34	59.38	40.62	100
35-39	60.96	39.04	100
40-44	62.97	37.03	100
45-49	62.69	37.31	100
50-54	62.36	37.64	100
55-59	61.66	38.34	100
60-64	64.32	35.68	100
65-69	64.76	35.24	100
70-74	68.88	31.12	100
75-79	66.45	33.55	100
80-84	68.21	31.79	100
85-89	67.26	32.74	100
90+	55.88	44.12	100

Note: Accident percentages represent the proportion of all accidents occurring at intersections and non-intersections.

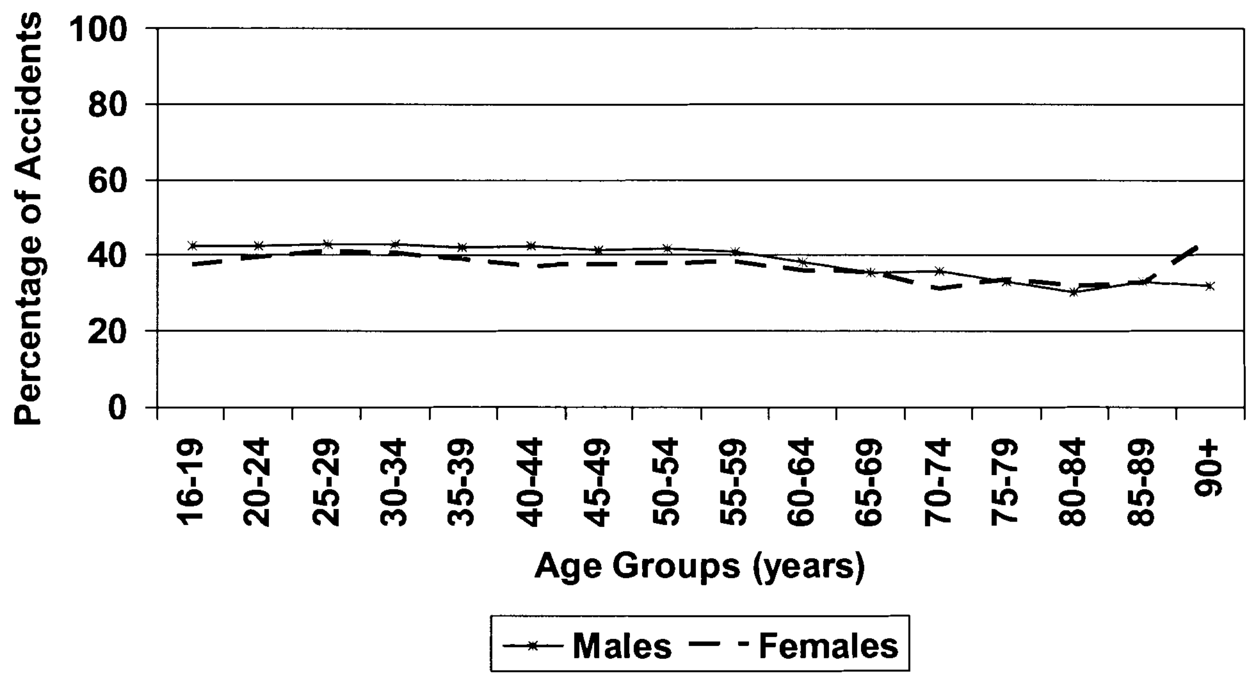
The gradual increase in the percentage of intersection accidents with age is shown in Figure 4.1. This can be compared with Figure 4.2 that presents the percentage of non-intersection accidents, where there is a gradual decrease with age with the exception of the females 90 year and over age group.

Figure 4.1: Percentage of Accidents at Intersections, B.C. (1996-2000)



Note: Percentage of accidents represents the proportion of all accidents occurring at intersections.

Figure 4.2: Percentage of Accidents at Non-Intersection Locations, B.C. (1996-2000)



Note: Percentage of Accidents represents the proportion of all accidents occurring at non-intersection locations.

Tables 4.6 and 4.7 show the accident rate trends of licensed drivers by age. The percentages of intersection accidents for licensed drivers shown in Tables 4.6 and 4.7 indicate that there are proportionately more accidents at intersections for both males and females. Also, the percentage is larger for most of the older age groups compared to middle-aged drivers. For example, for the oldest age group of licensed males 67.79% of accidents occur at intersections while only 57.72% of the accidents for middle-aged male drivers and 57.69% of the accidents for younger male drivers occur at intersections. Therefore, those males 90 years and older are more likely to have intersection accidents, compared to non-intersection accidents, than other age groups (see Figure 4.3). For females, a similar trend is found with 67.65% of accidents occurring at intersections for the 85-89 year age group while middle-aged female drivers experience only 63.27% and younger female drivers experience only 62.75% of accidents at intersections (see Figure 4.4). The oldest females, aged 90 years and over, had only 55.93% of accidents at intersections. However, the numbers are small in this age group (intersection accidents= 19; non-intersection accidents= 15). All of these percentages are in the expected direction, as anticipated in Hypothesis 1.

Table 4.6: Percentage of Male Licensed Drivers Involved in Accidents, B.C. (1996-2000)

Age Groups (years)	Licensed Drivers Accidents* (%)	Licensed Drivers Intersection Accidents (%)	Licensed Drivers Accidents Non-Intersection (%)	Percentage of Intersection vs. All Accidents (%)
16-19	4.42	2.55	1.87	57.69
20-24	3.19	1.83	1.36	57.37
25-29	2.30	1.32	0.98	57.39
30-34	2.04	1.17	0.87	57.35
35-39	1.71	0.99	0.72	57.89
40-44	1.49	0.86	0.64	57.72
45-49	1.34	0.79	0.55	58.96
50-54	1.22	0.71	0.51	58.20
55-59	1.18	0.70	0.49	59.32
60-64	1.06	0.65	0.40	61.32
65-69	0.97	0.63	0.35	64.95
70-74	0.96	0.61	0.34	63.54
75-79	1.11	0.74	0.37	66.67
80-84	1.25	0.87	0.38	69.60
85-89	1.17	0.78	0.39	66.67
90+	1.49	1.01	0.47	67.79

Note: Percentage of intersection vs. all accidents represents the proportion of all accidents that occur at intersections for licensed drivers.

** Licensed drivers accidents represent the percentage of licensed drivers involved in accidents.*

Table 4.7: Percentage of Female Licensed Drivers Involved in Accidents, B.C. (1996-2000)

Age Groups (years)	Licensed Drivers Accidents* (%)	Licensed Drivers Intersection Accidents (%)	Licensed Drivers Accidents Non-Intersection (%)	Percentage of Intersection vs. All Accidents (%)
16-19	2.55	1.60	0.95	62.75
20-24	1.75	1.06	0.68	60.57
25-29	1.28	0.75	0.52	58.59
30-34	1.12	0.67	0.46	59.82
35-39	1.01	0.61	0.39	60.40
40-44	0.98	0.62	0.36	63.27
45-49	0.87	0.54	0.32	62.07
50-54	0.74	0.46	0.28	62.16
55-59	0.65	0.40	0.25	61.54
60-64	0.61	0.39	0.22	63.93
65-69	0.62	0.40	0.22	64.52
70-74	0.72	0.50	0.22	69.44
75-79	0.83	0.55	0.28	66.27
80-84	0.98	0.67	0.31	68.37
85-89	1.02	0.69	0.33	67.65
90+	1.18	0.66	0.52	55.93

Note: Percentage of intersection vs. all accidents represents the proportion of all accidents that occur at intersections for licensed drivers.
** Licensed drivers accidents represent the percentage of licensed drivers involved in accidents.*

Figure 4.3: Percentage of Intersection Accidents for Male Licensed Drivers, B.C. (1996-2000)

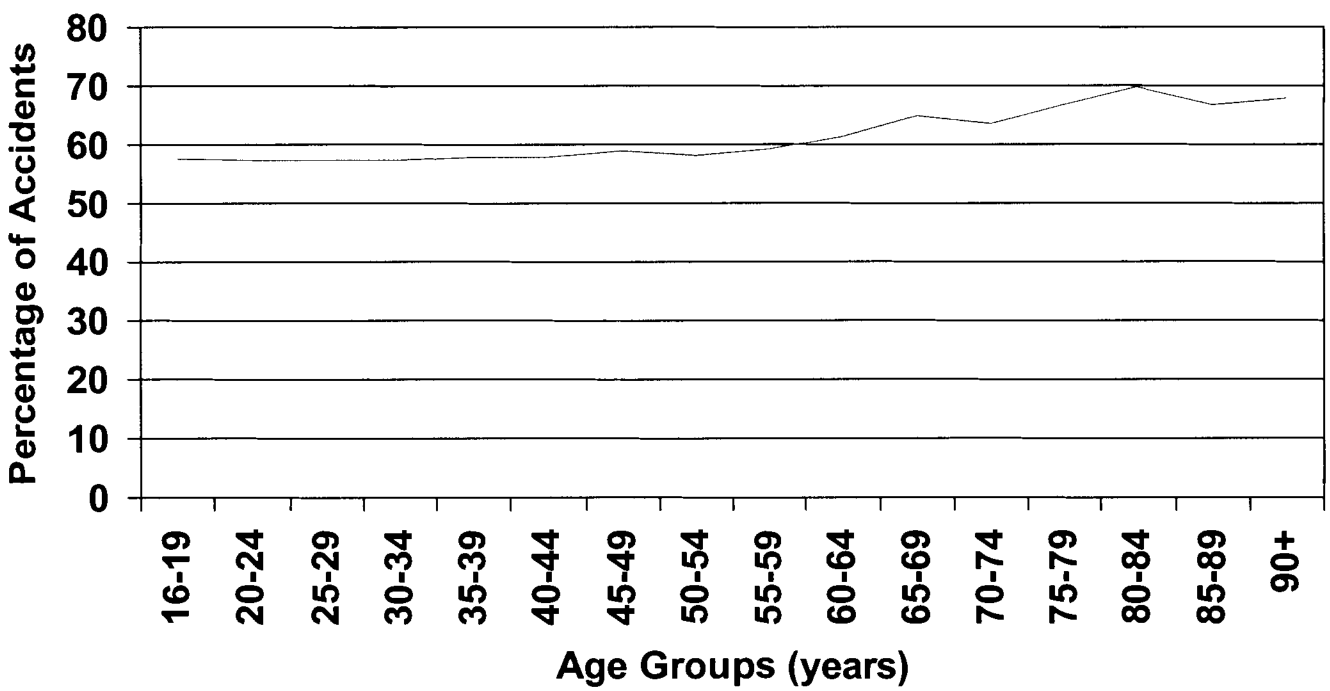
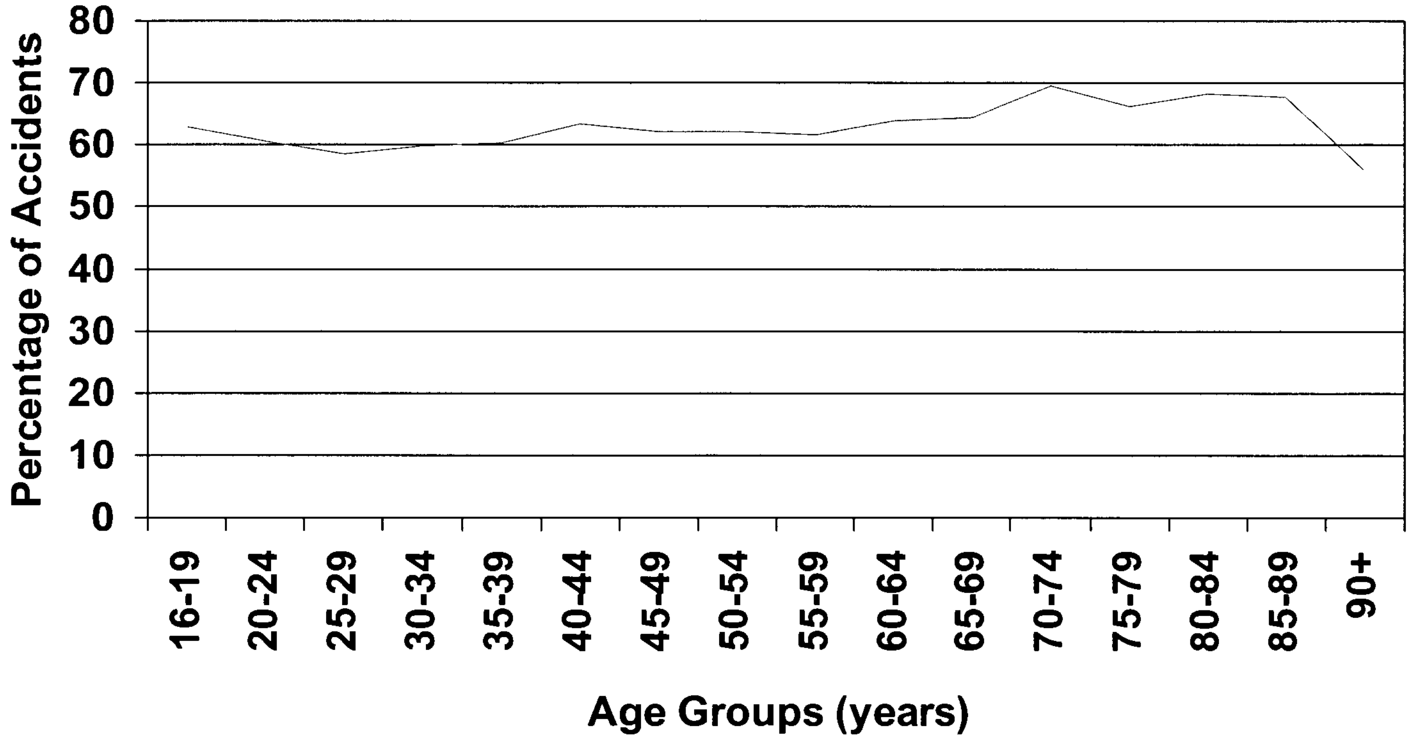


Figure 4.4: Percentage of Intersection Accidents for Female Licensed Drivers, B.C. (1996-2000)



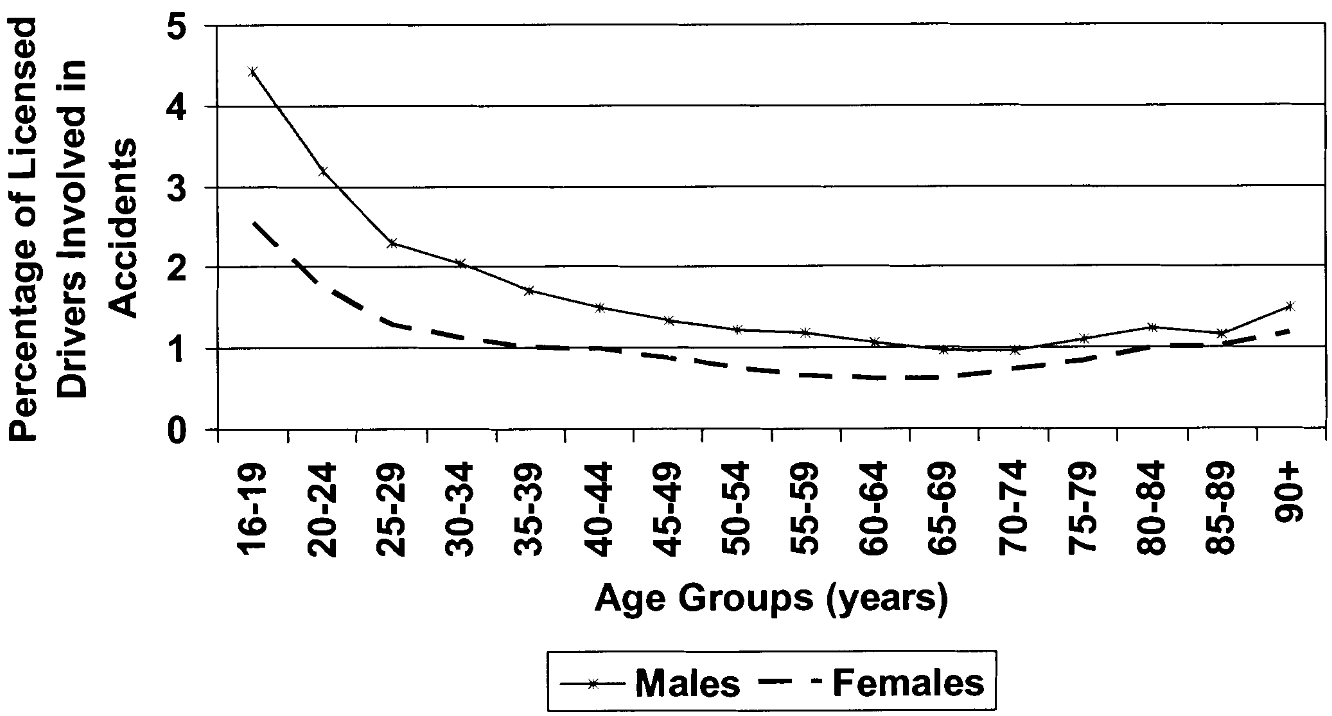
When controlling for the decrease in licensed drivers with age, a subtle U-shaped or curvilinear relationship appears for the percentage of all accidents, intersection accidents, and non-intersection accidents in British Columbia by age (see Figures 4.5, 4.6, and 4.7 respectively). These patterns are consistent with those found in previous studies.

4.3 Intersection Data

To test hypotheses two through six developed in Section 2.5, cross-tabulations are performed on the data collected on 39 Greater Vancouver Region intersections. The subsequent analysis consists of the cross-tabulation of the adjusted accident rate by age and individually layered by the 11 other independent variables. This is done to evaluate for an interaction between age and the independent variables on the adjusted accident rates. The independent variables include: 1) age, 2) gender, 3) driver pre-action, 4) prior offender, 5) contributing factors, 6) time of day, 7) illumination, 8) weather, 9) turning treatments, 10) entrances/exits, 11) medians/dividers, and 12) visual environmental complexity.

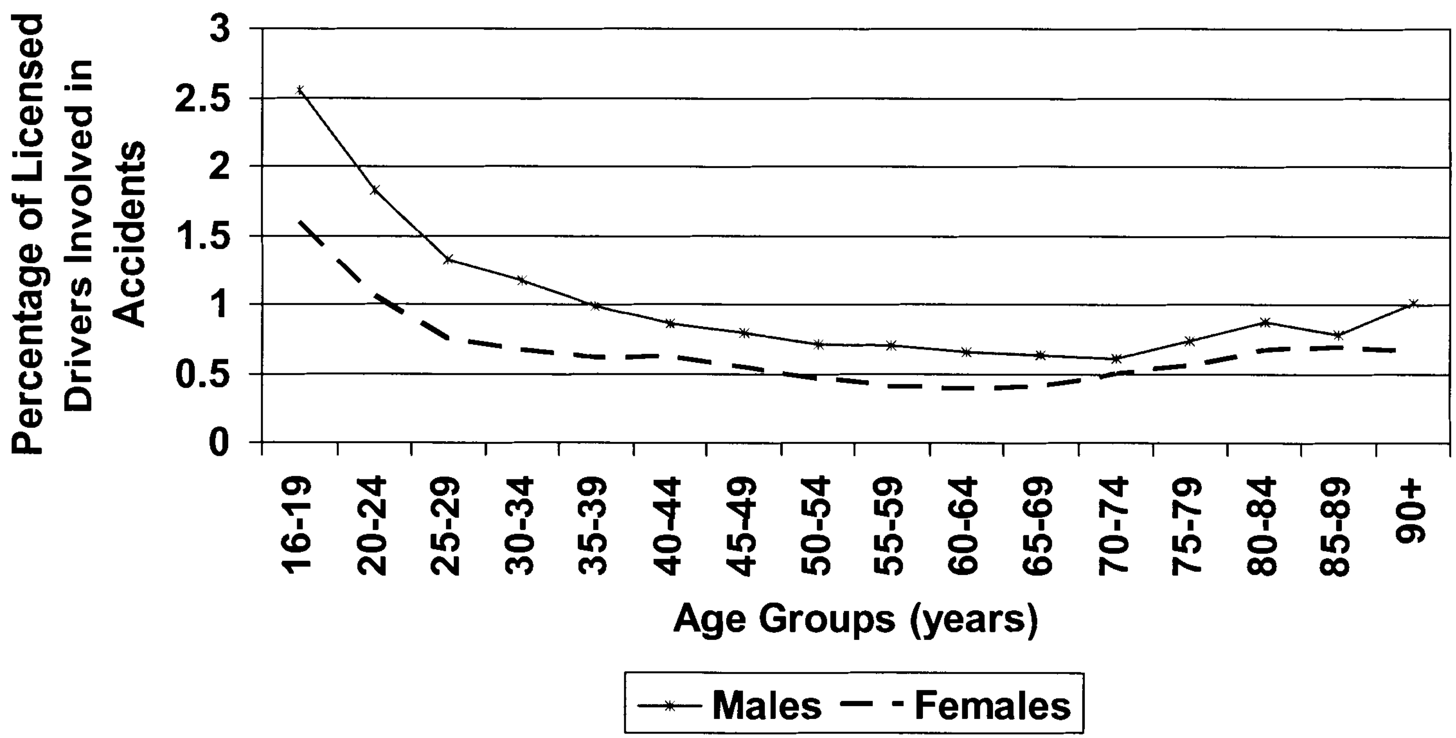
To report the results, general patterns are discussed, in addition to unique patterns that stand out across the categories and the age groups. Each category for the independent variables is analyzed across age using a consistent reference age group (40-44 years) to assess percentage differentials among young (16-19 years) and the oldest (80 years and over) groups. The middle-age group (40-44 years) is used as the reference group in the across age analysis because of the hypothesized curvilinear pattern for age. To calculate the percentage differential, the percentage of adjusted accidents for the

Figure 4.5: Percentage of Licensed Drivers Involved in Accidents, B.C. (1996-2000)



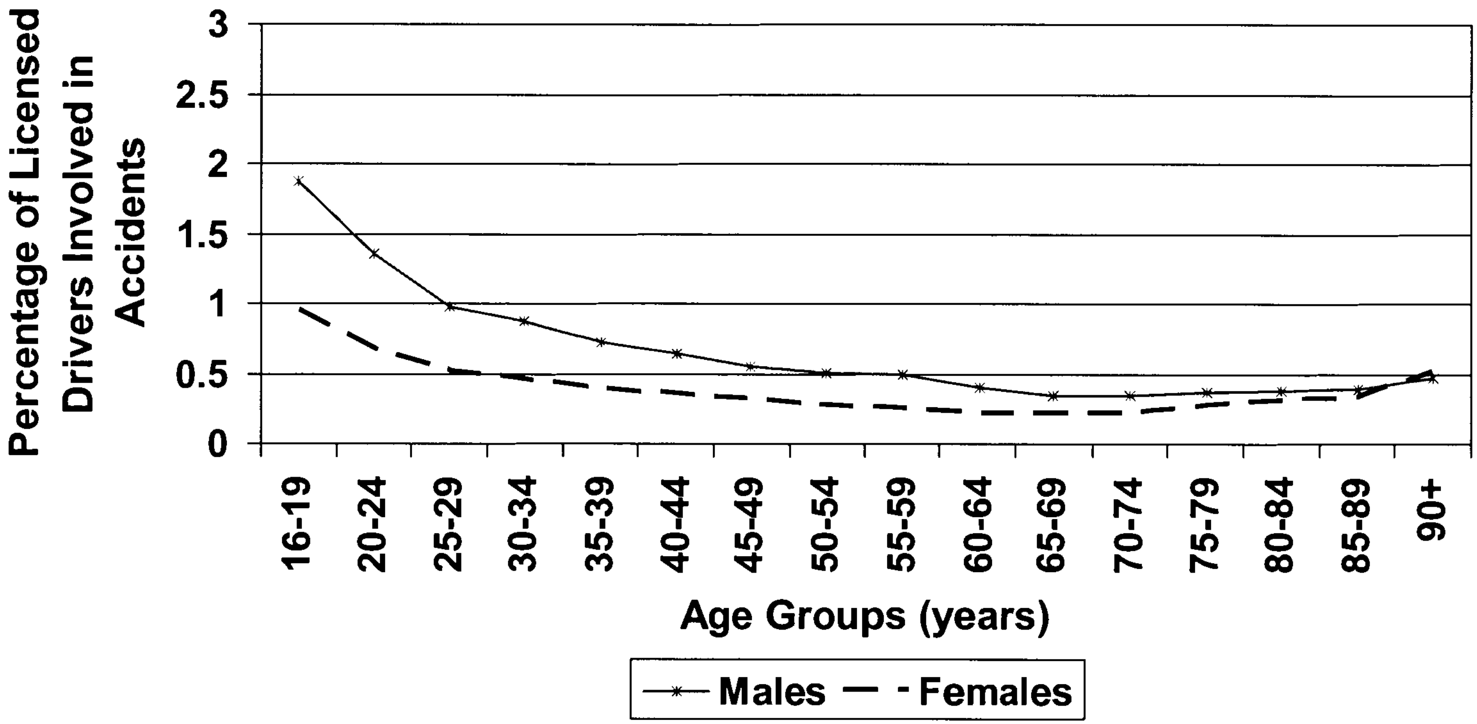
Note: Percentage of licensed drivers involved in accidents represents the proportion of licensed drivers per age group involved in all accidents.

Figure 4.6: Percentage of Licensed Drivers Involved in Accidents at Intersections, B.C. (1996-2000)



Note: Percentage of licensed drivers involved in accidents represents the proportion of licensed drivers per age group involved in intersection accidents

Figure 4.7: Percentage of Licensed Drivers Involved in Accidents at Non-Intersection Locations, B.C. (1996-2000)



Note: Percentage of licensed drivers involved in accidents represents the proportion of licensed drivers per age group involved in non-intersection accidents.

reference group (40-44 years) is subtracted from the target age group (i.e., 16-19 years or 80 years and over) and then divided by the former. These allow for direct comparison across the targeted age groups.

Hypothesis 2

The oldest drivers have more accidents at intersections than other age groups when controlling for the number of licensed drivers.

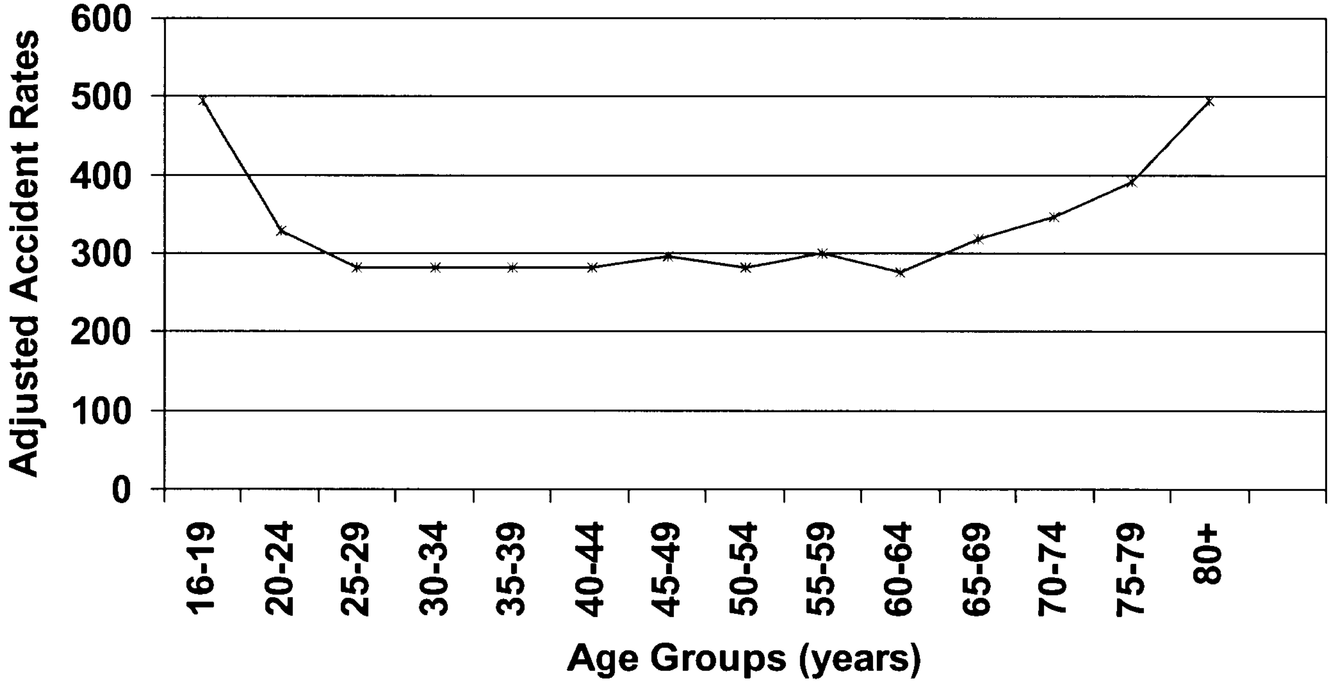
This hypothesis states that older drivers are expected to have higher adjusted accident rates in comparison to other drivers. Younger and older age will be positively associated with adjusted accident rates. Indeed, a curvilinear or U-shaped pattern can be seen in Table 4.8 and Figure 4.8. This pattern is present, with the exception of a subtle decrease occurring at age 60-64 years, where the percentages are the lowest for adjusted accident rates. A strong positive differential is found for both of the focus age groups when compared to the middle-age group. Those 80 years and over are 76.26% more likely, and those 16-19 years are 76.26% more likely, to have higher adjusted accident rates than the middle-age group (40-44 years).

Table 4.8: Adjusted Accident Rate by Age Groups, Selected Intersections, October 1996-October 2001

Age Groups (years)	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80+
Dependent Variable														
Adjusted Accident Rate *	494.9	327.9	281.2	282.3	281.8	281.0	295.5	282.3	300.7	275.7	318.0	346.0	390.5	495.3

* *Adjusted accident rate represents the number of accidents per 100 million cars, per selected intersection, per percentage licensed drivers by age groups.*

Figure 4.8: Accident Rates Adjusted for Traffic Flow, License Rates by Age Groups, Selected Intersections, B.C. (Oct. 1996-Oct. 2001)



Note: Adjusted accident rates represents the number of accidents per 100 million cars, per selected intersection, and per percentage licensed drivers by age group.

The cross-tabulation of adjusted accident rates by age is layered by other independent variables to observe if there is an interaction. Gender is examined first for exploratory purposes. Males were expected to have more accidents than females and across age both males and females were expected to have higher adjusted accident rates with increasing age. There is a consistent differential across the gender categories with males exhibiting more accidents compared to females with a positive, strong overall percentage difference of 91.55%. Gender patterns are maintained across age groups for the different categories with a few exceptions (see Table 4.9 and Figure 4.9).

Comparing across the age groups, males with increasing age are more likely to be involved in accidents. A moderate, positive differential is found for the 80 year and over age group and an inverse, non-significant association is found for the 16-19 year age group compared to the middle-age group. The percentage differentials reveal that the oldest males have a 33.49% higher adjusted accident rate while the youngest males are 2.72% less likely to have accidents than the reference age group (40-44 years).

For the oldest females compared to the reference age group, there is a strong, inverse relationship while the youngest female drivers exhibit a positive but non-significant association with the middle-age group. Females who are 80 years and over are 73.24% less likely, whereas those 16-19 years are 4.52% more likely, to have an higher adjusted accident than the reference age group (40-44 years). The strength of this interaction for the oldest females is less for the 75-79 year age group with a moderate, inverse differential (-20.21%). However, these results indicate that females who are older are less likely to be involved in accidents than middle-aged female drivers.

Table 4.9: Accidents by Age Groups and Gender, Selected Intersections, October 1996-October 2001

Age Groups (years)	**16-19 n (%)**	**20-24 n (%)**	**25-29 n (%)**	**30-34 n (%)**	**35-39 n (%)**	**40-44 n (%)**	**45-49 n (%)**	**50-54 n (%)**	**55-59 n (%)**	**60-64 n (%)**	**65-69 n (%)**	**70-74 n (%)**	**75-79 n (%)**	**80+ n (%)**	**Total n (%)**
Demographic Variables															
Gender															
Male	82 (60.7)	147 (67.1)	128 (64.0)	113 (66.9)	112 (69.1)	78 (62.4)	67 (56.3)	67 (74.4)	35 (64.8)	27 (71.1)	17 (70.8)	12 (63.2)	14 (70.0)	15 (83.3)	914 (65.7)
Female	53 (39.3)	72 (32.9)	72 (36.0)	56 (33.1)	50 (30.9)	47 (37.6)	52 (43.7)	23 (25.6)	19 (35.2)	11 (28.9)	7 (29.2)	7 (36.8)	6 (30.0)	3 (16.7)	478 (34.3)
Total	135 (100)	219 (100)	200 (100)	169 (100)	162 (100)	125 (100)	119 (100)	90 (100)	54 (100)	38 (100)	24 (100)	19 (100)	20 (100)	18 (100)	1392 (100)
Acc. by Age*	135 (9.7)	219 (15.7)	200 (14.4)	169 (12.1)	162 (11.6)	125 (9.0)	119 (8.5)	90 (6.5)	54 (3.9)	38 (2.7)	24 (1.7)	19 (1.4)	20 (1.4)	18 (1.3)	1392 (100)

* *Acc. by age represents the number of accidents by age group not adjusted.*

Figure 4.9: Percentage of Accidents for Males and Females by Age Group, Selected Intersections, B.C. (October 1996-October 2001)

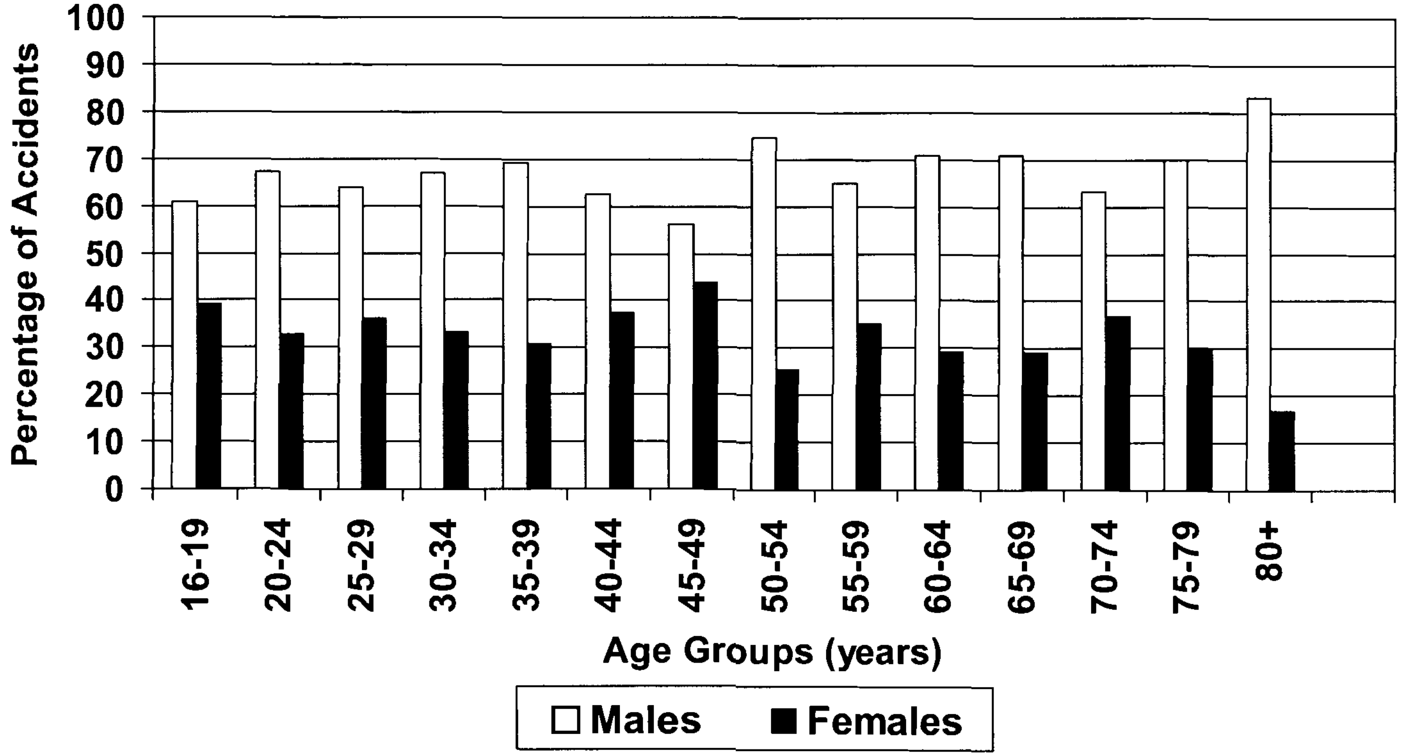


Table 4.10: Accidents by Behavioral Variables and Age Groups, Selected Intersections, October 1996-October 2001

Age Group (years)	16-19 n (%)	20-24 n (%)	25-29 n (%)	30-34 n (%)	35-39 n (%)	40-44 n (%)	45-49 n (%)	50-54 n (%)	55-59 n (%)	60-64 n (%)	65-69 n (%)	70-74 n (%)	75-79 n (%)	80+ n (%)	Total n (%)
Pre-action															
Going Straight	68 (50.4)	136 (62.1)	117 (58.5)	100 (59.2)	89 (54.9)	70 (56.0)	63 (52.9)	46 (51.1)	28 (51.9)	22 (57.9)	17 (70.8)	6 (31.6)	8 (40.0)	13 (72.2)	783 (56.3)
Turning	58 (43.0)	60 (27.4)	52 (26.0)	40 (23.7)	36 (22.2)	34 (27.2)	35 (29.4)	27 (30.0)	16 (29.6)	11 (29.0)	6 (25.0)	11 (57.9)	8 (40.0)	5 (27.8)	399 (28.7)
Stopping	6 (4.4)	14 (6.4)	24 (12.0)	20 (11.8)	30 (18.5)	16 (12.8)	18 (15.1)	15 (16.7)	9 (16.7)	4 (10.5)	0 (0)	1 (5.3)	2 (10.0)	0 (0)	159 (11.3)
Other	3 (2.2)	9 (4.1)	7 (3.5)	9 (5.3)	7 (4.3)	5 (4.0)	3 (2.5)	2 (2.2)	1 (1.9)	1 (2.6)	1 (4.2)	1 (5.3)	2 (10.0)	0 (0)	51 (3.7)
Total	135 (100)	219 (100)	200 (100)	169 (100)	162 (99.9)	125 (100)	119 (99.9)	90 (100)	54 (100.1)	38 (100)	24 (100)	19 (100.1)	20 (100)	18 (100)	1392 (100)
Prior Offend															
Not Prior Offend	95 (70.0)	157 (72.0)	148 (74.0)	131 (78.0)	130 (80.0)	97 (78.0)	97 (82.0)	67 (74.0)	38 (70.0)	24 (63.0)	16 (67.0)	14 (74.0)	15 (75.0)	10 (55.6)	1039 (74.6)
Prior Offend	40 (30.0)	62 (28.0)	52 (26.0)	38 (22.0)	32 (20.0)	28 (22.0)	22 (18.0)	23 (26.0)	16 (30.0)	14 (37.0)	8 (33.0)	5 (26.0)	5 (25.0)	8 (44.4)	353 (25.4)
Total	135 (100)	219 (100)	200 (100)	169 (100)	162 (100)	125 (100)	119 (100)	90 (100)	54 (100)	38 (100)	24 (100)	19 (100)	20 (100)	18 (100)	1392 (100)

Note: Pre-action categories: Turning was recoded to include those making left turns and right turns. Stopping includes those who were slowing or stopping and those stopped in traffic. Other was recoded to represent backing, changing lanes, jack-knife, making U turn, merging, overtaking, skidding, starting in traffic, swerving, other, and unknown.

Table 4.10 (cont): Accidents by Behavioral Variables and Age Groups, Selected Intersections, October 1996-October 2001

Age Group (years)	16-19 n (%)	20-24 n (%)	25-29 n (%)	30-34 n (%)	35-39 n (%)	40-44 n (%)	45-49 n (%)	50-54 n (%)	55-59 n (%)	60-64 n (%)	65-69 n (%)	70-74 n (%)	75-79 n (%)	80+ n (%)	Total n (%)
Cont. Factor															
Without Due Care	10 (7.4)	14 (6.4)	7 (3.5)	13 (7.7)	9 (5.6)	5 (4.0)	6 (5.0)	4 (4.4)	3 (5.6)	0 (0)	0 (0)	1 (5.3)	1 (5.0)	2 (11.1)	75 (5.4)
Inexp.	21 (15.6)	3 (1.4)	1 (0.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (5.3)	0 (0)	0 (0)	0 (0)	0 (0)	27 (1.9)
Failing To Yield	24 (17.8)	29 (13.2)	38 (19.0)	25 (14.8)	25 (15.4)	14 (11.2)	17 (14.3)	20 (22.2)	10 (18.5)	6 (15.8)	6 (25.0)	7 (36.8)	6 (30.0)	6 (33.3)	233 (16.7)
Ignore Control Device	17 (12.6)	28 (12.8)	18 (9.0)	11 (6.5)	7 (4.3)	16 (12.8)	7 (5.9)	9 (10.0)	6 (11.1)	1 (2.6)	3 (12.5)	1 (5.3)	3 (15.0)	3 (16.7)	130 (9.3)
Other	26 (19.3)	55 (25.1)	45 (22.5)	34 (20.1)	35 (21.6)	30 (24.0)	31 (26.1)	16 (17.8)	11 (20.4)	12 (31.6)	9 (37.5)	2 (10.5)	5 (25.0)	5 (27.7)	316 (22.7)
UN/NA	37 (27.4)	90 (41.1)	91 (45.5)	86 (50.9)	86 (53.1)	60 (48.0)	58 (48.7)	41 (45.6)	24 (44.4)	17 (44.7)	6 (25.0)	8 (42.1)	5 (25.0)	2 (11.1)	611 (43.9)
Total	135 (100.1)	219 (100)	200 (100)	169 (100)	162 (100)	125 (100)	119 (100)	90 (100)	54 (100)	38 (100)	24 (100)	19 (100.1)	20 (100)	18 (99.9)	1392 (99.9)

Note: *Cont. Factors= Contributing Factors*
Inexp.= Driver Inexperience
UN/NA= Unknown/Not Applicable

Hypothesis 3

Behavioral factors (i.e., pre-action, prior offender, and contributing factors) will be associated with age patterns in adjusted accident rates at intersections.

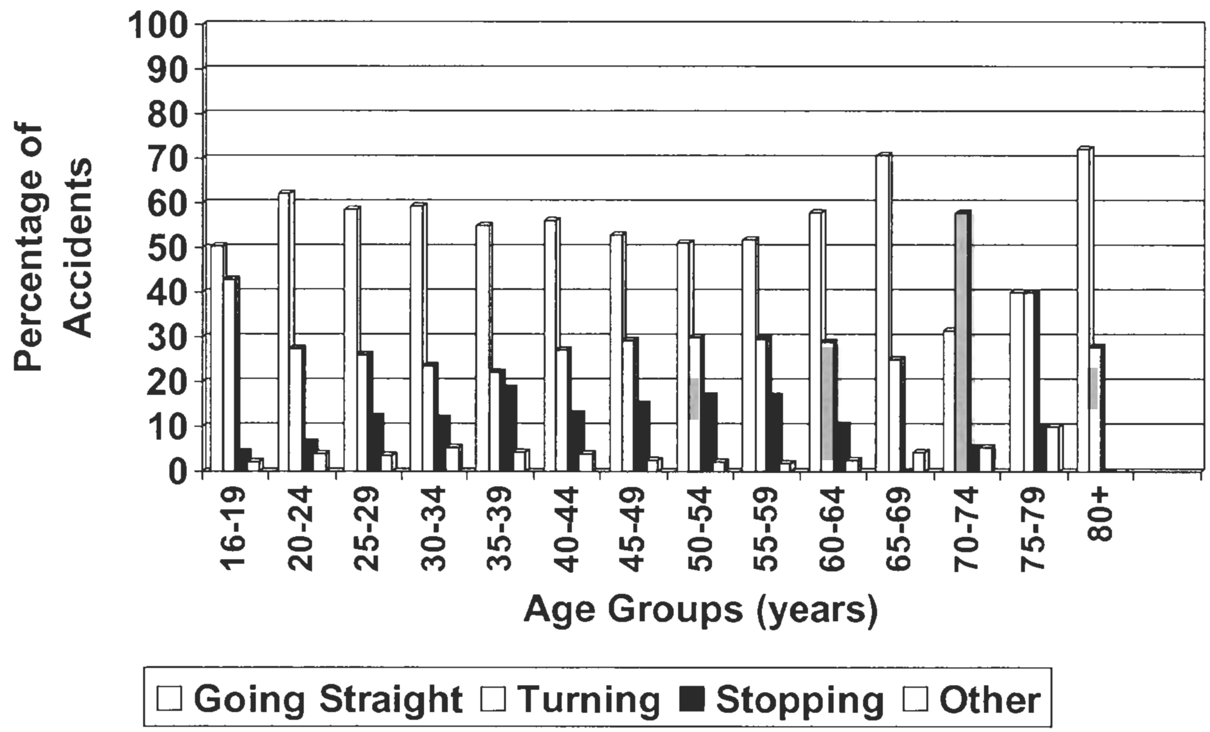
This hypothesis presumes that behaviors of the driver will have an interaction with age that is associated with adjusted accident rates. To test this hypothesis, three independent variables are individually used as a layer in the cross-tabulation of age with adjusted accident rates (see Table 4.10). These are measured using the following variables: driver pre-action, prior offender, and contributing factors. For the variable, driver pre-action, it was anticipated that the going straight category would have the highest adjusted accident rate for all age groups but that older drivers would have a higher adjusted accident rate for the turning category than other age groups. The prior offender variable was hypothesized to indicate a greater proportion of accidents for the not prior offender group and that older drivers who were prior offenders would have a higher adjusted accident rate than middle-aged drivers from this category. Contributing factors, the third behavioral variable tested, was expected to indicate higher adjusted accident rates for older and younger drivers for all categories except the unknown/not applicable category. Specifically, younger drivers will be positively associated with the inexperience category while older drivers will be positively associated with the without due care, failing to yield, and ignoring control devices categories.

First, for the independent variable, driver pre-action, the categories and the percentage of accidents for each include: going straight (56.3%), turning (28.7%), stopping (11.3%), and other (3.7%). The greatest percentage of accidents occurs when people are going straight.

A slight curvilinear pattern can be seen for the category going straight when examining across age groups in Figure 4.10, with a couple of exceptions. The going straight category shows a positive, moderate relationship for the 80 years and over age group. Yet the 70-74 year and the 75-79 year age groups exhibit negative, moderate to strong associations when compared to the 40-44 year age group. The percentage differentials for the going straight category reveal that 80 year and over drivers have a 28.93% higher adjusted accident rate, while the 70-74 year and 75-79 year age groups have a 43.57% and 28.57% respectively lower adjusted accident rate than the middle-aged drivers. A weak inverse differential is found for the 16-19 year age group when compared to the 40-44 year age group. The 16-19 year age group has a 10.00% lower adjusted accident rate going straight compared to the middle-age group. However, the 20-24 year age group has a relationship in the opposite direction with a positive, weak association (10.89%).

The pre-action with the second leading percentage of accidents is the turning category. There is a slight curvilinear pattern across age groups with fluctuations in the middle-age groups. The oldest age group suggests a positive but non-significant percentage differential but the 70-74 year and 75-79 year age groups exhibit a strong positive association with the pre-action turning compared to the 40-44 year age group. Those who are 80 years and over are 2.21% more likely, while those 70-74 years are 112.87% more likely, and those 75-79 years are 47.06% more likely, to have higher adjusted accident rates than the middle-age group with the pre-action turning. A strong positive differential is found for the youngest drivers when compared to the middle-age

Figure 4.10: Percentage of Accidents for Driver's Pre-Action by Age Groups, Selected Intersections, B.C. (October 1996-October 2001)



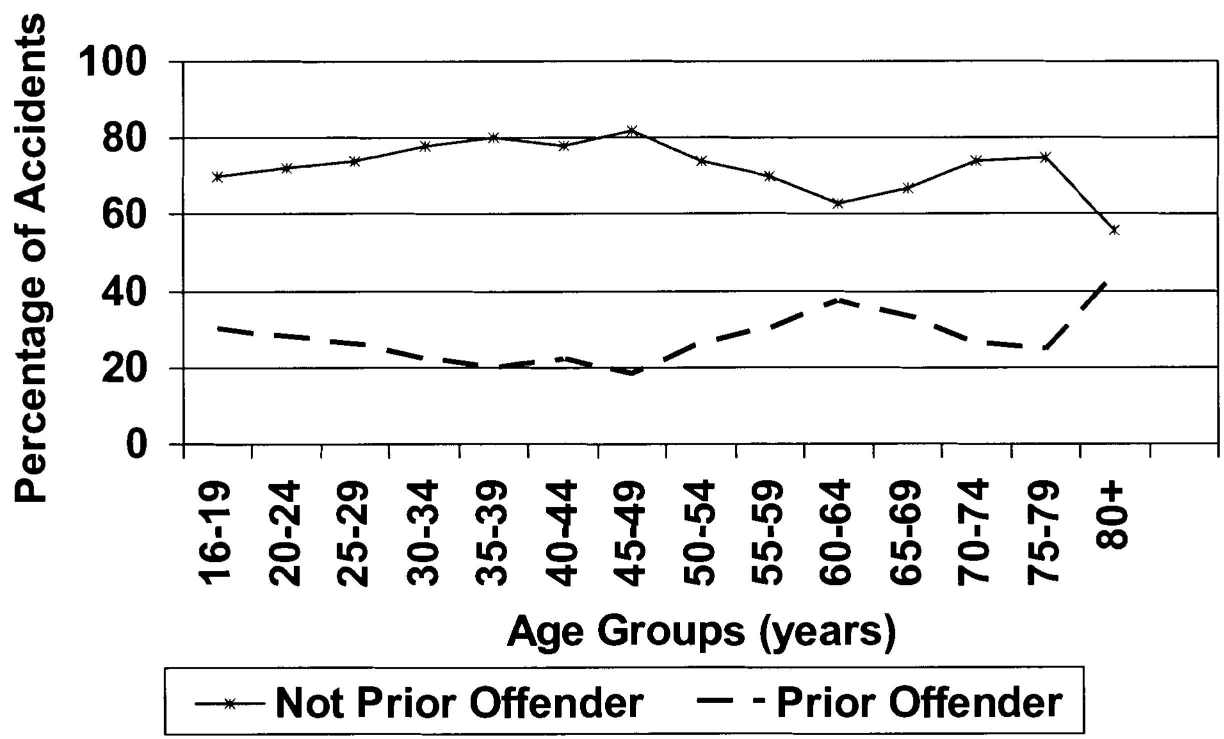
Note: Turning was recoded to include those making left turns and right turns. Stopping includes those who were slowing or stopping and those stopped in traffic. Other was recoded to represent backing, changing lanes, jack-knife, making U turn, merging, overtaking, skidding, starting in traffic, swerving, other, and unknown.

group. The percentage differential reveals that those 16-19 years have a 58.09% higher adjusted accident rate than the 40-44 year age group. The lowest percentage differential across age for the turning category is the 35-39 year age group with a negative, weak association. Therefore, drivers 35-39 years are 18.38% less likely to be involved in accidents compared to the 40-44 year age group when the driving behavior is turning.

The stopping category suggests the presence of an inverse, curvilinear pattern. This indicates that accidents associated with the stopping behavior occur more in the middle-age groups. Strong inverse associations are found for both the 80 year and over and 16-19 year age groups. For example, the oldest age group had a 100% lower, and the youngest group had a 65.63% lower, adjusted accident rate stopping compared to the middle-age group. The lowest points for this category are for the 65-69 year and 80 and over year age groups where the percentage of accidents occurring when the pre-action is stopping equals zero percent creating a negative 100% differential. The other category demonstrates no clear pattern across age with some higher percentages in the lower and middle-age groups that are not significant due to the small numbers in this category. However, the percentage differentials exhibit that 80 year and over drivers have a 100% lower adjusted accident rate and 16-19 year drivers have a 45% lower adjusted accident rate than 40-44 year drivers.

Second, the independent variable, prior offenders, reveals that there is an inverse, strong association for prior offender compared to not prior offender. Those who have been prior offenders before are 65.95% less likely to be involved in an accident. Across age groups the data indicate that there is a curvilinear relationship in the proposed direction (see Figure 4.11). There is a moderate inverse differential for the 80 year and

Figure 4.11: Percentage of Accidents by Prior Offenders versus Not Prior Offenders by Age Groups, Selected Intersections, B.C. (Oct. 1996-Oct. 2001)



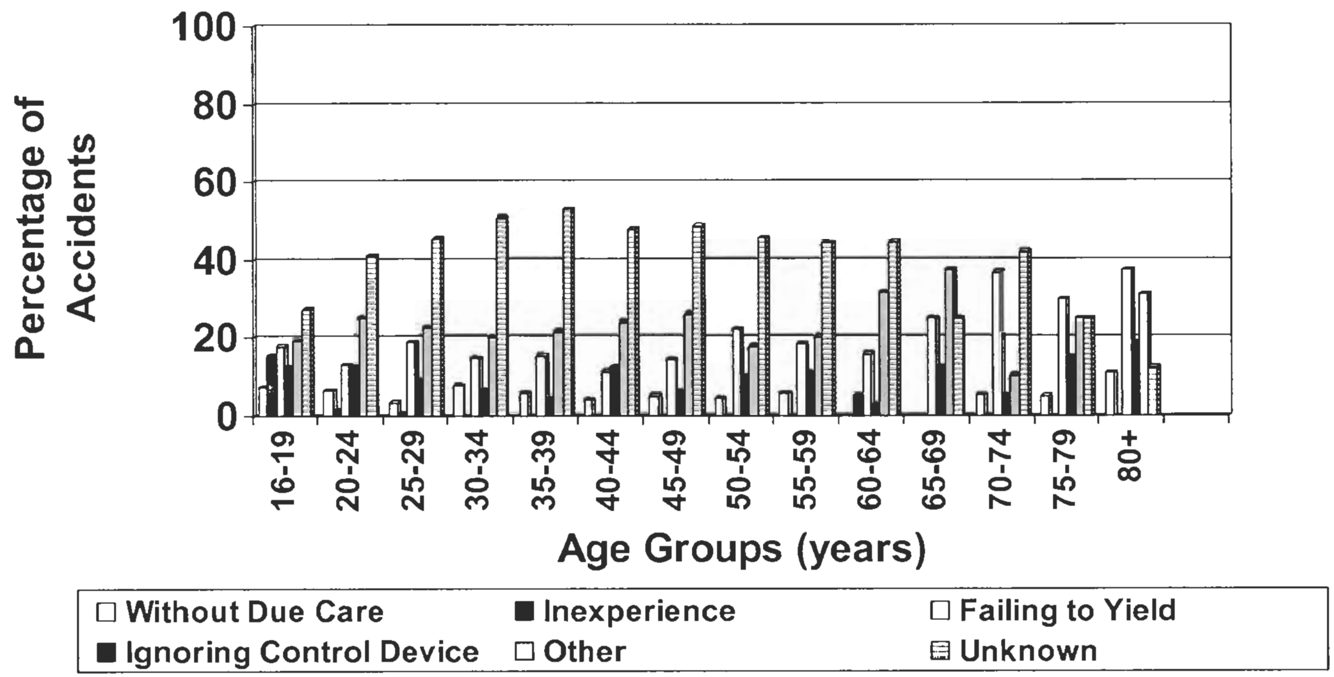
over age group and a weak inverse relationship for the 16-19 year age group compared to the 40-44 year age group. Adjusted accident rates are 28.72% lower for older drivers and 10.00% lower for younger drivers compared to middle-aged drivers who are not prior offenders.

For the prior offender category, positive, significant associations for the 80 year and over and 16-19 year age groups indicates a significant curvilinear pattern in the proposed direction. Older and younger drivers who are prior offenders are 101.82% and 36.36% more likely to have accidents than middle-age drivers who are prior offenders. At 60-64 years both age categories fluctuate with a decrease in accidents for the not prior offenders and an increase for the prior offenders. The 60-64 year age group for the prior offender category is 68.18% more likely to experience an accident than the 40-44 year age group and for the not prior offender category is 19.23% less likely to have an accident compared to the reference group.

The third behavioral variable, contributing factors, has six nominal categories. When the cross-tabulation of adjusted accident rates by age is layered by contributing factors, results reveal that the total percentages of accidents per category are: 5.4% without due care, 1.9% inexperience, 16.7% failing to yield, 9.3% ignoring control devices, 22.7% other, and 43.9% related to the unknown/not applicable category.

Patterns across age groups can be seen in Figure 4.12. For the without due care category, the percentage differentials indicate the presence of a curvilinear relationship with strong positive associations for the oldest and youngest age groups compared to the middle-age group. Those who are 80 years and over are 177.50% more likely, and those 16-19 years are 85.0% more likely, to have higher adjusted accident rates than the 40-44

Figure 4.12: Percentage of Accidents for Contributing Factors by Age Groups, Selected Intersections, B.C. (October 1996-October 2001)



Note: Without due care recoded to represent backing unsafely, cutting in, driving on wrong side of road, driving without due care, improper passing, improper turning, following too closely, and unsafe speed. Other includes avoiding VEH/PED/CYCLE, defective headlights, defective steering, extreme fatigue, fell asleep, illness, obstruction/debris on road, Pedestrian error/confusion, physical disability, road/intersection design, sunlight glare, unsafe speed, visibility impaired, and weather condition.

year age group when the contributing factor is without due care. However, a number of scores fluctuate in between these comparison groups. For example, for the 60-64 year age group and 65-69 year age group there are no accidents related to the without due care category and the 30-34 year age group has a 92.50% higher adjusted accident rate driving without due care compared to the 40-44 year age group. The inexperience category is positively related to the youngest age group with a 15.60% higher adjusted accident rate than middle-age drivers. Those 80 years and over demonstrate no association with zero accidents occurring for the inexperience category. The only anomaly in this category is for the 60-64 year age group where 5.3% of accidents for this age group are experienced.

For the failing to yield category, the data replicates a general pattern across age groups with some fluctuations until 70 years and onwards where the percentage of accidents for these groups increases. There is a strong positive percentage differential found for both the focus age groups when compared to the middle-aged group. There is an age interaction for the failing to yield category with a particularly strong association for the older age groups with a 234.82% higher adjusted accident rate and for those 16-19 years who had a 58.93% higher adjusted accident rate compared to the middle-age group.

The ignoring control device category revealed a fluctuating pattern with the lowest scores in the 35-39 year and 60-64 year age groups. The highest percentage differential is for the 80 year and over age group who are 46.88% more likely to have accidents than the 40-44 year age group. The 16-19 year drivers show no interaction with a zero differential. The other category has no clear pattern with fluctuation across the age groups. For this category the 80 year and over age group has a moderate positive association whereas, the 70-74 year age group display a strong inverse relationship.

Those who are 80 years and over are 30.42% more likely, and those 16-19 years are 19.58% less likely, to have higher adjusted accident rates than the reference age group. There is an inverse curvilinear pattern for the unknown/not applicable category where greater percentages of middle-aged drivers are involved in accidents and have unknown/not applicable contributing factors. For example, the 80 year and over age group has a 73.96% lower adjusted accident rate and the 16-19 year age group possess a 42.92% lower adjusted accident rate than the 40-44 year age group when the contributing factor is unknown or not applicable.

Hypothesis 4

Natural environment factors (i.e., time of day, illumination, and weather) will be associated with age patterns in adjusted accident rates at intersections.

This hypothesis postulates that the natural environment will have an interaction with age that is positively associated with adjusted accident rates. To test this hypothesis, three variables are individually used as a layer in the cross-tabulation of age by adjusted accident rate. These encompass: time of day, illumination, and weather (see Table 4.11). For the time of day variable it is anticipated that older drivers will have a higher adjusted accident rate during daytime hours (i.e., morning or afternoon/evening). Older drivers will be positively associated with the daylight illumination category and with clear/dry weather.

First, the independent variable, time of day, captures three time frames: morning (6am-12:59pm), afternoon/evening (1pm-7:59pm), and night (8pm-5:59am). The total percentage of accidents across categories is relatively stable (morning=30.8%,

Table 4.11: Accidents by Natural Environment Variables and Age Groups, Selected Intersections, October 1996-October 2001

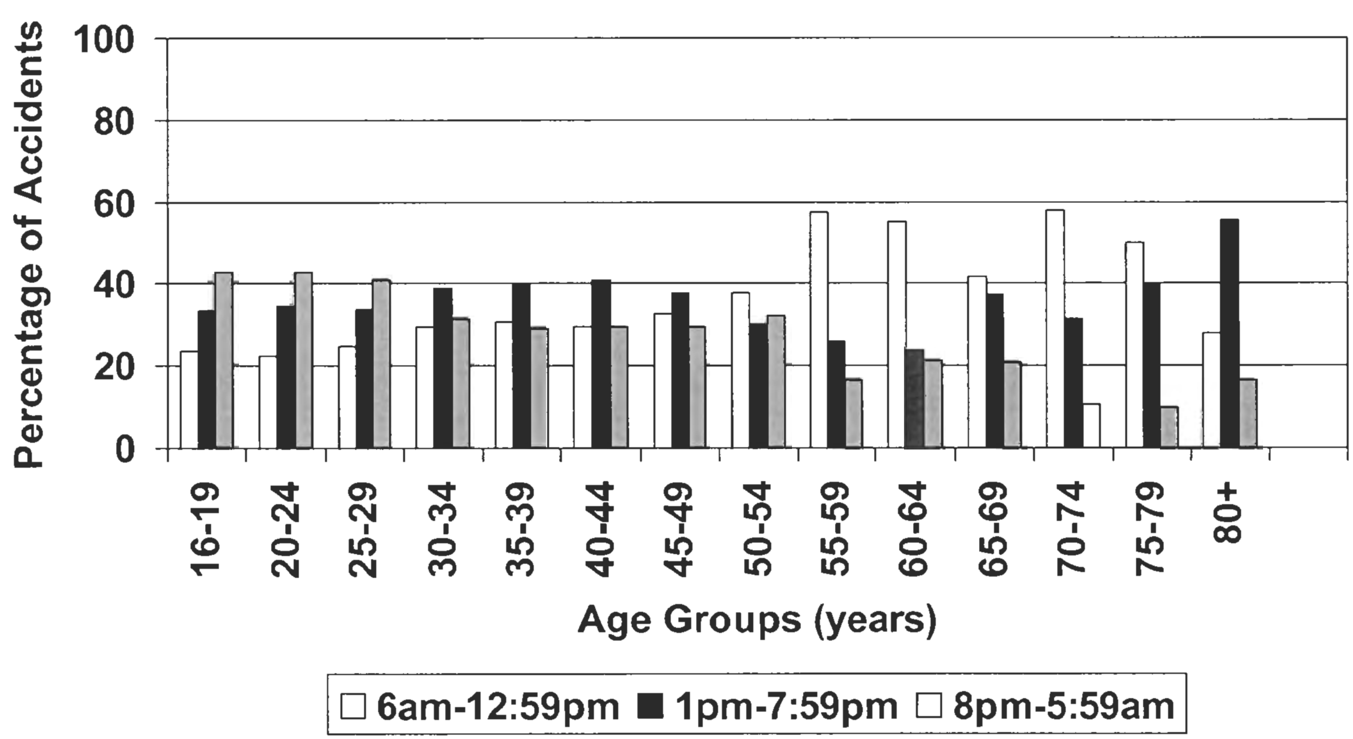
Age Groups (years)	16-19 n (%)	20-24 n (%)	25-29 n (%)	30-34 n (%)	35-39 n (%)	40-44 n (%)	45-49 n (%)	50-54 n (%)	55-59 n (%)	60-64 n (%)	65-69 n (%)	70-74 n (%)	75-79 n (%)	80+ n (%)	Total n (%)
Time Day															
6am-12pm	32 (23.7)	49 (22.4)	50 (25.0)	50 (29.6)	50 (30.9)	37 (29.6)	39 (32.8)	34 (37.8)	31 (57.4)	21 (55.3)	10 (41.7)	11 (57.9)	10 (50.0)	5 (27.8)	429 (30.8)
1pm-7pm	45 (33.3)	76 (34.7)	68 (34.0)	66 (39.1)	65 (40.1)	51 (40.8)	45 (37.8)	27 (30.0)	14 (25.9)	9 (23.7)	9 (37.5)	6 (31.6)	8 (40.0)	10 (55.6)	499 (35.9)
8pm-5am	58 (43.0)	94 (42.9)	82 (41.0)	53 (31.4)	47 (29.0)	37 (29.6)	35 (29.4)	29 (32.2)	9 (16.7)	8 (21.1)	5 (20.8)	2 (10.5)	2 (10.0)	3 (16.7)	464 (33.3)
Total	135 (100)	219 (100)	200 (100)	169 (100)	162 (100)	125 (100)	119 (100)	90 (100)	54 (100)	38 (100)	24 (100)	19 (100)	20 (100)	18 (100)	1392 (100)
Illum.															
Daylight	59 (43.7)	92 (42.0)	97 (48.5)	80 (47.3)	78 (48.1)	58 (46.4)	64 (53.8)	53 (58.9)	34 (63.0)	28 (73.7)	14 (58.3)	15 (78.9)	16 (80.0)	11 (61.1)	699 (50.2)
Other Illum.	76 (56.3)	127 (58.0)	103 (51.5)	89 (52.7)	84 (51.9)	67 (53.6)	55 (46.2)	37 (41.1)	20 (37.0)	10 (26.3)	10 (41.7)	4 (21.1)	4 (20.0)	7 (38.9)	693 (49.8)
Total	135 (100)	219 (100)	200 (100)	169 (100)	162 (100)	125 (100)	119 (100)	90 (100)	54 (100)	38 (100)	24 (100)	19 (100)	20 (100)	18 (100)	1392 (100)
Weather															
Clear/Dry	95 (70.4)	166 (75.8)	148 (74.0)	114 (67.5)	112 (69.1)	94 (75.2)	89 (74.8)	64 (71.1)	41 (75.9)	30 (78.9)	19 (79.2)	13 (68.4)	17 (85.0)	17 (94.4)	1019 (73.2)
Other	40 (29.6)	53 (24.2)	52 (26.0)	55 (32.5)	50 (30.9)	31 (24.8)	30 (25.2)	26 (28.9)	13 (24.1)	8 (21.1)	5 (20.8)	6 (31.6)	3 (15.0)	1 (5.6)	373 (26.8)
Total	135 (100)	219 (100)	200 (100)	169 (100)	162 (100)	125 (100)	119 (100)	90 (100)	54 (100)	38 (100)	24 (100)	19 (100)	20 (100)	18 (100)	1392 (100)

Note: Time of day missing cases recoded into the 1pm-7pm category, originally an interval variable. Other category for illumination represents dark/full Ill, dark/no Ill, dark/some Ill, dawn, dusk, and unknown. For weather the other category was recoded to include cloudy, raining, snowing/sleet, and unknown. Illum.=Illumination.

afternoon/evening=35.9%, and night=33.3%). Figure 4.13 displays the patterns across the age groups by categories. The 6am-12:59pm category indicates a gradual linear pattern that increases with age with the exception of the oldest age group. The 80 year and over age group exhibits an inverse, but non-significant relationship with the reference group while the 16-19 year age group also reveals a weak inverse differential. The percentage differentials indicate that those in the 80 year and over age group are 6.08% less likely to have accidents, and in the 16-19 year age group are 19.93% less likely to have accidents, compared to the 40-44 year age group. However, the 75-79 year age group experiences 68.92% higher adjusted accident rates than middle-age drivers in this time category with a strong positive association. There is an increase across age from 55 years onwards in accidents during the morning (6am-12:59pm) time period with the exception of the 80 year and older age group.

A clear pattern is not exhibited across the age groups for the afternoon/evening (1pm-7:59pm) category except for the slight increase seen from 65 years to 79 years. There is a moderate positive association for the 80 year and over age group and a weak inverse differential for the 16-19 year age group compared to the 40-44 year age group for the afternoon/evening category. Percentage differentials indicate that 80 year and over drivers have a 36.27% higher adjusted accident rate than middle-age drivers while 16-19 year old drivers have a 18.38% lower adjusted accident rate compared to the reference group. The lowest accident rates for this category appear between the ages of 55 years to 64 years that reveal an average inverse percentage differential of 39.22%. The final category, night (8pm-5:59am), suggests a linear pattern that decreases with age. The 80 year and over age group demonstrates a strong inverse relationship while the 16-

Figure 4.13: Percentage of Accidents at Different Times of the Day by Age Groups, Selected Intersections, B.C. (October 1996-October 2001)



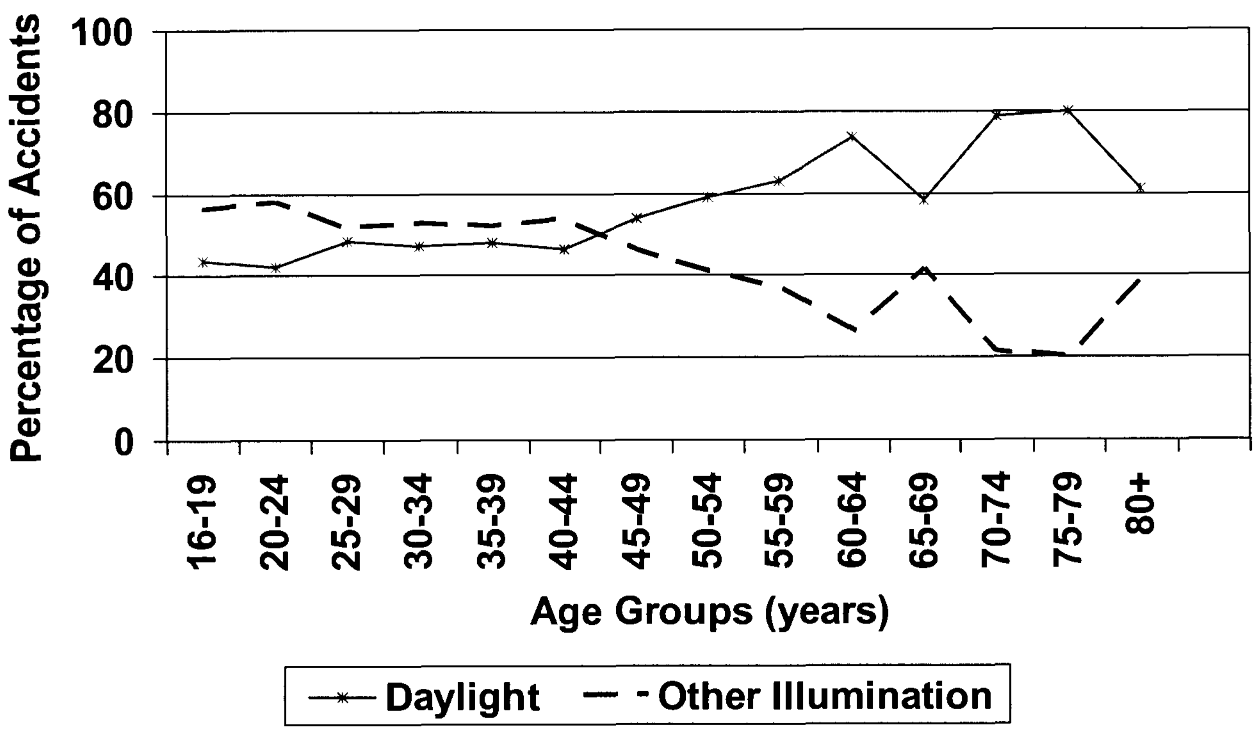
Note: Time of day missing cases recoded into the 1pm-7pm category, originally an interval variable.

19 year age group presents a strong positive differential compared to the reference group when it is nighttime. For example, those 80 years and over are 43.58% less likely to experience accidents at night than the 40-44 year age group while the 16-19 year age group is 45.27% more likely to have accidents within the 8pm and 5:59am time period than middle-aged drivers.

Second, for the illumination variable, there is an even distribution between the total accidents that occur in daylight (50.2%) versus other illumination (49.8%). There is a fairly even percentage of accidents across categories for each age group until the age of 45 years. Across categories for the age groups between 16 and 44 years of age there is a greater percentage of accidents in the other illumination category. Across age groups for each category the percentage differentials exhibit a consistent pattern with an increase in the percentage of adjusted accident rates for the daylight category and a corresponding decrease for the other illumination category (see Figure 4.14). A moderate positive differential is found for the 80 year and over age group while a non-significant but inverse association is discovered for the 16-19 year age group compared to the 40-44 year age group for the daylight category. Those who are 80 years and over are 31.68% more likely, whereas those 16-19 years are 5.82% less likely, to have higher adjusted accident rates than the middle-age group (40-44 years). For the other illumination category, the 16-19 year age group has 5.04% higher adjusted accident rates and the 80 years and over age group displays 27.43% lower adjusted accident rates compared to the reference age group.

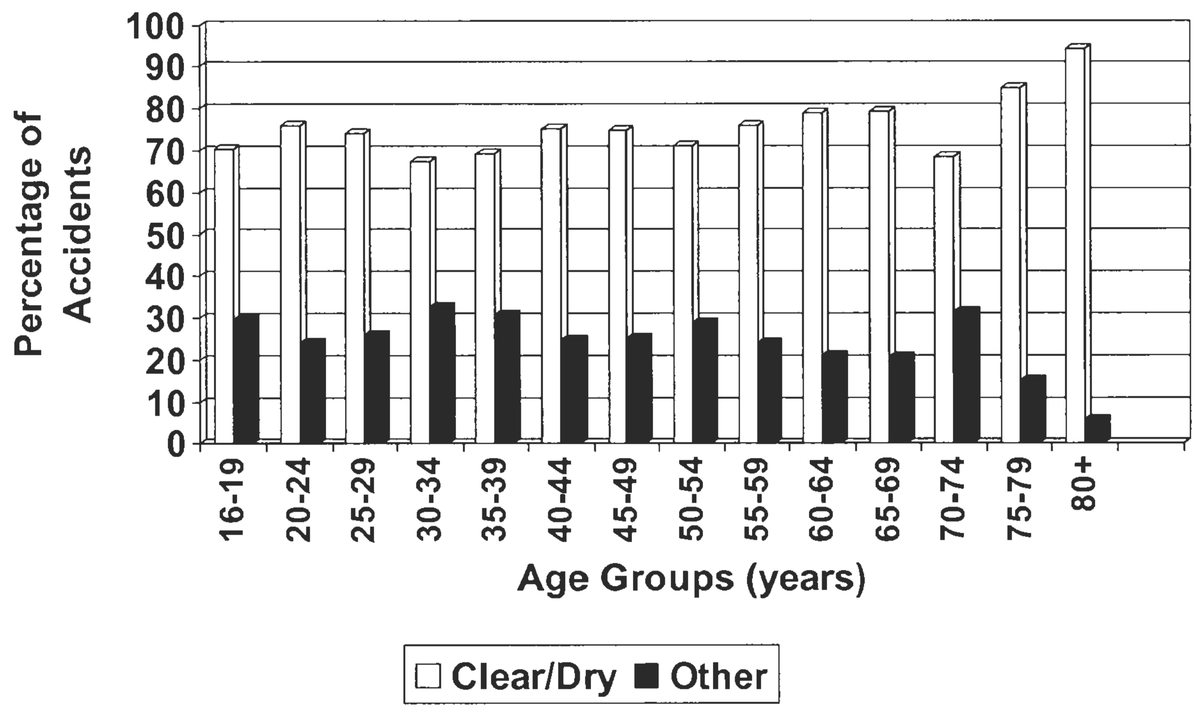
Weather, the third natural environment variable reveals that 73.2% of all accidents occur in clear/dry conditions (see Figure 4.15). The 80 years and over age

Figure 4.14: Percentage of Accidents in Daylight and Other Illumination Levels by Age Groups, Selected Intersections, B.C. (October 1996-October 2001)



Note: Other category for illumination represents dark/full Ill, dark/no Ill, dark/some Ill, dawn, dusk, and unknown.

Figure 4.15: Percentage of Accidents When there is Clear/Dry or Other Weather by Age Groups, Selected Intersections, B.C. (October 1996-October 2001)



Note: The other category was recoded to include cloudy, raining, snowing/sleet, and unknown.

group has a moderate positive differential compared to the 40-44 year age group for the clear/dry category. Therefore, older drivers are 25.53% more likely to experience accidents compared to middle-aged drivers when the weather is clear/dry while these drivers are 77.42% less likely to have accidents than the 40-44 year drivers for the other weather category. In contrast, the 16-19 year age group experiences the opposite with an inverse, non-significant association for the clear/dry category and a positive, weak percentage differential for the other category. Those 16-19 years old have a 6.38% lower adjusted accident rate when the weather is clear/dry, and a 19.35% higher adjusted accident rate when the weather category is other, compared to middle-age drivers. However, these percentages for the clear/dry category fluctuate back up for the 20-24 year age group who have a non-significant but positive relationship with the reference group (0.80% differential).

Hypothesis 5

Road environment factors (i.e., turning treatments, entrances/exits, and medians/dividers) will be associated with age patterns in adjusted accident rates at intersections.

This hypothesis states that elements of the road environment will have a positive association with accident rates and age. Three independent variables are used to test this hypothesis by individually layering them in the cross-tabulation of adjusted accident rate by age. These are measured using the following variables: turning treatments, entrances/exits, and medians/dividers (see Table 4.12). For the turning treatment variable, it is hypothesized that older drivers are positively associated with the less

Table 4.12: Accidents by Road Environment Variables and Age Groups, Selected Intersections, October 1996-October 2001

Age Groups (years)	**16-19 n (%)**	**20-24 n (%)**	**25-29 n (%)**	**30-34 n (%)**	**35-39 n (%)**	**40-44 n (%)**	**45-49 n (%)**	**50-54 n (%)**	**55-59 n (%)**	**60-64 n (%)**	**65-69 n %)**	**70-74 n (%)**	**75-79 n (%)**	**80+ n (%)**	**Total n (%)**
Turning Treat.															
Less Treat.	74 (54.8)	107 (48.9)	112 (56.0)	91 (53.8)	81 (50.0)	61 (48.8)	58 (48.7)	39 (43.3)	25 (46.3)	19 (50.0)	16 (66.7)	7 (36.8)	12 (60.0)	9 (50.0)	711 (51.1)
More Treat.	61 (45.2)	112 (51.1)	88 (44.0)	78 (46.2)	81 (50.0)	64 (51.2)	61 (51.3)	51 (56.7)	29 (53.7)	19 (50.0)	8 (33.3)	12 (63.2)	8 (40.0)	9 (50.0)	681 (48.9)
Total	135 (100)	219 (100)	200 (100)	169 (100)	162 (100)	125 (100)	119 (100)	90 (100)	54 (100)	38 (100)	24 (100)	19 (100)	20 (100)	18 (100)	1392 (100)
Ent./ Exits															
No Ent./ Exits	66 (48.9)	108 (49.3)	93 (46.5)	85 (50.3)	76 (46.9)	59 (47.2)	62 (52.1)	39 (43.3)	24 (44.4)	16 (42.1)	14 (58.3)	6 (31.6)	10 (50.0)	5 (27.8)	663 (47.6)
Ent./ Exits	69 (51.1)	111 (50.7)	107 (53.5)	84 (49.7)	86 (53.1)	66 (52.8)	57 (47.9)	51 (56.7)	30 (55.6)	22 (57.9)	10 (41.7)	13 (68.4)	10 (50.0)	13 (72.2)	729 (52.4)
Total	135 (100)	219 (100)	200 (100)	169 (100)	162 (100)	125 (100)	119 (100)	90 (100)	54 (100)	38 (100)	24 (100)	19 (100)	20 (100)	18 (100)	1392 (100)
Median/ Divider															
No Median/ Divider	59 (43.7)	102 (46.6)	93 (46.5)	70 (41.4)	71 (43.8)	61 (48.8)	57 (47.9)	30 (33.3)	21 (38.9)	18 (47.4)	11 (45.8)	4 (21.1)	10 (50.0)	10 (55.6)	617 (44.3)
Median/ Divider	76 (56.3)	117 (53.4)	107 (53.5)	99 (58.6)	91 (56.2)	64 (51.2)	62 (52.1)	60 (66.7)	33 (61.1)	20 (52.6)	13 (54.2)	15 (78.9)	10 (50.0)	8 (44.4)	775 (55.7)
Total	135 (100)	219 (100)	200 (100)	169 (100)	162 (100)	125 (100)	119 (100)	90 (100)	54 (100)	38 (100)	24 (100)	19 (100)	20 (100)	18 (100)	1392 (100)

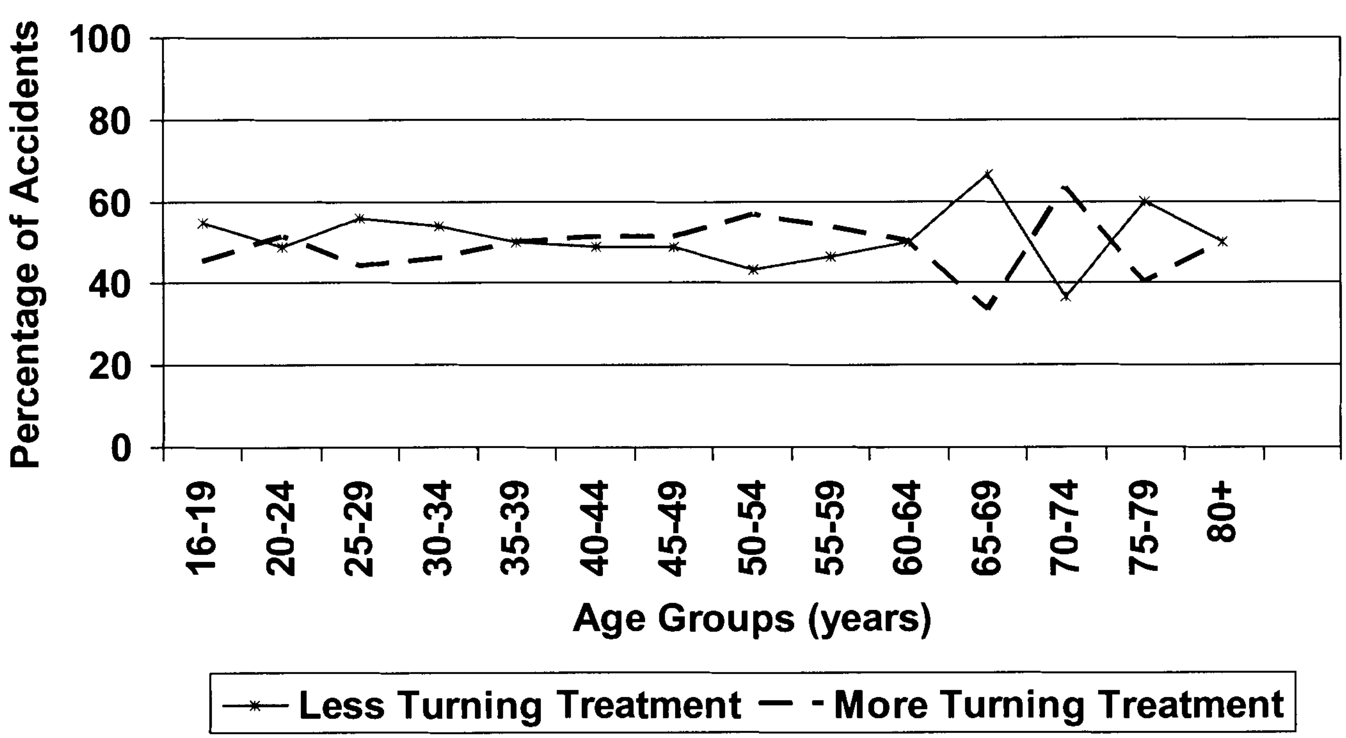
Note: Turning Treatment is a scale with less treatment=0-1.50 and more treatment=1.51+. No Entrances/Exits=0 and Entrances/Exits=1-4. No Median/Divider=0 and Median/Divider=1-4. Ent./Exits=Entrances/Exits.

turning treatment category than middle-aged drivers indicating that they will have higher adjusted accident rates when intersections have fewer turning treatments. The entrances/exits variable is anticipated to show that older adults have higher adjusted accident rates at intersections with entrances/exits compared to middle-aged drivers. For the medians/dividers variable, it is expected that older drivers will be positively associated with intersections that have no medians/dividers.

First, the independent variable, turning treatment, exhibits a fairly equal percentage of accidents at intersections with less turning treatments (51.1%) and more turning treatments (48.9%) (see Figure 4.16). Differentials across age for each category indicate the presence of this curvilinear pattern. A positive differential is found for both of the focus groups when compared to the reference age group for the less turning treatment category. Those who are 80 years and over are 2.46% more likely, and 16-19 years are 12.30% more likely, to have higher adjusted accident rates than the 40-44 year age group when intersections have less turning treatments. An inverse association exists for both the older and younger drivers compared to middle-aged drivers when intersections possess more turning treatments. The percentage differentials reveal that the 80 year and over age group has 2.34% lower adjusted accident rates, and the 16-19 year age group has 11.72% lower adjusted accident rates, than the middle-aged group (40-44 years) when intersections have more turning treatments.

There is a moderate positive association found for both the 65-69 year age group and the 75-79 year age group compared to the 40-44 year age group when intersections possess less turning treatments. Therefore, those 65-69 years have 36.68% higher adjusted accident rates, while those 75-79 years display 22.95% higher adjusted accident

Figure 4.16: Percentage of Accidents at Selected Intersections with More or Less Turning Treatments by Age Groups, B.C. (October 1996-October 2001)

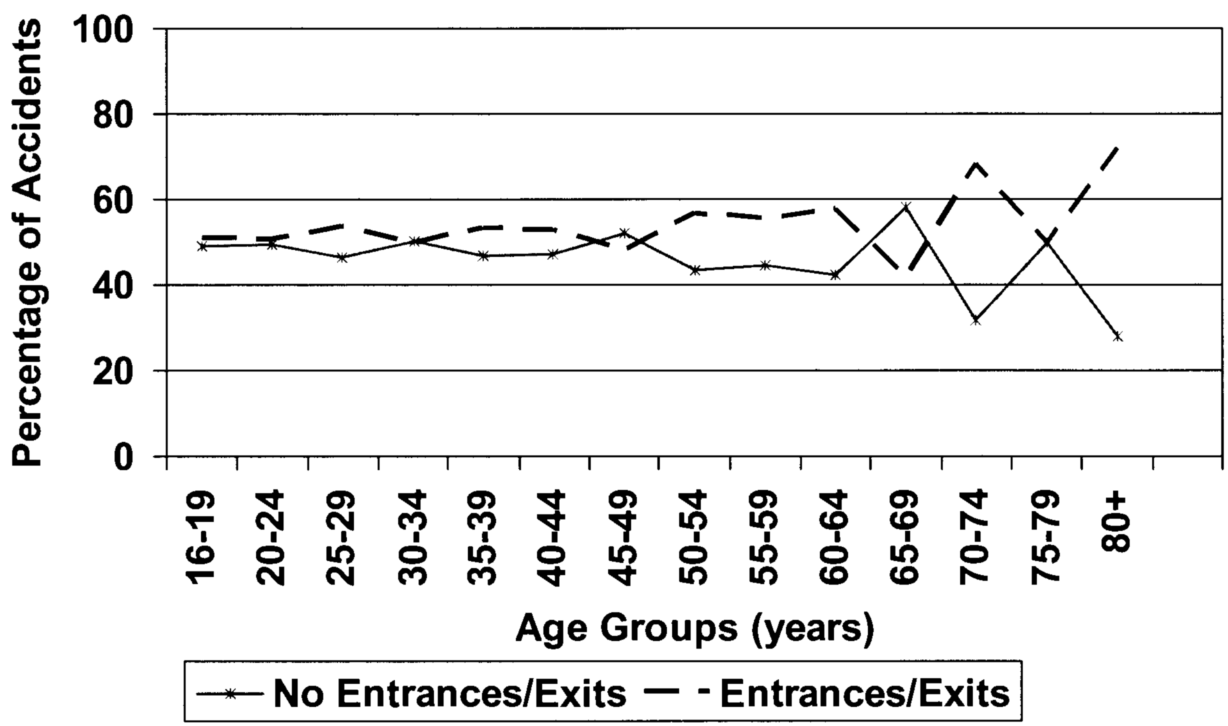


Note: Turning Treatment is a scale with less treatment=0-1.50 and more treatment=1.51+.

rates, than middle-aged drivers at intersections with less turning treatments. However, a fluctuation in the opposite direction occurs for the 70-74 year age group where there is a strong inverse association. Those 70-74 years are 24.59% less likely to experience accidents than the 40-44 year age group at intersections with less turning treatments.

For the road environment variable, entrances/exits, accidents are 10.08% more likely to occur at intersections with entrances/exits than no entrances/exits (see Figure 4.17). Across age groups for each category there are generally more accidents at intersections with entrances/exits with a few exceptions. This relationship increases with age with the 80 year and over age group showing a moderate positive association for the entrances/exits category and a strong inverse differential for the no entrances/exits category. This suggests that older drivers are 36.74% more likely than middle-aged drivers to have accidents at intersections with entrances/exits while they are 3.22% less likely to have accidents at intersections with no entrances/exits when compared to the 40-44 year age group. The opposite is true for the younger drivers who are 3.22% less likely to have adjusted accident rates at intersections with entrances/exits, and 3.60% less likely to have adjusted accident rates when there are no entrances/exits present, compared to the middle-age group. Two low points occur in Figure 4.17, with the 45-49 year age group and the 65-69 year age group. An inverse differential is found for both of these age groups compared to the reference age group. Those 45-49 years are 8.06% less likely, and those 65-69 years are 28.47% less likely, to have higher adjusted accident rates than the 40-44 year age group.

Figure 4.17: Percentage of Accidents at Selected Intersections With and Without Direct Entrances/Exits by Age Groups, B.C. (October 1996-October 2001)

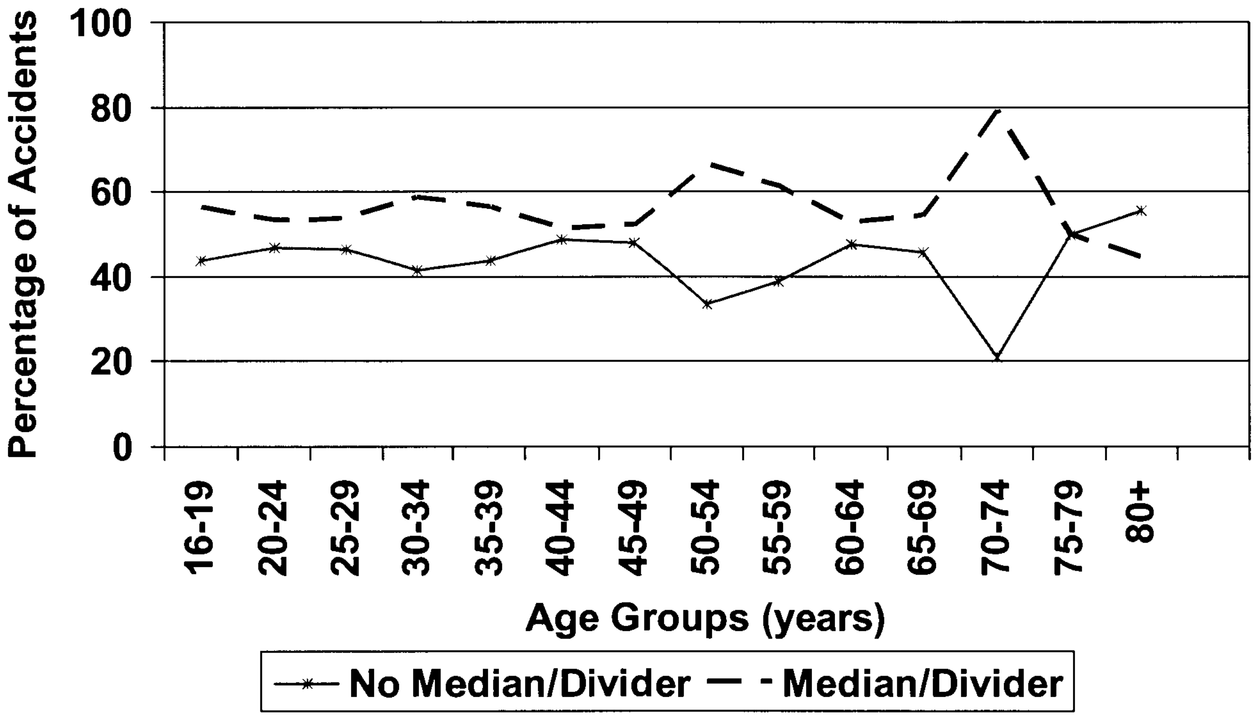


Note: No Entrances/Exits=0 and Entrances/Exits=1-4.

Third, the independent variable, medians/dividers, drivers are 20.47% less likely to have accidents at intersections with no medians/dividers (see Figure 4.18). Across age groups for each category there is an increase in the percentage of accidents that occurs at intersections with medians/dividers and a decrease at those with no medians/dividers with increasing age until the 80 year and over age group. The percentage differentials demonstrate that the 80 year and over age group has a 13.93% higher adjusted accident rate, while the 16-19 year age group has 10.45% lower adjusted accident rates. This compares to the 40-44 year age group when intersections have no medians/dividers. A weak inverse association is found for the older drivers when compared to the middle-age group for intersections with medians/dividers. Older drivers have a 13.28% lower adjusted accident rate at such intersections in comparison to the 40-44 year age group. The opposite is true for the 16-19 year age group where 9.96% higher adjusted accident rates are experienced in contrast to the middle-age group at intersections with medians/dividers.

Other than the 80 year and over age group there are two other noticeable fluctuations including the 50-54 year age group who have a moderate positive differential and the 70-74 year age group who display a strong positive association with the medians/dividers category compared to the reference age group. Those 50-54 years are 30.27% more likely, and those 70-74 years are 54.10% more likely, to have higher adjusted accident rates than the middle-age group.

Figure 4.18: Percentage of Accidents at Selected Intersections With and Without Medians/Dividers by Age Groups, B.C. (October 1996-October 2001)



Note: No Median/Divider=0 and Median/Divider=1-4.

Hypothesis 6

Visual environmental complexity (i.e., signage and architectural complexity) will be associated with age patterns in adjusted accident rates at intersections.

This hypothesis postulates that older drivers are more likely to have accidents at intersections with high visual complexity. A higher percentage of the total accidents occur at intersections with higher complexity with a positive, moderate percentage difference of 26.76% (see Table 4.13). With increasing age, drivers are more likely to have accidents at higher complexity intersections. The two points where there are significant inverse relationships between the categories can be seen. For example, when examining by age groups comparing across categories the 45-49 year age group has an inverse, weak association (-10.96% differential) and the 75-79 year age group displays an inverse, strong relationship (-46.15% differential).

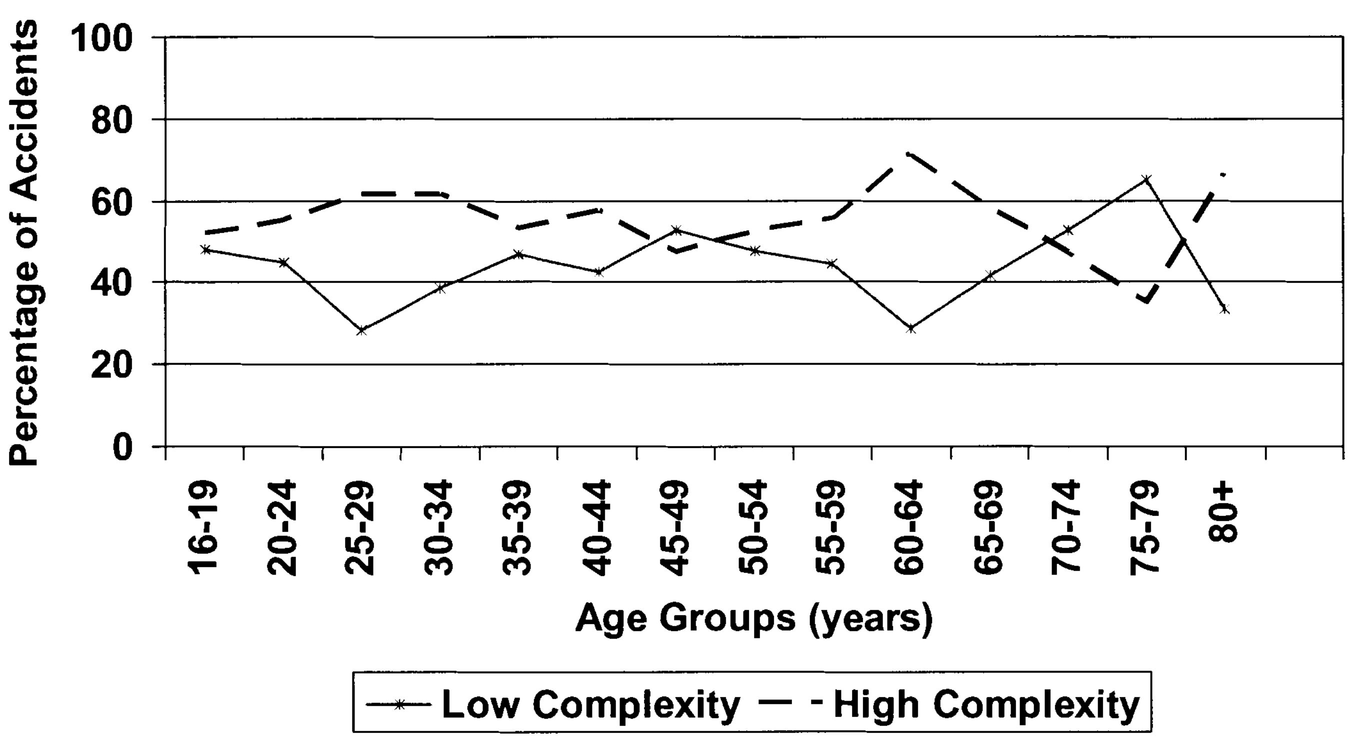
Figure 4.19 shows the fluctuations across age groups for each category. Across age groups for the low complexity category there is a moderate inverse relationship for the 80 year and over age group, and a weak but positive association for the 16-19 year age group. The older drivers have 21.09% lower adjusted accident rates, and younger drivers have 13.44% higher adjusted accident rates, compared to the middle-age group at intersections with less visual environmental complexity. The comparison across age groups for the high complexity category exhibits a weak positive association for the 80 year and over age group, while the 16-19 year age group reveals a non-significant inverse differential. At intersections with higher visual environmental complexity, older drivers have a 15.80% higher adjusted accident rate whereas younger drivers have a 9.90% lower adjusted accident rate, than middle-age drivers. There is a moderate positive association

Table 4.13: Accidents by Visual Environmental Complexity and Age Groups, Selected Intersections, October 1996-October 2001

Age Groups (years)	16-19 n (%)	20-24 n (%)	25-29 n (%)	30-34 n (%)	35-39 n (%)	40-44 n (%)	45-49 n (%)	50-54 n (%)	55-59 n (%)	60-64 n (%)	65-69 n (%)	70-74 n (%)	75-79 n (%)	80+ n (%)	Total n (%)
Comp. Scale															
Low Comp.	65 (48.1)	98 (44.7)	77 (38.5)	65 (38.5)	76 (46.9)	53 (42.4)	63 (52.9)	43 (47.8)	24 (44.4)	11 (28.9)	10 (41.7)	10 (52.6)	13 (65.0)	6 (33.3)	614 (44.1)
High Comp.	70 (51.9)	121 (55.3)	123 (61.5)	104 (61.5)	86 (53.1)	72 (57.6)	56 (47.1)	47 (52.2)	30 (55.6)	27 (71.1)	14 (58.3)	9 (47.4)	7 (35.0)	12 (66.7)	778 (55.9)
Total	135 (100)	219 (100)	200 (100)	169 (100)	162 (100)	125 (100)	119 (100)	90 (100)	54 (100)	38 (100)	24 (100)	19 (100)	20 (100)	18 (100)	1392 (100)

Note: Comp. Scale (Complexity Scale) represents the visual complexity (signage and architectural) at an intersection. Low complexity=1-2.74; High complexity=2.75+.

Figure 4.19: Percentage of Accidents at Low and High Complexity Selected Intersections by Age Groups, B.C. (October 1996-October 2001)



Note: Complexity Scale represents the visual complexity (signage and architectural) at an intersection. Low complexity=1-2.74; High complexity=2.75+.

for the 60-64 year age group compared to the 40-44 year age group for the high complexity category consistent with the hypothesized relationship. This age group indicates a 23.44% higher adjusted accident rate compared to the reference age group at intersections with higher visual complexity. But for the 75-79 year age group there is a moderate inverse differential that is contrary to the expected hypothesis. Those who are 75-79 years are 39.24% less likely have higher adjusted accident rates than the middle-age group (40-44 years).

4.4 Summary

Relative percentage differentials between the intersection accidents and non-intersection accidents were obtained for Part One. For Part Two the relative percentage differential between the dependent variable (adjusted accident rate) and the independent variable (age) is reported. In addition, the interactions between the 11 other independent variables with the cross-tabulation between age and adjusted accident rate support or fail to support the hypotheses.

Major findings Summarized:

1) Hypothesis one is fully supported, showing that older drivers are more likely to have accidents at intersections than other locations and age groups.
2) Hypothesis two is fully supported. Accidents at intersections are positively associated with older age groups compared to middle-aged drivers.
3) Gender revealed an interaction with age and adjusted accident rate. There is a positive association for older male drivers with accident rates and an inverse relationship is discovered for older female drivers. Older males are more likely to

have accidents and older females are less likely to have accidents compared to middle-aged drivers.

4) Hypothesis three, focusing on behavioral factors, is partially supported. Across categories, for the pre-action variable, drivers are more likely to have accidents when going straight. Across all ages, certain age groups demonstrate a greater likelihood of having accidents for the different categories. Younger drivers and two of the older driver age groups are more likely to have accidents when turning compared to middle-aged drivers. Although less prior offenders have accidents, of those who did, younger and older drivers are more likely to have accidents. Older and younger drivers are more likely to have a contributing factor whereas middle-aged drivers are positively associated with the unknown/not applicable category.
5) Hypothesis four, concentrating on natural environmental components, is fully supported. Older drivers are more likely to have accidents in the daytime hours, in daylight, and in clear/dry weather than middle-aged drivers. Younger drivers are more likely to have accidents at night and in other weather conditions.
6) Hypothesis five, focussing on road environmental elements, is partially supported. Younger and three of the older age group categories of drivers are more likely to have accidents at intersections with less turning treatments. Older drivers are more likely to have accidents at intersections with entrances/exits. The oldest drivers are inversely associated with medians/dividers. This is significant in the opposite direction to the predicted relationship revealing that less accidents occur

at intersections with medians/dividers for older drivers compared to middle-aged drivers.

7) Hypothesis six, examining visual environmental complexity, is partially supported. The oldest drivers are more likely to have accidents at intersections with high complexity. However, the age group 75-79 years is more likely to have accidents at lower complexity intersections.

Table 4.14: A Summary of Percentage Differentials Across Age Groups by Categories Compared to the 40-44 Year Age Group

Age Groups (years)	**16-19 (% Dif)**	**80+ (% Dif)**
Demographic Variables		
Age	76.12	76.26
Gender		
Males	-2.72	33.49
Females	4.52	-73.24
Behavioral Variables		
Pre-Action		
Going Straight	-10.00	28.93
Turning	58.09	2.21
Stopping	-65.63	-100.00
Other	-45.00	-100.00
Prior Offender		
Not Prior Offender	-10.26	-28.72
Prior Offender	36.36	101.82

Table 4.14 (cont.): A Summary of Percentage Differentials Across Age Groups by Categories Compared to the 40-44 Year Age Group

Age Groups (years)	**16-19 (% Dif)**	**80+ (% Dif)**
Behavioral Variables (cont.)		
Contributing Factors		
Without Due Care	85.00	177.50
Inexperience	15.60	0.00
Failing to Yield	58.93	234.82
Ignoring Control Device	0.00	46.88
Other	-19.58	30.42
Unknown/Not Applicable	-42.92	-73.96
Natural Environmental Variables		
Time of Day		
Morning (6am-12:59pm)	-19.93	-6.08
Afternoon/Evening (1pm-7:59pm)	-18.38	36.27
Night (8pm-5:59am)	45.27	-43.58
Illumination Level		
Daylight	-5.82	31.68
Other	5.04	-27.43
Weather		
Clear/Dry	-6.38	25.53
Other	19.35	-77.42

Table 4.14 (cont.): A Summary of Percentage Differentials Across Age Groups by Categories Compared to the 40-44 Year Age Group

Age Groups (years)	16-19 (% Dif)	80+ (% Dif)
Road Environmental Variables		
Turning Treatment		
Less Treatment	12.30	2.46
More Treatment	-11.72	-2.34
Entrances/Exits		
No Entrances/Exits	3.60	-41.10
Entrances/Exits Present	-3.22	36.74
Medians/Dividers		
No Medians/Dividers	-10.45	13.93
Medians/Dividers Present	9.96	-13.28
Visual Environmental Complexity		
Visual Complexity		
Low Complexity	13.44	-21.09
High Complexity	-9.90	15.80

Note: %Dif = Percentage Differential

CHAPTER 5: DISCUSSION

5.1 Overview

In the first section of this chapter the results are interpreted by integrating the findings with the person-environment fit theory and literature in this area. The discussion is followed by an evaluation of the implications and limitations of the research, as well as future directions for research. Each hypothesis is evaluated separately in this discussion of the findings.

The hypotheses provide specific expectations of relationships between environmental challenge and the older driver's competency with respect to adjusted accident rates at intersections. Until recently, most of the literature evaluating accident rates and driving behaviors has utilized aggregate population statistics. Some of this research has identified an association between age related declines and increased accident rates when controlling for exposure.

Research has shown that a higher proportion of accidents occur at intersections than in any other traffic environment. An abundance of literature examines behavioral factors and functional abilities of the older drivers without evaluating the myriad of environmental elements in the intersection that present a risk for older drivers. Accidents should not be evaluated in isolation from the complexity of the environment and the physical structures that play a role in the event. The concept of environmental complexity in this thesis originates from the person-environment fit theory discussed in Section 2.3, where high levels of environmental press can reduce peoples ability to function if his/her level of capability does not fit the demand created by the environment. This thesis investigates behavioral factors, as well as the elements in the traffic environment, that may play a role in increasing the risk of accident involvement for older drivers.

5.2 Main Findings and Interpretations

Hypothesis 1: The proportion of intersection accidents increases with age.

The results lend strong support to the hypothesis postulating that older drivers have more of his/her accidents at intersections. Intersections represent environmental complexity. Based on the person-environment fit theory, the intersection is assumed to be an environment that is associated with a higher level of environmental press. This traffic environment requires the use of executive functioning, defined as the ability to interpret multiple sources of information while performing multiple tasks. There is a positive and strong association between intersection and non-intersection accidents that increases in strength with increasing age. More accidents occur at intersections for all age groups and a greater percentage of the accidents for older drivers occur at intersections. These findings are consistent with previous research on accident rates (Garber & Srinivasan, 1991a; Garber & Srinivasan, 1991b; Motor Vehicle Branch, 2001; Preusser et al., 1998; Staplin et al., 1998). The only inconsistency in the data is found in the female data for the oldest age category of 90 years and over age group where there is a significant decrease in the percentage differential. This finding may be explained by the small number of events in this category in comparison to other age group categories. Overall, this data supports the premise that the intersection is a form of complexity imposing a higher level of press on drivers.

Hypothesis 2: The oldest drivers have more accidents at intersections than other age groups after controlling for the number of licensed drivers.

The younger and older age groups have more accidents at intersections than middle-aged drivers, after controlling for exposure. Previous research demonstrated that from the age of 50 years functional declines begin to occur, directly influencing a person's level of driving competency (McCracken et al., 1998; Millar, 1999; Park & Smith, 1991; Reuben et al., 1988). The person-environment fit theory stipulates that those with lower levels of competency would have a reduced capacity to function when environmental demand increases. Although the focus of this investigation is on older drivers, it is also assumed that competency not only is influenced by functional declines, but by lack of experience resulting in inappropriate driving behaviors. In the youngest age group categories it is thought that the reduced competency is due to the lack of experience and outweighs the greater sensory abilities. The ability to formulate decisions within a complex environment requires more than simple sensory reactions.

The results from this study indicate that there is an increase in accident rates at intersections that begins as early as the 45-49 year age group but more consistently starting from 65 years of age. In addition, there are also higher accidents for those 16-24 years of age. The significant association between adjusted accident rates and age supports the person-environment fit theory. With reduced driver competency in environments with increased press such as the intersection, more accidents occur when controlling for exposure.

Accident patterns at intersections are also examined by gender. Findings are consistent with the previous research, as males are found to have more accidents than females. In the intersection data, there is a significantly higher accident rate for males compared to females and this increases with age. Interestingly, when examined across age, older female drivers are less likely to have intersection accidents when compared to other female age groups. Population projections noted earlier indicate an increase in the older population in British Columbia. In particular, females have a greater life expectancy and probability of requiring the use of their automobile for longer. The results for Part Two suggest that as the population ages, older females will continue to have lower accident rates. This prediction is contrary to those made in prior research but this is an important finding indicating that older female drivers will pose less risk to society. The results could indicate that females are more likely to avoid traveling through four-way light operated intersections that, in general, are higher density and in commercial locations. This would support the exposure concept presented in the literature showing that older drivers self-regulate his/her driving behaviors by limiting exposure to risky situations (see Section 2.2.1). These findings cannot be considered conclusive, since the age categories in the intersection data contain small numbers for some of the older age groups and females commit less of these accidents.

Hypothesis 3: Behavioral factors (i.e., pre-action, prior offender, and contributing factors) will be associated with age patterns in adjusted accident rates at intersections.

Three different behavioral factors are tested: pre-action, prior offender, and contributing factors. Previous research has found that these behavioral factors are important predictors for accidents for all drivers (Garber & Srinivasan, 1991a; Millar, 1999; Preusser et al., 1998; Rothe et al., 1990). This hypothesis is partially supported.

Results for the pre-action variable reveal that the highest percentage of accidents occur when drivers are going straight. This is a finding consistent with prior research. When categories are individually examined across age groups, the oldest drivers exhibit a greater occurrence of accidents going straight compared to other age groups. However, the 70-74 and 75-79 year age groups show fewer associations for the going straight category. The older drivers in these two age groups are more likely to have accidents when turning. Therefore, the older drivers from 70-79 years of age have a positive, significant association with turning, a behavior requiring executive functioning. This finding is consistent with the person-environment fit theory because it indicates that when a more complex behavior is performed additional faculties are required to execute the function. Therefore, if there is a lower level of capability along with a high level of demand in the environment, an accident will happen. The lack of significant association for turning in the oldest age group may be explained by the supposition that older drivers adapt by self-restricting driving behaviors avoiding functions that are considered more difficult such as turning.

The findings for the prior offender variable are opposite to the expected direction of the relationship since a greater likelihood of accidents occurs for drivers who are not prior offenders. However, when analyzed across all age groups for the prior offender category, a strong positive curvilinear relationship emerges. Younger and older drivers are more likely to have accidents if they are prior offenders compared to middle-aged drivers. This is consistent with the literature that has discovered that older drivers involved in accidents are often prior offenders and are more likely to repeat offend.

The contributing factor category is designed to give cause for the accident from the perspective of a third party as to why the accidents happen. The greatest percentage of accidents occurs in the unknown/not applicable category. This can be explained because it is not mandatory for the attending police officer to designate a contributing factor, as it is an optional category. The findings demonstrate that younger and older drivers are more likely to have a contributing factor labeled than middle-aged drivers. Some age related biases could explain these patterns. For example, these contributing factors can be related to literature on older adults demonstrating decreases in reaction time and speed of processing multiple stimuli resulting in the assumption that all older adults experience similar deficits. In addition, older drivers may be stereotyped as forgetful or fragile. Younger drivers are also often presumed to be irresponsible and reckless on the road.

Overall, across age groups for the oldest drivers, accidents are less likely to take place when the contributing factor is inexperience, and unknown/not applicable compared to middle-aged drivers. For the youngest age group, there is a weak positive association with the inexperience category. This supports the literature that stipulates younger drivers are influenced by his/her inexperience that reduces driving competency in complex environments.

Hypothesis 4: Natural environment factors (i.e., time of day, illumination, and weather) will be associated with age patterns in adjusted accident rates at intersections.

Three independent variables are used to test this hypothesis: time of day, illumination, and weather. Previous work indicates that most accidents occur during daylight illumination and when the weather is clear and dry. This is because older drivers adapt driving practices traveling in ideal circumstances. Adaptation of driving practices is described in the driving literature as self-regulation (Horowitz, A., Boerner, K., & Reinhardt, J. P., 2002). Older drivers not only self-regulate by reducing the time and distance traveled but by limiting exposure to less ideal circumstances (i.e., rainy weather). The literature also discloses that older drivers have difficulty during daytime hours. Age is often not examined separately in these studies and time of day only looks at daytime in contrast to nighttime. In this thesis, the time of day variable is further separated into three categories: morning, afternoon/evening, and night. This hypothesis is fully supported.

Time of day, the first variable tested, reveals that an equivalent percentage of accidents take place during the three different time frames in the day. However, the concentration of accidents is varied across age groups. The younger drivers have most of his/her accidents during the night while the oldest drivers experience most of his/her collisions in the afternoon/evening compared the middle-age group. However, the latter finding is only true for the oldest age category. For the majority of older drivers, aged 55 through 79 years, most of his/her accidents occur in the morning hours. These findings are consistent with the literature that suggests that older drivers avoid nighttime driving and it confirms what part of the day during which older adults tend to travel.

For the second variable, illumination levels, a moderate positive association is demonstrated for the older drivers relative to the middle-aged drivers for the daylight category. The percentage of accidents at intersections increases with age in the daylight illumination category with no significant fluctuations across age. This finding supports the hypothesized relationship. The literature has stipulated that older drivers avoid driving in unclear conditions, choosing to travel when there is ideal illumination, thereby limiting his/her exposure.

The results for weather are also consistent with the literature, demonstrating that most accidents occur in clear/dry weather. The findings reveal a positive significant association for older drivers with accidents in clear/dry weather. These behavioral variables support prior research that argues older drivers self-regulate driving behaviors to compensate for reduced capabilities.

Hypothesis 5: Road environment factors (i.e., turning treatments, entrances/exits, and medians/dividers) will be associated with age patterns in adjusted accident rates at intersections.

There are three road environment variables: turning treatments, entrances/exits, and medians/dividers. These variables are included to test structural components in the environment that alter the level of environmental press at an intersection. The literature mentioned earlier indicates that medians and turning treatments such as designated left turn lanes and signs reduce the level of environmental press at intersections. However, this literature studied these factors separately combining those 65 years and older into a single category. Prior research has not examined the influence of entrances/exits directly into intersections for their influence on older drivers but it was expected that the conflict these elements create with the normal traffic flow would increase the environmental complexity at an intersection. Partial support is found for this hypothesis.

Results for the turning treatment variable partially support the hypothesis. There is a positive association for the youngest drivers and three of the older age groups compared to middle-aged drivers at intersections with less turning treatments. These age groups are more likely to have higher adjusted accident rates than the middle-age group when intersections possess less turning treatments. Although the results for the oldest age group are non-significant for the less treatment category relative to middle-aged drivers, they are in the expected direction. The lack of a significant relationship for the oldest age group could relate to adaptation behavior in the form of self-regulating practices associated with self-assessed lower levels of driving competency. Perhaps more of the drivers in the oldest age group avoid intersections with less turning treatments. Interestingly, younger drivers and one of the older driver categories (75-79 years) that are significantly associated with accidents at intersections with less turning treatments also exhibit a significant pre-action association with the turning behavior. These results may reflect behavioral patterns or the influence of inexperience and functional declines. However, a moderate inverse relationship is discovered for the 70-74 year age group with the less turning treatment intersections when compared to the middle-age group. This is contrary to the hypothesized association and could be explained by the small numbers within this category.

The entrances/exits variable demonstrates support for this hypothesis. Results indicate a positive, weak relationship between accidents at intersections with entrances/exits and age. For most age groups this is true with a greater percentage of accidents occurring at intersections with entrances/exits. There is a linear relationship across age suggesting that with increasing age, drivers are more likely to have accidents at intersections with entrances/exits. This is consistent with the belief that increased environmental press will negatively influence those with decreased competency. However, drivers from the 65-69 year age group are less likely to have accidents at intersections with entrances/exits than middle-aged drivers. Again this could be related to the practice of reducing exposure.

The final variable tested for the road environment is the medians/dividers variable. The results partially support this hypothesis. Although more accidents occur at intersections with medians/dividers than at intersections without these components, across age the direction of the relationship changes at the age category 75-79 years. The oldest age category (80 years and over) shows a reversed relationship compared to the middle-age group when medians/dividers are not present while the 75-79 year age group has a positive but non-significant association. The oldest drivers are more likely to have accidents at intersections without medians/dividers than middle-aged drivers as proposed in the hypothesis. Two other older driver age groups (i.e., 50-54 years and 70-74 years) exhibit positive associations with the no medians/dividers category. This suggests that the latter age groups are also more likely to experience higher adjusted accident rates than middle-aged drivers. The lack of significant relationships for the other older driver age groups may be explained by the way the medians/dividers variable is created. Due to the small unit of analysis (intersections), medians, dividers, and boulevards are all included in this category. The previous literature in this area discussed earlier had larger samples affording the use of only the median as a measure (Garber et al., 1991b; Marottoli, 1997; Pline, 1996; Staplin et al., 1998). The latter literature reveals a significant relationship with the presence of medians in reducing the likelihood of accidents for all age groups.

Hypothesis 6: Visual environmental complexity (i.e., signage and architectural complexity) will be associated with age patterns in adjusted accident rates at intersections.

This hypothesis is examined using the visual environmental complexity variable that is developed based on the concepts surrounding the person-environment fit theory (Lawton, 1982). Assuming that age is associated with functional decline, a gauge of environmental complexity that encompasses a number of physical components in the environment into one measure is necessary to evaluate the person-environment fit theory. Some literature has treated environmental factors but often these structural elements are tested separately. The myriad of different structural elements within a traffic environment produces a complex network. The hypothesis stipulates that with increased visual environmental complexity those with reduced levels of competency will have a greater number of accidents. Partial support is obtained for this hypothesis.

Across categories for age groups, accidents are significantly more likely to occur at intersections with higher complexity. Across age groups, the oldest drivers have slightly more accidents at intersections displaying high visual complexity. However, the 75-79 year age group exhibits fewer accidents, a significant inverse relationship with the high visual complexity category. This is contrary to the expected relationship for this age group indicating that drivers 75-79 years of age are less likely to have accidents at intersections with more visual environmental complexity. As mentioned previously, this age group category contains a small number of cases and may avoid complex intersections, explaining this anomaly.

5.3 Implications

As the driving population ages, the importance of safety will fuel research and influence the older adult's ability to maintain an independent lifestyle. This thesis reveals an important relationship between a driver's competency level and the surrounding environmental complexity of the traffic environment. It encourages a new direction for future research and policy, focusing on not only the behavior of drivers, but also on the combination of behavioral and environmental factors. The results reflect the importance of studying the entire contextual situation, examining interactions between the driver and the environment to assess the level of fit or congruency between performance and environmental press.

Encouragement for examination of issues such as driving and older adults from the person-environment fit perspective can reduce unnecessary incongruence between drivers and his/her environment. Investigations such as these may help to partially eliminate the policy dilemma that exits between the conflicting rights of older drivers and the rest of society. This research supports the body of growing literature that utilizes an environmental theory.

There is a relationship between the structures in the road environment, age, and adjusted accident rates. Changes made to traffic environments to accommodate drivers at risk benefit all drivers (i.e., less direct entrances/exits and less complex signage and architecture). As shown in this thesis some changes will directly benefit more than one age group. For example, changes made to increase turning treatments (i.e., turning lanes and lights) at intersections will benefit both younger and older drivers, directly reducing his/her risk of accidents. The integration of the elements in the traffic environment into the evaluation of accident risk for older adults may change the way we view this issue. Instead of placing all of the blame on the individual's functional level or driving behaviors, the environment, which can be easily manipulated, can be examined as a possible underlying factor causing the limitations in these drivers' abilities.

The study of the visual environmental complexity through the evaluation of signage and architectural components at an intersection can lead to changes in intersection engineering. Changes can be subtle for example, limiting size and shape of signage, or they can be substantial, including limitations to architectural development and structures surrounding certain intersections. In addition, certain high risk intersections can be re-evaluated for their structural complexity, and re-engineered to reduce accident rates at these intersections. With the person-environment fit framework, environmental press will be identified and adaptations made to the traffic environment reducing constraints imposed on the older driver's ability to navigate safely. The need to develop a traffic environment that is congruent with the older driver's competency level will increase in importance as the driving demographics change in Canada.

This thesis clearly identifies the relevance of examining these issues across age groups without homogenizing the older age groups into one category. Not all older driver age groups experience difficulties in the same areas or ways. For example, not all older drivers have problems maneuvering in intersections that have no medians/dividers. Only the oldest age groups have a significantly higher risk of accidents. The evaluation by different age groups is especially important when developing policies for older drivers.

The policy dilemma discussed earlier in the literature review, in which the rights of the older driver to remain independently mobile and the rights of the rest of society to a safe environment conflict, can be addressed utilizing an environmental theory. Information derived from this thesis can be used to evaluate the intersection environment and implement changes appropriate for older drivers. The construction of traffic environments has used the middle-aged person as the model driver but as the population ages, considerations will be needed to accommodate the older driver's needs.

City planners should try to incorporate some of the findings of this thesis in future intersection design in areas of high elderly traffic volume. Changes may include reducing the visual complexity at intersections, especially reducing non-traffic related signage such as advertising, and reducing the number of entrances/exits at complex intersections. In addition, if space is adequate, medians/dividers and advance left turn signals and lanes may be helpful. Re-training programs aimed at older drivers with early cognitive or functional decline, or those involved in prior accidents may help elderly drivers maintain mobility for longer.

This thesis also adds to the literature on exposure. The use of license rates does not produce as strong an association as information on distance traveled will but it is more reliable controlling for the total number of possible drivers per age group. Therefore, although the results indicated an association between age and adjusted accident rates the findings may under represent the accident rates for older drivers.

Information gathered from this type of study can be used to develop more accurate criteria for licensing restrictions. By encouraging study of the traffic environment as it relates to the older driver, impact assessments can be utilized to create driving restriction regulations. This may reduce the occurrence of unnecessary mandatory driving cessation.

5.4 Limitations

There are a few minor methodological limitations present in this thesis. First, the intersection sample is a non-random convenience sample. This limits the generalizability of the results by producing a biased sample group. Moreover, although the intersections are randomly chosen from a map in a general regional area, only light operated four-way intersections are included in the sample.

Selection bias is also created through the use of data from police attended post-accident reports. Only accidents attended by a police officer with a monetary damage value greater than $1000, injury, or fatality are treated in this thesis. This limits the scope of the data. For example, accidents that are not reported to police or have less severe consequences are not represented in this study. Data are not generalizable to intersection accidents not attended by police officers. It is unknown how many of these accidents actually occur and how they would change the data, as they are not reported. Further, differentiation was not made between those who were victims versus offenders in the accidents. Liability has not been controlled for so caution should be used when drawing conclusions on causation.

The unit of analysis, intersections, is limited. The small sample size reduces the ability to associate results with conclusive causal relationships. However, findings are consistent with previous literature in the area demonstrating that more accidents are at intersections and younger and older drivers have higher adjusted accident rates relative to middle-aged drivers.

This thesis uses a cross-sectional research design. Data are collected for one continuous five-year time period with no follow-up collection with which to compare results. This limits the ability to draw causal conclusions. A longitudinal study of the intersections and the police reported data set would have permitted the formulation of conclusions based on causation. The comparison group created with a longitudinal analysis enables more conclusive findings. The longitudinal design controls for some of the extraneous factors that cannot be controlled in a cross-sectional design, allowing the analysis to evaluate causal relationships.

There is also room for human error with manual data entry and calculations. There is a large number of police officers entering data, using a standardized form, but there may still be errors in interpretation of factors surrounding an accident. This error is thought to be limited as only a small number of data items are missing and the data provided appear accurate, although this cannot be tested extensively due to the confidential nature of the data.

This thesis presents problems inherent in doing research based on secondary data. For the police attended post-accident data set a number of variables are not available. More specifically, demographic and socio-demographic information are not available because of the sensitive nature of these data. Information on co-morbidity would have also been interesting to investigate the presence of diseases and disabilities in this population and determine if they are associated with higher accident rates.

There is also no opportunity to control for the possible structural changes that occurred at intersections in the five-year time period, since this information is unobtainable. Reviewing maps of the city of Vancouver during the time of the study suggests that no major re-routing of traffic at the 39 selected intersections was performed during the duration of the study. However, information on more minor changes such as alterations in traffic signage cannot be obtained.

Even though the intersection complexity scale is rated separately by two independent raters with training in the built environment, the scale is still somewhat subjective. These raters used a number of criteria to guide his/her measurement of the intersection complexity but no definitive scale was used. However, the high inter-rater reliability rating (Pearson r=0.94), confirms that this scale is reproducible.

In light of these concerns, the limitations of the research are deemed to be small and the results of the study still support the hypotheses. It is anticipated that with future research the limitations in this study may be overcome and more evaluations will address environmental complexity in predicting the adjusted accident rates for older driver age groups.

5.5 Future Research

There are several avenues that can be explored in future research. Increasing the size of the sample of intersections and expanding the time frame of the study may add more statistical strength to the study. In addition, including accidents in which property damage is less than $1,000 may also help increase the sample size. Including accidents that are not attended by police officers would also increase sample size, but there may be increased data entry problems as accident reporting would be less standardized than if police officers entered the data, although, designing a standardized accident reporting form that is simple and easy to use for drivers to report accidents that are not attended by a police officer may help overcome some of these problems.

In the future, collecting more demographic information and medical data on people involved in an accident may be helpful to further determine if any of these factors have an influence on accident rates. It may be beneficial to control for medication use, since this can create side effects such as drowsiness. Comorbid diseases can also decrease driving ability such as dementia, cardiac disease, and arthritis (Bedard et al., 1998; Kaszniak et al., 1991; Millar, 1999; Simpson et al., 2000).

Future research can further examine the different dimensions addressed in this thesis. For example, it would be interesting to evaluate the influence that different forms of visual environmental complexity, including signage and architectural complexity, have on accident rates separately. Extension of a similar scale measuring perceived environmental complexity for other activities that older adults experience functional difficulties with, could implicate elements within the environment that are creating these limitations.

A study evaluating intersections in two different communities, one rural and one urban, would enable a comparative analysis of the level of environmental complexity in each region. This may also help control for variations in traffic flow and driving habits in different communities.

The environmental measures used in this study are selected from a number of additional variables of interest. For example, left turn signs can be differentiated from each other and tested for their influence on accident rates. Division of the medians/dividers variable into different variables to test for different relationships may also lead to interesting discoveries. Further refinement of the visual environmental complexity scale can also be examined using a larger sample with a larger number of raters to evaluate levels of complexity. Structural components can be altered at an intersection, such as adding turning lanes or signals and determining whether they lower accident rates.

Other variables of interest present in the intersection data set that are not selected for this study can be examined in subsequent research, for example, liability information indicating the proportion of blame as assigned by the Insurance Corporation of British Columbia. Perhaps older drivers are less at fault in accidents occurring at intersections. Further, a variable for the gravity of the collision for example, property value loss, injury, or fatality may be helpful.

Similar to road design, very little research has examined factors within the automobile to evaluate structural changes that can be made to optimize the use of vehicles for older drivers. Accommodations for the older driver can incorporate bigger numbers on dashboard perhaps digitally displayed or navigation devices with oral communication to reduce the visual complexity of the dashboard surface. Structural alterations to the passenger vehicle for older drivers may reduce accident rates.

Ideally, a study incorporating both quantitative and qualitative information by performing road tests to evaluate skill levels separate from driving record and accident information would increase the level of control and information obtained. Information on exposure (i.e., mean hours and distance driven) can also be surveyed within this population. This type of evaluation would significantly broaden the issues.

CHAPTER 6: SUMMARY AND CONCLUSION

The goal of this thesis was to investigate the importance of environmental challenge for older drivers through the examination of data on adjusted accident rates. In particular, these questions were addressed: 1) Are intersections higher risk locations for older drivers? 2) Are older drivers adversely influenced by increasing complexity of elements in the traffic environment at intersections?

In the review of the literature (Chapter 2) on driving and older adults, it was suggested that population aging trends are increasing the importance of safety evaluation in the traffic environment for the increasing number of older drivers. The influence of the measures currently used in evaluating risks associated with driving were discussed along with a review of the literature on what such risks mean to older drivers and the rest of society. The person-environment fit theory was presented, identifying the importance of looking at the congruency between the person and his/her environment. This theory proposes that the reduction in the older driver's ability to drive safely depends partly on an imbalance between the environmental press and the person's level of competency. The intersection was proposed to display a form of environmental complexity that could be measured. Literature was evaluated for the influence of different elements within the traffic environment. Based on the theoretical framework and the empirical literature, six hypotheses were developed to investigate the role of behavioral, natural environment, road environment, and visual environmental complexity as mediating factors between age and adjusted accident rates.

Chapter 3 presented the research methodology for Part One (aggregate data) and Part Two (intersection data) of the thesis encompassing data source and collection, as well as the sample description. The results for the analysis of the aggregate data and the intersection data were described in Chapter 4. An analysis of the aggregate data revealed that more accidents occur at intersections and older drivers have more of his/her accidents at intersections. The findings for the intersection data revealed that: 1) older (and younger) age groups had higher adjusted accident rates, 2) older female drivers had lower adjusted accident rates, 3) two behavioral factor variables (pre-action and contributing factors) were positively associated by age with adjusted accident rates, 4) one behavioral factor variable (prior offender) was inversely related to adjusted accident rates across categories but exhibited a positive association across age with adjusted accident rates, indicating that older (and younger) prior offenders had higher adjusted accident rates than middle-aged prior offenders, 5) natural environment (time of day, illumination, and weather) was associated across age with adjusted accident rates, 6) one road environment variable (turning treatments) revealed a partial positive association by age with adjusted accident rates, 7) one road environment variable (entrances/exits) was positively associated by age with higher adjusted accident rates, 8) one road environment variable (medians/dividers) showed that more accidents occurred at intersections with medians/dividers this was contrary to the hypothesized relationship, however, the oldest age group had higher adjusted accident rates at intersections with no medians/dividers relative to middle-aged drivers, 9) older drivers were more likely to have accidents at more visually complex intersections than middle-aged drivers.

Chapter 5 presented a discussion of the findings and interpretations that integrated these results with the person-environment fit theory and the previous literature on behavior and driving. There was modest support for the hypotheses that were tested to answer the main questions. Intersections were found to be higher risk locations for older drivers and older drivers had more accidents at those intersections with greater environmental complexity. Older drivers' behaviors were consistent with the previous research in this area. Age and natural environment variables were predictive of adjusted accident rates. This was also consistent with the behavioral adaptation literature that indicated older drivers avoid driving during less ideal circumstances supporting the assumption that due to reduced level of competency older drivers self-restrict driving patterns. Environmental press and age were predictive of adjusted accident rates with only one road environment variable (medians/dividers) showing relationships counter to what was expected.

The discussion concluded with an assessment of the study limitations and implications. Suggestions were also made for future research in this field. Research addressing current areas where policy debates exist, such as driving and the older adult, can aid in examining the issues to create new goals for possible interventions. The integration of a larger older driving population into the traffic environment will require redevelopment of the conventional system, which is designed around the middle-aged driver to help reduce accident rates.

Overall, results from this thesis lend strong support to the idea that older and younger drivers are more likely to have more accidents at intersections when controlling for hours and distance driven. Various environmental factors within the intersection, such as turning treatments, entrances/exits, and visual complexity can be altered in intersection design as new intersections are being constructed or remodeled. Future road design should incorporate these factors to help reduce accident rates for everyone.

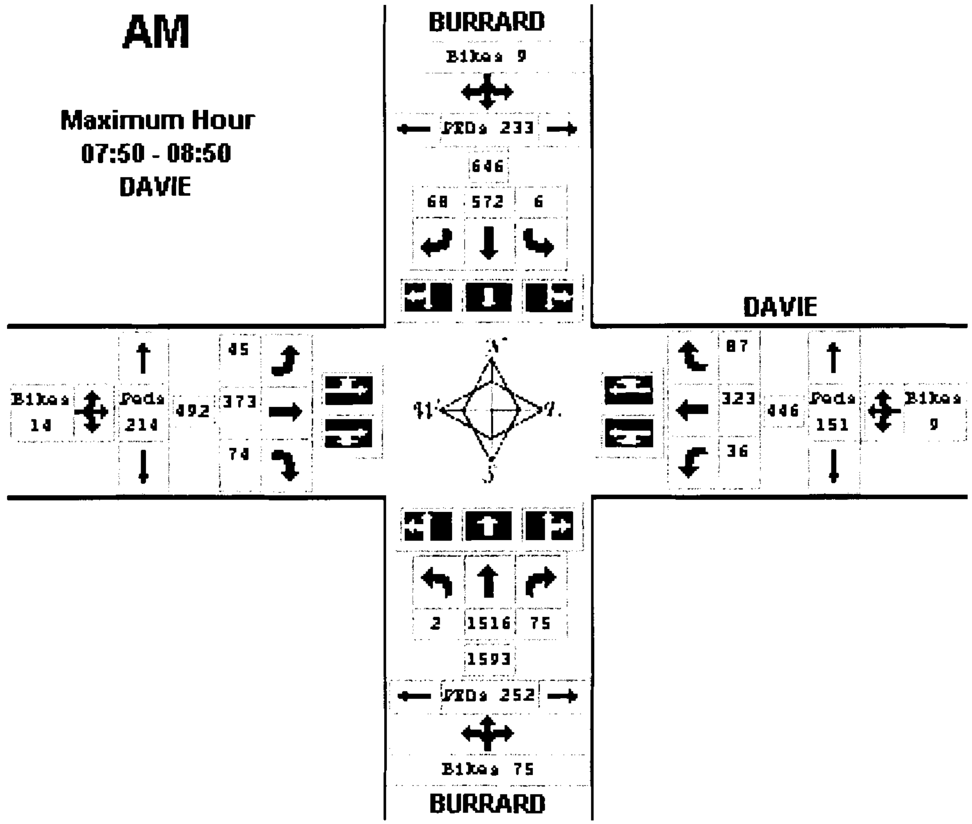
Appendix A: Flow Diagram

1995 Monday, July 10, 1995 BURRARD AND DAVIE Coordinate: 120612
weather: CLOUDY Signalized

City of Vancouver
Manual Traffic Count
Intersection Flow Diagram

AM

Maximum Hour
07:50 - 08:50
DAVIE



North	Left Lane 3	Thru Lane 3	Thru Lane 2	Thru Lane 1	Right Lane 1	Total	Bikes	Peds
AM Max Hour 07:50 - 08:50	6	210	340	22	68	646	9	233
2 Hour Totals 07:00 - 09:00	14	367	595	33	127	1136	15	419

South	Left Lane 3	Thru Lane 3	Thru Lane 2	Thru Lane 1	Right Lane 1	Total	Bikes	Peds
AM Max Hour 07:50 - 08:50	2	627	757	132	75	1593	75	252
2 Hour Totals 07:00 - 09:00	11	1007	1269	189	131	2607	120	390

Source: *Traffic Management Department of the City of Vancouver, British Columbia, Canada.*

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