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Evaluation of restricted driver licensing for medical impairments in Saskatchewan

by

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Thesis submitted to

the School of Graduate Studies and Research

in partial fulfilment of the requirements for the

MSc degree in Epidemiology

University of Ottawa

DATE: July, 2000

0-612-57137-8

Abstract

Driving ability may be adversely affected by many medical conditions and many jurisdictions therefore allow for a restricted license that permits driving under specified conditions. The objective of this retrospective cohort study was to evaluate restricted licensing by comparing "at-fault" crash and traffic violation rates for drivers with a restricted license to the general driving population and also to compare driving pre and post restriction. Following multivariate Poisson regression, the adjusted IRR for "at-fault" crashes and traffic violations for restricted versus non-restricted drivers were 0.92 (95% CI, 0.89 to 0.95) and 0.87 (95% CI, 0.85 to 0.90) respectively. Interventional time series analysis demonstrated a significant decrease in "at-fault" crash and traffic violation rates post imposition of restrictions. Restricted licensing programs are effective and allow persons with decreased driving ability due to medical conditions to continue driving under specific conditions.

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Acknowledgements

I would like to thank my wife, Nathalie, who as always has been exceptionally supportive of my work and completing my Master's program as well as worrying about my health. I would also like to acknowledge my children Philip, Patrick and Katherine who have undoubtedly lost time with their father while he tries to complete his thesis. I would like to thank my parents, Kerr and Mary Ann for providing the opportunities that have allowed me to pursue my goals in life. I would also like to thank my in-laws, Verna and Laurier who are so supportive in many ways. I would also like to thank the Associates in Physical Medicine and Rehabilitation for supporting my studies.

I would like to particularly thank David Koch with whom I spent many hours discussing the data in preparation for this thesis. If it had not been for David's help, this study would never have been completed. I would also like to thank Saskatchewan Government Insurance for their support and co-operation with this project.

Finally, I would like to thank Bob Spasoff as my thesis supervisor, whose direction and organization greatly assisted me in completing my thesis. Bob, you are an excellent supervisor. I would also like to thank Rama Nair and Carl van Walraven who each were very helpful and always quick to respond to questions.

Chapter 1: Introduction

In North America, motor vehicles have become so prevalent that driving has almost become a basic activity of daily living [1]. Due to efficient public transit systems, a driver's license is often not imperative for community mobility in urban areas. In contrast, dependency on being able to drive is much greater in smaller towns and rural regions. Unfortunately, it is often the disabled who have the least ability to drive, secondary to their medical impairments. For some of these individuals, the ability to drive permits continued independent living [2] while loss of this ability might result in dependency and the need for increased community support.

In some provinces and states, efforts have been made to provide restricted or conditional licenses for persons who have medical impairments that affect their driving ability [3]. Restricted driver's licenses allow a person with a medical impairment to drive under specific conditions such as daylight hours only, or within a certain radius of their home. Compared to persons without medical impairments, those with medical conditions and full unrestricted licenses overall do have higher crash rates [4]. However, the effectiveness of programs providing restricted licenses for persons with known medical impairments has not been previously evaluated. If restricted licensing is effective for decreasing crash and traffic violation rates, then there may be increased potential for use of this intervention in jurisdictions, such as Ontario, where full driver licensure is the only available option [5].

The first report of a traffic accident attributable to a seizure came as early as 1906[6]. Since those early days, significant consideration has been given to the impact of specific medical impairments and their effect on the ability to drive. Some of the more common medical conditions believed to affect driving include visual impairment, cognitive impairment, and conditions resulting in temporary loss of consciousness such as seizure or syncope [7]. Other medical conditions such as cardiovascular or cerebrovascular disease may or may not have an effect on the ability to drive, depending on the degree of severity to which the individual is affected [4,7,8]. In fact, guidelines provided for physicians regarding medical fitness to drive [7,9,10] often make general recommendations that are difficult to apply in patient specific situations. For example, following head injury, the "Physicians' guide to driver examination", published by the Canadian Medical Association [7], recommends that patients be "fully evaluated", but does not specify what this evaluation might include.

There are at least three important perspectives on the effect of medical impairments on an individual's ability to drive. The patient perspective concerns the desire to drive in order to maintain independence in the community and the symbolic importance for the patient of the ability to drive and hold a driver's license [2]. Second, society expects that the safety and interests of the public will supersede the desires or needs of the individual to drive. The Canadian Medical Association supports this stance and stipulates for physicians that where the interests of the individual driver and the safety of the public come into conflict, the latter should take priority [11]. The third, often less emphasised, perspective is that of the physician in his or her role with regards to determining medical fitness to drive. Although the responsibility for issuing or revoking drivers' licenses rests firmly with provincial or state agencies, in many jurisdictions the physician is legally required to report medical conditions that may affect a patient's ability to drive [5,12]. In this situation, physicians may be torn between their role as patient advocate and their responsibility to report a patient who may be medically unfit to drive[13]. This situation is further complicated by the fact that available guidelines are often of little assistance in determining or assessing medical fitness to drive at the individual level.

1.1 Literature Review

1.1.1 The Driving Task

The determination of medical fitness to drive is very difficult, since driving is a complex, over-learned skill [14]. Driving involves physical, cognitive, and perceptual skills and abilities that are further influenced by past driving experience, individual attitudes and behaviour [15,16]. Differing conceptual models of driving have been proposed [15,16,17], generally in reference to specific impaired populations. Simms [16] has proposed a perceptual information-processing model of the driving task for persons following stroke, in which visual attention and perception have been emphasised. A similar model had been previously developed for non-disabled drivers by Mihal and Barrett, and been positively correlated to motor vehicle accidents in commercial drivers[18]. Expanding on the element of visual attention, more recent work has used a measure called the Useful Field of View (UFOV) [19-21]. This measure takes into account the functional peripheral vision of the driver while concentrating on the central driving task. Persons who have less ability to divide their attention have a proportionately smaller field of vision while driving and are therefore at greater risk of missing environmental cues or signs that are necessary to make safe driving decisions. Owsley et al [19] have prospectively shown that elderly drivers with impaired visual attention were much more likely to be involved in motor vehicle accidents.

The above models emphasise specific attributes highly involved in driving, such as visual attention and visual perceptual skills. Michon's model [17] for conceptualisation of driving is unique in using a hierarchical structure. Michon describes three levels of decision making involved in driving: strategic, tactical and operational. At the strategic level, the highest level, decisions are made regarding planning for the driving task, such as the route, the impact of weather conditions and the time of day to travel. At the next level of decision making, the tactical level, the driver makes decisions about handling the vehicle such as the speed, following distance or passing. The lowest level, the operational level, involves common driving actions such as braking, steering or dealing with impending danger. It is evident that decisions made at a higher level will have an impact on the decisions or actions necessary at a lower level. For example, a driver who is involved in a crash while tailgating with icy road conditions might have been able to avoid the crash by a decision at the strategic level to not drive on icy roads. The crash may have also been avoided at the tactical level by a decision not to tail gate, or even at the operational level, if the driver had excellent car handling skills and superior reaction times. Although this model aids in the conceptualisation and understanding of driving as a complex task, it has not been validated [15].

Galski et al [15] have proposed the "Cybernetic Model of Driving", which emphasises perceptual and cognitive information believed to be important for driving following cerebral damage such as stroke or traumatic brain injury. This model describes how environmental information is collected, processed and transformed into driving action. (Figure 1). Although this model was developed primarily for persons who had suffered cerebral damage, some of its key elements help clarify the large discrepancy in driving skill between drivers with similar levels of injury. In the Cybernetic model, a key element is the "General Driving Program" which is the culmination of past driving experiences and driving education that Galski et al [15] describe as being "burned" into the central nervous system. Therefore for persons with new onset of medical impairments affecting the ability to drive, the amount and sophistication of development of the "General Driving Program" has significant effect on current ability to drive. The "General Driving Program" is the background used for all driving situations, while a "Specific Driving Program" represents the driving goal at hand. This element parallels Michon's model [17] since decisions regarding the driving task at hand are made such as route, adaptations to driving conditions and vehicle handling. This model has been taken beyond mere conceptualisation in that Galski et al [15] have attempted to develop a driving evaluation system. A pre-driver assessment battery was developed based on the Cybernetic model, with specific tests included to reflect individual elements in the model. Using the pre-driver assessment combined with a driving simulator evaluation, the authors have demonstrated that 93% of on-road driving performance, for persons suffering cerebral damage, could be explained using multivariate regression.

To date, most conceptual models of driving have not been further developed or validated. Driving is a complex task involving combined physical, perceptual, attentional and cognitive attributes. Medical impairment at any level - psychological, physiological or anatomical- could affect an individual's ability to drive.

Due to the complexity of the driving task and variability in driving skill level between individuals, predicting whether or not an individual is safe to drive remains difficult.

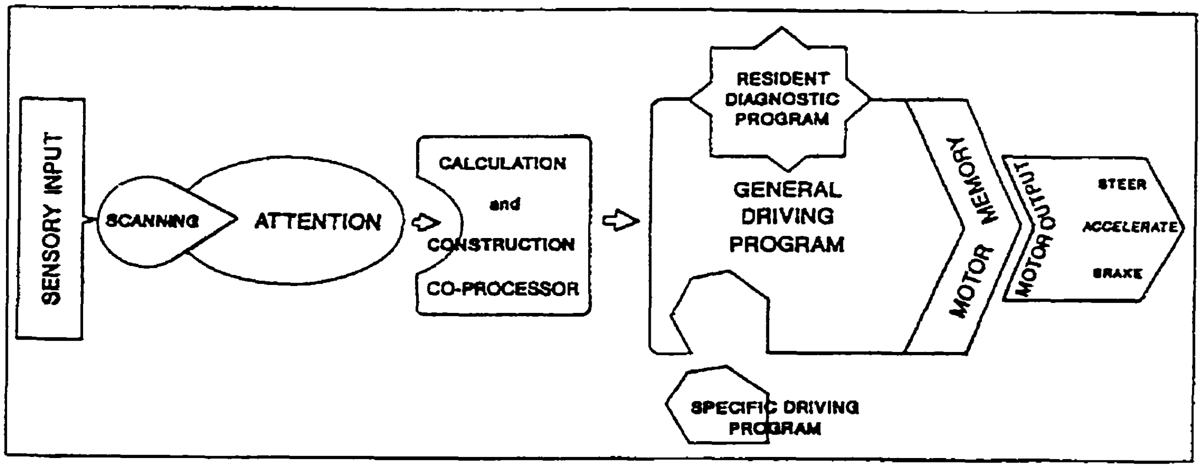


Figure 1: The Cybernetic Model of Driving [15]

1.1.2 Effect of Impairment on Driving

As can be seen from the different driving models, driving is a complex task involving multiple cognitive and physical skills. Medical impairments decrease the ability to drive by negatively affecting individual components or skill sets required for driving. Medical impairments affecting driving may be broadly categorised into cognitive and physical impairments, as well as certain conditions resulting in sudden loss of consciousness. Elderly drivers are a special consideration, since many have multiple impairments that alone or in combination may affect driving ability [22,23].

1.1.3 Physical Impairment and Driving

Physical impairments that can affect driving ability include weakness, pain, restricted range of motion of joints, and loss of co-ordination. Some specific examples of medical conditions are severe arthritis, limb amputation, muscular dystrophy, polyneuropathy and spinal cord injury. Although physical impairments may be more visible than cognitive or visuospatial impairments, this type of impairment is often the most readily accommodated when returning patients to driving [24,25]. In many instances, simple structural alterations to the motor vehicle may be sufficient to allow safe control when driving [24,25], whereas complex alterations may be necessary for patients with spinal cord injury. In Michon's [17] driving model, physical impairment would only be involved at the operational (lowest) level where vehicle control and operation are of paramount importance. In fact, van Zomeren [1] concluded that most researchers considered physical impairment, such as hemiparesis, as relatively unimportant for brain injured patients even at the operational level, when cognitive impairment also had to be taken into account. Similarly, in the Cybernetic Driving Model [15] physical impairments would have their primary effect at the "Motor Output" level, which once again represents a small proportion of this model.

Another form of physical impairment that has significance to driving is sensory impairment such as vision, hearing or sensation loss. Clearly, environmental information is essential for safe vehicle operation, and it has been estimated that 90% of the information required for driving is obtained through visual input [16]. Vision itself, is distinct from visual perception, which is generally considered a cognitive ability. Sensory input is the first component of "The Cybernetic model of Driving", although vision is not weighted more heavily than other sensory input such as hearing, proprioception or kinaesthetic sensations [15]. Vision is assessed traditionally by static visual acuity measurement and by visual fields. The perceived importance of vision to driving is apparent in that all Canadian provinces require vision testing prior to attaining a driver's licence [26]. Although visual requirements vary for different provinces and states, the Canadian Medical Association guidelines recommend that for a class 5, general licence (Appendix A), the minimum corrected monocular acuity should be 20/40 with a minimum visual horizontal field of 120° [7]. Levy et al [27] have shown impaired vision to be associated with increased crash risk and fatality and they have also demonstrated that state visual acuity testing programs for the elderly driver reduce fatal accidents. Owsley and Ball [21] have established a link between eye health and visual function, but have further determined that poor visual function and eye health do not necessarily contribute to increased crash risk [19,21]. The authors go on to hypothesise that drivers compensate for impaired visual function by self-restricting driving, such as driving only during daylight hours or in less complex traffic situations.

1.1.4 Cognitive Impairments and Driving

Although physical impairments and sensory impairments can directly affect the ability to drive, research and public policy have been primarily focussed on cognitive and visuoperceptual deficits as they relate to driving [28-35]. Cognitive deficits affecting driving include memory impairment, poor sequencing skills, impaired insight and judgement, apraxia and slowed processing time [14,30,32,35-40]. Perceptual deficits, especially visuoperceptual impairment, are an important subset of cognitive skills directly related to driving ability [16,33,37,41]. Perception has been defined as "the means by which an individual organises and comes to understand information received by the bodily senses" [16](p363) Although visual input is essential to the driving task, it has not been found to contribute independently to crashes when attentional processes are also considered[19,21]. The size of the Useful Field of View (UFOV), a concept developed by Owsley and Ball [42], is defined as "that eccentricity at which observers can localise peripheral targets correctly 50% of the time". (p3112) [42] It is, in essence, a dynamic measure incorporating visual perception and the ability to divide attention. In a recent prospective study, Owsley and Ball [19] demonstrated that older adults with a 40% or more restriction in UFOV were 2.2 times more likely to be involved in a motor vehicle crash than controls when followed over 3 years.

Similarly, assessing medical fitness to drive of individuals with other medical conditions such as stroke, brain injury and dementia that can affect cognition has been an ongoing concern at both medical and societal levels [14,28,32,38,39,43-46]. Non-progressive conditions such as stroke and brain injury often require assessment of driving skills due to the physical and cognitive implications associated with these disorders [15,30,31,47]. Efforts have been made to develop neuropsychological test batteries to predict who is unfit to drive following stroke or brain injury, but no single protocol has been found sufficient to replace the gold standard of an on-road driving evaluation [30,32,33,35,38,39]. Cognition and attention are very important aspects of the driving task and in the Cybernetic Model of driving cognitive skills play a role in processing information as well as being an integral part of the general driving program, specific driving program and the resident diagnostic program [15]. A primary concern with assessing medical fitness to drive for those with dementia is that unlike the static nature of stroke or traumatic brain injury, dementia is a progressive disorder. This leads to concerns regarding the frequency of assessment for persons with progressive disorders.

Few studies have examined crash rates for persons with cognitive disorders such as stroke, traumatic brain injury or dementia. Megdeysi and Koch [4] found increased crash rates in the presence of cerebrovascular disease and cerebral trauma compared to controls. Reviews of crash rates for persons with dementia have generally supported increased crash risk in this population [48,49], but the most recent study by Trobe [50] did not find an increased crash risk. These authors suggested that persons with dementia may have been more likely to self restrict their driving and therefore would have less exposure to the risk of being involved in a crash.

1.1.5 The Elderly and Driving

Independent of progressive dementia, changes in health status related to ageing may have an impact on driving ability [45,51-54]. Changes in vision, reaction time and co-ordination, as well as debilitation related to chronic conditions such as cardiovascular disease, diabetes mellitus or arthritis may affect ability to drive [23,52,54,55]. Considering Michon's hierarchical model [17] compensatory driving strategies could be implemented at the strategic and tactical levels to accommodate physical impairments that would lessen capabilities at the operational level. For example, by driving under optimum weather and traffic conditions only and increasing following distance, deficits in reaction time or braking response (operational level) may be accommodated. In the Cybernetic model of driving [15] the effects of ageing would have an impact primarily on sensory input (vision, hearing, position sense) and motor output (reaction time, power, co-ordination) as well as minor effects on attention, scanning and calculation abilities.

Crash rates have been found to be higher for elderly drivers compared to middle-aged drivers [56-58]. Brorsson [57] found that the crash rate was four to six times higher for the elderly compared to middle-aged drivers; however, this increased crash rate was similar to that for the 18-19 year old age group. This "U-shaped" curve for crash rates by age group has been previously demonstrated [52], and raises the argument that if society is able to tolerate higher crash rates among young drivers, then similar tolerance should be shown for the elderly. Typically, crash rates have been attributed to medical impairments in the elderly population but to risk-taking behaviour and inexperience in younger, adolescent drivers.

A serious category of impairments that affect medical fitness to drive is sudden loss of consciousness due to epilepsy, certain cardiac arrhythmias and hypoglycaemic reactions associated with diabetes mellitus management [6,8,59-65]. Crash rates have been shown to be higher in epileptics who are driving, but as for persons driving with diabetes mellitus, Hansotia et al [62] did not believe that the increased crash rate for these drivers warranted restriction. Unfortunately, a strong bias of this study, not indicated by the authors, is that many of the uncontrolled diabetics and seizure disorder persons have likely been restricted from driving, minimising the effect of these disorders. In fact, the older literature has not demonstrated a difference in crash rates for those groups with diabetes mellitus or cardiac disease [668]. However, in a more recent Saskatchewan study, crash rates were found to be higher for persons affected with diabetes mellitus or seizure disorder [4].

1.1.6 Driving Assessment

When the conceptual models for driving are considered, it is clear that many medical conditions can affect attributes required for driving. Typically, driving assessments for individuals are completed either through mandated on-road assessment or through driving evaluation programs specifically designed to assess driving ability in the face of significant medical impairment [31,46,67]. A driving evaluation program assessment includes a pertinent patient history and physical examination as well as a battery of neuropsychological tests to assess cognitive and visuoperceptual skills [31,46]. Based on the preliminary evaluation, typically an on-road driving evaluation is completed, involving a driving instructor and occupational therapist to objectively observe the patient's driving ability. Recommendations for the patient are then made regarding fitness to drive as well as driving skills that could possibly be improved upon.

Although efforts have been made to make broad generalisations regarding medical fitness to drive based on diagnosis [28,49,50,63,66,68], due to the differing severity and effects of medical conditions on different patients, the trend has been toward individual assessment as described above. However, the end result of interest to society is not whether a person has been able to pass a driver evaluation, but whether or not the disabled driver is safe to drive. In fact, the outcome of interest is the subsequent driving record of the disabled driver. Few studies have looked at driving records post assessment [28,69,70] and generally most studies have concentrated on comparing controls to patients on test assessment batteries and on the "on-road" assessment pass/fail rates for disabled patients [14,29-31,71].

Traditionally, crash and traffic violation rates have been the primary indicators used to assess driving record [27,50,56-58,62,66,72-75]. Crashes are likely the event associated with driving that places society and the individual driver most at risk. Motor vehicle crashes and traffic violations are anticipated events in our current society, and are therefore monitored by governing agencies. As discussed previously, many medical conditions are associated with increased crash and traffic violation rates compared to a control population, and therefore policies have been developed such as mandatory physician reporting for persons considered to be medically unfit to drive [5,12,13,76]. The effectiveness of new laws and policies governing driving is then usually evaluated by comparing the changes in the traffic violation and crash rates [72-74,77].

Traffic violation and crash rates may be obtained by either of two methods: self-report or government records [78-80]. Earlier studies from the 1970's demonstrated that self-report provided more complete and reliable crash rate information compared to government records based on police reports [79,80]. A more recent study published by Marottoli et al [78] found that self-report and Connecticut State records provided complementary information, since unreported crashes were identified with each method. In this study state records were believed to have an advantage over self-report when memory difficulties may be present or when there was fear of possible repercussion. The authors also found indirect evidence that state records were more likely to identify severe crashes compared to self-report. The disadvantages of state records were that not all crashes were reported and that police may not have actually filed a report if the event was considered minor. Although this study was recently published in 1997, the study actually took place from September 1989 to August 1990; therefore this study may not reflect current standards for state or provincial record keeping. Another advantage of using crash and traffic violation rates based on state or provincial records is that reliable information may be obtained over a long time span of up to a decade or more. Further, information can be collected for a complete population versus information from a smaller sample collected by self-report. However, a typical disadvantage of using government records is that the determined crash rates are generally provided in person-years versus per kilometres driven. Crash rates of older drivers, based solely on number of licensed drivers, are similar to the overall population, however when mileage driven is taken into account, the highest crash rate per mile driven is for the youngest and oldest drivers.[56,57]

1.1.7 Restricted Licensing

Variation in driving ability and skill level exists even for drivers not affected by medical impairments. For those with more severe medical conditions, often physical or cognitive limitations impair the ability to safely operate a motor vehicle under some or all driving conditions. However, driving is an integral part of many individuals' lives and especially for the disabled, driving may be necessary to maintain community independence [2]. Both increased rates of depression and decreased social integration have been confirmed in ex-drivers compared to drivers, even when adequate public transportation is available [81]. Acknowledging that there is often a need for persons with medical impairment to drive, even if driving skills have been affected, some authors, national societies and state and provincial governments have supported restricted licensing [3,5,13,82].

The American Association of Retired Persons (AARP) has advocated the increased use of restricted licensing [3]. The AARP actually refers to restricted licensing as "graduated licensing", however this term is unique to the AARP and all other government agencies and published reports use the term restricted licensing. A restricted license or graduated license may be defined as "a driver's license that for one reason or another has a restriction attached to it. To operate a motor vehicle, holders of such a license must meet some special requirement or must restrict their driving practices in some well-specified fashion" (p3)[3]. Crancer et al [83] define two broad types of restrictions: medical driving restrictions and medical licensing restrictions. Medical driving restrictions involve specific driving restrictions such as necessary vehicle modifications (automatic transmission, special mirrors, hand controls) or license limitations possibly including day time driving only or driving within a certain radius of the driver's home address. In fact, the most common medical driving restriction is the use of corrective lenses while driving [5]. Medical licensing restrictions refer to increased health monitoring requirements in order to maintain license certification such as regular physician examination or eye examinations.

Most states and provinces allow some form of restricted licensing to occur, but there is great variation in the type of restrictions implemented as well as the frequency used [3,5]. Of the Canadian provinces and territories, Ontario, New Brunswick and the Northwest Territories seldom allocate restricted licenses [5]. The province of Saskatchewan implements restricted licenses for medical impairment that may affect driving ability. The restriction categorisation (Appendix B) includes both types of restrictions, medical driving and medical licensing, identified by Crancer et al [83].

Although there is wide use of restricted licensing in North America, there has been little research completed to evaluate it [3,83,84]. The earliest study to investigate medical licensing restrictions found that persons diagnosed with epilepsy, diabetes mellitus, fainting as well as "other" conditions had higher accident rates than controls, whereas drivers with heart disease or vision deterioration did not have a significant difference [83]. Similarly, violation rates were increased in epilepsy, diabetes mellitus and "other categories", but not for vision deterioration, heart disease or fainting. When Crancer and O'Neall later studied license restrictions for heart disease in Washington State [8], they found once again that the overall accident rate for heart disease was comparable to a control population. However, in this study, when specific heart disease groups were explored, the arteriosclerotic and hypertensive groups had significantly higher crash rates. They further found that more frequent medical follow-up (6 months versus every one to two years) was a predictor of increased crash rate. In this study, Crancer and McMurray [83] also investigated medical driving restrictions and their effect on crash rates. All medical driving restrictions were grouped together in this study. The results are inconsistent, since one outlying group, women age 36 to 50 with medical driving restriction, have a dramatically higher crash and violation rate than any other control or restricted group. Overall, the results indicate that the medical driving restriction group has a statistically higher violation and crash rate; however, for men and all other women age categories, the rates are actually lower than for control groups. The authors were unable to offer an explanation for these findings.

No further studies have directly studied the impact of restricted licensing. Medgyesi and Koch [4], however, have studied the impact of a medical review program for Saskatchewan drivers from 1980 to 1989. This medical review program involved reviewing persons known to have medical conditions by Saskatchewan Government Insurance (SGI), which is the licensing authority for Saskatchewan. Some drivers undergoing medical review had medical driving restrictions or medical licensing restrictions imposed, but these restrictions were not specifically addressed. They did find increased at–fault crash rates for drivers with history of alcohol/drug dependence, cardiovascular disease, cerebrovascular disease, disorders of co-ordination and muscular control, diabetes, essential hypertension, seizure disorders and visual disorders. This study also demonstrated the effectiveness of the medical review program since "at-fault" relative to "not-at-fault" crash rates were shown to improve after the medical review process for persons with history of alcohol/drug dependence, cardiovascular disease, cerebrovascular disease, diabetes, and visual disorders.

Many medical conditions impair the ability to drive and in many states and provinces restricted licenses are provided in order to allow persons to continue driving under specific conditions. Although Crancer and McMurray[83] have shown a tendency for most age groups to have lower crash and violation rates for the medically impaired compared to controls, their results were inconclusive. Therefore, the effectiveness of restricted licensing programs, although widely used, has not been demonstrated.

1.2 Formulation of the Problem

Medical impairments affecting cognition, visuoperceptual skills, motor skills or even behaviour may impair the ability to operate a motor vehicle. Many states and provinces have acknowledged that individuals with medical impairments may not be able to drive under all conditions and because of this, restricted licensing has been introduced[5]. The two general approaches or categories of restricted licensing used are medical licensing restriction and medical driving restriction [83]. Although most states and provinces use restricted licensing to varying degrees, little research has been conducted to evaluate the effectiveness of this licensing intervention. It is necessary to evaluate restricted licensing since it is an important intervention that can maintain and promote independence in the community for disabled persons. Further, it is important to demonstrate the effectiveness of driving restrictions for persons with medical impairment since if this intervention is not effective then the public could be placed at increased risk at the expense of the individual driver.

1.3 Contribution to the literature

This study will evaluate the effectiveness of both medical driver restriction and medical license restriction in the province of Saskatchewan. A retrospective cohort design from April 1989 to April 1999 will be used. The main outcome measure will be crash and violation rates as indicators of driving performance. Medical driving and licensing restrictions will be evaluated to assess effectiveness.

This study will provide an evaluation of restricted licensing, which has not been evaluated since the early 1970's; even at that time there was little evidence to support or refute the practice of restricted licensing. The study of Saskatchewan drivers will allow examination of the two general types of restrictions, licensing and driving, to explore the effect of each type on "at-fault" crash and violation rates for drivers with medical impairments. For example, an annual medical examination (licensing restriction) versus driving only within a forty kilometre radius of home (driving restriction) are very different types of restrictions. It is anticipated that this retrospective study will elucidate the effectiveness of restricted licensing and set the stage for future prospective evaluation of this intervention.

1.4 Objectives

1. To determine if Saskatchewan drivers who have been granted restricted driver licenses for medical impairments have "at-fault" crash rates or traffic violation rates comparable to Saskatchewan drivers of similar age, sex and residence who have unrestricted, class 5 (general) licenses.
2. To determine if initiation of a restricted driver license affects an individual's "at-fault" crash rate or traffic violation rate.

Chapter 2: Methods

2.1 Acquisition of Saskatchewan Government Insurance Dataset

Saskatchewan Government Insurance (SGI) is the sole motor vehicle insurer in the province of Saskatchewan and therefore the agency through which all motor vehicle insurance claims are processed. Although SGI acts as an insurance company, it is also mandated to monitor all issues related to driving in the province of Saskatchewan such as issuance of driver licences, recording and monitoring of all driving related convictions, and determination of medical fitness to drive. This dual role of SGI as both a public insurer and government agency provides an uncommon situation where comprehensive driver information is recorded through one agency. For instance, in other provinces such as Ontario, the insurance industry and the Ministry of Transportation collect different types of driving related information. Further, since restricted licensing is implemented in Saskatchewan, the SGI driver information database has the potential to evaluate the effectiveness of this driving licence intervention.

The primary investigator contacted SGI by telephone in May 1998. Initial conversations centred around the ability of SGI to participate in this research study, the ability of the database to provide appropriate information to address the objectives of the study and the steps required to obtain the data. After many months of conversations to confirm a specific data request from SGI, a formal letter to confirm the data request from SGI was sent on April 22, 1999 (Appendix C). The datasets for the study were created on April 19, 1999 and received in a CD-ROM format on April 26, 1999. SGI provided, at no charge to the investigator, the datasets as well as a great deal of time through technical support.

2.2 Dataset Description

A total of 7 SAS® datasets (Appendix D) were provided by SGI on CD-ROM. The population represented in the datasets consists of all Saskatchewan drivers, identified by driver licence number. For confidentiality, a unique identifier ("alias") was derived from the driver licence number in order to provide a link variable for all datasets. The datasets were created on April 19, 1999. SGI continuously updates driver records and regularly purges the data. SGI staff and administrators consider the dataset information current to April 1, 1999. Since these data come from an administrative database, many of the datasets have varying numbers of rows of information for each driver requiring the use of statistical software that can handle data in this format. Six of the seven datasets provided were used for this study.

2.2.1 Customer Data (EXT_DATA.CUST)

This dataset contains demographic (birth date, sex, postal code) information on all Saskatchewan drivers. It provides information on a greater than expected number of drivers (1,176,486) since the information dates back to 1986 and this dataset information is not purged. The variable "POSTAL3" provides the first 3 digits of the current postal code in order to distinguish rural from urban drivers.

2.2.2 Driver Registration Data (EXT_DATA.DRREG)

The driver registration dataset describes the driving status of all drivers. Driving licences in Saskatchewan are renewed on an annual basis and this dataset identifies the effective date of the driver licence and the expiry date of the licence. Driving licence class is also indicated on an annual basis. This dataset is arranged such that any change in licence status such as licence renewal, suspension or cancellation is recorded as a separate row of information for the driver. Therefore each driver has multiple rows of information in this dataset. As annual information is added, information greater than 7 years old is purged from the dataset. Information greater than 7 years old is maintained if new information is not added; for example, if a driver's licence was cancelled in 1993 then information from 1986 to 1993 would remain in the dataset.

2.2.3 Claims Data (EXT_DATA.CLAIMS)

This dataset contains information on all insurance claims made with SGI. All insurance claims are recorded in this dataset, not only collisions. For example theft claims and vehicle damage claims secondary to natural disasters are included in this dataset. The type of coverage, indicated by the variable "COVR_TYP" (Appendix E), allows all collisions to be identified. Crash responsibility and crash date are also described.

2.2.4 Non-criminal conviction data (EXT_DATA.TYPE20)

This dataset identifies all driving related non-criminal convictions (Appendix F). As with other datasets, multiple rows of information/ observations may be devoted to individual drivers; however, drivers with no convictions will not be represented. This dataset, similar to the driver registration dataset, is purged of data on a 7-year cycle.

Unlike collisions, it is very possible for one driver to have multiple convictions on the same date as the result of one incident. Fine amounts and types of convictions are identified.

2.2.5 Criminal Conviction data (EXT_DATA.TYPE25)

This dataset identifies all driving related criminal convictions (Appendix F). This dataset is arranged similarly to the Type 20 convictions dataset. The only additional information provided in this dataset is whether or not a jail term was served and its duration.

2.2.6 Medical Condition or Driving Restriction data (EXT_DATA.TYPE70)

This dataset identifies all drivers who have ever had an identified medical condition or a driving restriction. A medical condition is reported to SGI via 2 main methods: driver self-report on their annual driver licence renewal and physician reporting, which became obligatory in Saskatchewan in August, 1996. The medical condition diagnostic groupings used are quite broad and in most instances appear to be clinically based (Appendix G). A driver may have multiple medical conditions that are assigned as letters represented in a single string variable, "DH70MIND". The medical condition coding was revised prior to 1992 and therefore this variable is only reliable from 1992 forward.

Different types of restrictions are also identified in this dataset. The most common restriction code indicates drivers who are required to wear prescribed corrective lenses while driving. There are 15 other types of driving restrictions implemented which fall into 2 broad categories (not specified by SGI): licensing restrictions and driving restrictions. The licensing restrictions require annual re-assessment of driving skills or medical status in order to maintain a driving licence status. Driving restrictions are actual limitations imposed on the driver's daily driving routine. Examples include driving during hours of full daylight only or driving within a 40-kilométre radius of the address shown on the driver licence. Individual, personalised restrictions are also possible and are coded as "under special conditions recorded on file". SGI administration confirms that this type of restriction would represent a more severe form of driving restriction compared to the other restriction codes.

As with other datasets, individual drivers may have multiple observations. Each time there is a change in medical condition or medical restriction, an observation is recorded. This dataset uses a single date variable to identify all changes to the dataset record for both medical condition and driving restriction changes. As with the medical condition variable, the driving restriction variable, "DH70REST", is a string variable consisting of single to multiple letters representing driving restrictions. Driving restriction variables have been recorded reliably in this dataset since 1986. Data from this dataset are never purged.

2.2.7 Traffic Accident Information System Data (EXT_DATA.TAIS)

The TAIS dataset represents the police record of reported crashes. The information for this dataset is collected in the field and provides information regarding specific details of the crash such as the number of vehicles involved, the crash environment and extent of damage resulting from the crash. An advantage of this dataset is that it provides very detailed information about crashes. However, when compared to the claims dataset the actual number of crashes recorded is far fewer, suggesting that many crashes are not captured through the TAIS dataset. This is not surprising, since there must be at least $1000.00 damage or personal injury in order for a collision to be reportable. (See Appendix H) A further disadvantage of the TAIS dataset is that driver crash responsibility is not clearly assigned, unlike the CLAIMS dataset, which does clearly assign responsibility. Since the data from the TAIS dataset were incomplete and could not identify driver responsibility, this dataset was not used in this study.

2.3 Data Screening and Culling

The datasets were sent as raw SAS datasets where no culling of information had been completed for the variables requested. Extensive editing of the data was required which included generation of summary variables, allocation of variables to appropriate person-year groupings and culling of variables to time frames of interest. Details of the greater than 100 programs and greater than 100 datasets created while editing the data are available from the author. Review of the data indicated that complete information, required for this study was available from January 1, 1992 to the date the datasets were created. Therefore, the data had to be culled in order to identify eligible drivers (Table 1). A detailed description of how eligible drivers were identified is provided in figure 2. The final sample size of 703,758 represents all drivers who have had a valid, class 5 (See Appendix A), driver license since January 1, 1992.

Table 1: Variables used to determine eligible drivers for study

Culling Variable	Variable Definition	Variable Derivation	Comments
Birth Date (birthdt)	Birth date of driver	Original variable from Customer Dataset	
Driving license effective date (deffdate)	Date for which driving license becomes effective.	Original variable from the Driver registration dataset	This variable is used to identify when the license is in effect after Jan.1, 1992. In combination with the expiry date, person-years for driving may be calculated.
Driver license class (hi_class)	This variable identifies the highest class of licence obtained by a driver since Jan. 1, 1992.	This variable, derived from "dclass", represents the highest license value obtained since Jan. 1, 1992.	Only drivers with general, class 5, licences are compared in this study. (See Appendix A)

Database	Sample Size	Action	Justification
Customer	1,176,486		
	(82,183)	Remove all drivers born after April 19, 1983 or before Jan. 1, 1900	1. Only persons 16 years or older eligible for class 5 licence 2. Coding errors are present which make for extreme ages 3. There are Y2K coding problems in this database, therefore people born before Jan. 1, 1900 may be misinterpreted as the birthdate occurring in the late 20th century
Customer & Driver Registration	1,094,303	Merge these 2 databases	1. Need to further cull data so drivers are known to be registered to calculate person-years
	(270,457)	Delete all driver registration observations prior to 1992	1. Driver registration data purged on a 7 year cycle and information only reliable for all drivers to Jan. 1, 1992 2. Collision and convictions data is similarly purged on a 7 year cycle, therefore outcome measures only reliable back to 1992 3. Medical condition data from the Type 70 dataset is only reliable from 1992 forwards
Customer & Driver Registration	824,566		
	(120,808)	Remove all drivers who have a driver licence class higher than class 5 since Jan. 1, 1992	1. Objective of study is to compare drivers with restricted licences or medical conditions to other drivers with general, class 5 licences. (See Appendix A) 2. Information for driving licence classes only reliable back to 1992, since these data are also purged on a 7-year cycle.
Customer & Driver Registration	**703,758**		

Figure 2: Determination of eligible drivers for study inclusion

2.4 Variables for the study model

Based on the objectives for this study the main outcome measures for this study are "at-fault" crashes and driving convictions. The model for this study is depicted in figure 3. The definition and description of the exposure, covariate and outcome variables are provided in tables 2, 3 and 4 respectively.

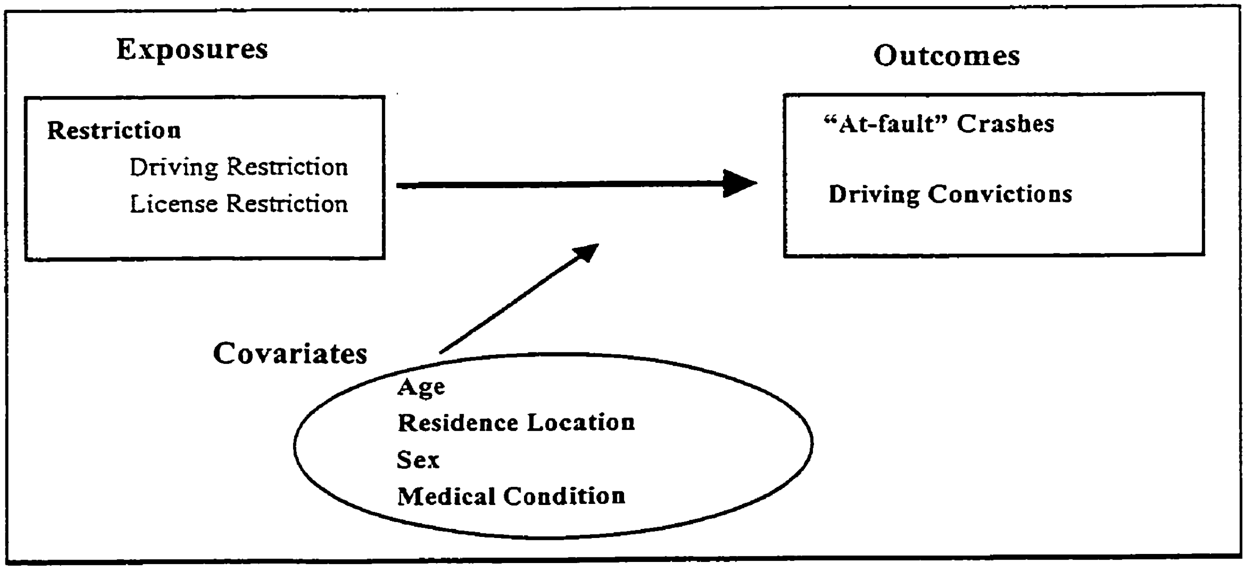


Figure 3: Model demonstrating inter-relationship of variables for study

Table 2: Exposure Variable descriptions

Variable	Variable Definition	Variable Derivation	Comments
Exposure Variables			
Restriction (restric)	Dichotomous variable identifying any driver who has ever had any driving restriction imposed for health related reasons	This variable is derived from the "dh70rest" variable, which identifies all driving restrictions. If the driving restriction was for vision correction only, then these drivers were ignored. Drivers may have more than one type of restriction. Onset date was determined by the first driving restriction date recorded.	The variable "dh70rest" has been recorded consistently since 1986.
Driving Restriction (act_rest)	Dichotomous variable identifying drivers who have at least one driving restriction that limits the conditions under which they may drive (Restrictions B to N inclusive – See Appendix B)	This variable is derived from the "restric" variable and includes any driver who has a type B to N inclusive driving restriction. Drivers may have more than one restriction and may also have a License restriction. The onset date is the first date where a B to N restriction was imposed.	
License Restriction (ann_rest)	Dichotomous variable identifying drivers whom must undergo regular evaluation in order to maintain their license. (Restriction X,Y,Z- See Appendix B)	This variable is derived from the "restric" variable and includes any driver who has a type X, Y or Z inclusive license restriction. Drivers may have more than one restriction and may also have a Driving restriction. The onset date is the first date where a X, Y or Z restriction was imposed.	

Table 3: Covariate Variable descriptions

Variable	Variable Definition	Variable Derivation	Comments
Covariates			
Age Category (Agecat)	Ordinal variable representing driver age category status as of April 19, 1999.	This variable is derived from birth dates ("birthdt"). Categories are broken down by decades.	April 19, 1999 is used since this is the date the datasets were created. Person-years are used in the analysis. Therefore it is common for 1 driver to contribute person-years of driving to 2 age categories.
Residence Location	Dichotomous Variable identifying urban or rural residence.	This variable is derived from "postal3" which represents the first 3 digits of the driver's postal code. The definition of rural is based on Canada post coding where a rural area is any area where the second digit is "0". Urban area second digit are "1" through "9".	Empirically reviewed Postal code listings to confirm. Canada post states that a rural versus urban status is established at the municipal level. The smallest identified urban centre is Kindersley, population 4, 679 (1996).
Sex	Dichotomous variable	Original variable "sex"	
Medical Condition (medcond)	Dichotomous variable identifying drivers who have a medical condition (See Appendix G)	This variable is derived from the "dh70mind" variable, which identifies drivers with known medical conditions. All medical conditions were included except for drug and alcohol abuse, since it was felt that these conditions reflect an addiction problem rather than permanent physical or cognitive impairments	"dh70mind" has only been recorded reliably since 1992. The method of identification of medical conditions is very limited and previous study has shown that many medical conditions are not identified in this dataset [4]

Table 4: Outcome Variable descriptions

Variable	Variable Definition	Variable Derivation	Comments
Outcome Variables			
"At-fault" Crash (resp_bin)	This dichotomous variable identifies all crashes for which a driver is responsible. Only crashes occurring after Jan. 1, 1992 are identified. This is expressed as any or no responsibility.	This variable is derived from the CLAIMS dataset. "covr_typ" identifies all claims made by drivers. A collision claim is identified as a type "31", "22", or "21". (Appendix E) Once collisions were identified then the variable resp_bin was created which identified responsibility for the collision.	Conversations held with SGI regarding the definition of collision and method of identifying it from the database.
Driving Convictions (Conv2025)	This dichotomous variable represents criminal and non-criminal driving convictions (see Appendix F). Only convictions occurring after Jan. 1, 1992 are identified.	This variable is derived from the combined Type 20 and Type 25 datasets. "dh20cvcd" and "dh25cvcd" were used to identify convictions. Criminal and non-criminal convictions were combined.	

2.5 Data Storage and Data Quality

The SAS datasets were stored on a UNIX operating system. Dataset manipulation and linkage was performed using the SAS system. The quality of the data was high. This was substantiated when the claims and customer datasets were combined and there were only 176 drivers not matched by alias for these datasets that contain all drivers. Further analysis showed that none of these 176 drivers had an effective licence after January 1, 1992. Therefore, over 700,000 drivers were matched successfully across datasets. Some problems were encountered with birth dates due to confusion with century of birth and for this reason all drivers born prior to January 1, 1900 were excluded.

2.6 Statistical Analysis

Frequencies for the dependent and independent variables will be presented in tables and charts. Frequency statistics were obtained using SAS® [85](version 6.12 for Unix). Crude incidence rates for "at-fault" crashes and traffic violations were also calculated for each of the independent variables using Stata® [86]. To address the first primary objective, crude incidence rate ratios as well as stratified incidence rate ratios, to assess for confounding and effect modification were calculated, as were Mantel-Haenszel estimates.

Poisson regression was used to develop multivariate statistical models to predict "at-fault" crash and traffic violation rates for Saskatchewan drivers with and without driving restrictions. Poisson regression analysis is the most appropriate regression technique for this study since it is used for modelling rates based on counts of discrete dependent variables [87]. The basic assumptions to be met for using Poisson regression are that outcomes "occur independently in different people and in the same person at different points in time, that the likelihood that a new case will occur in a short period is proportional to the number of people, and the [outcome] risks are homogeneous across people and time."[88] (p3) Interaction terms were explored to assess possible effect modification, but were only included in the model if the Pseudo R^2 value was substantially effected by a change of at least 1%.[87] The Pseudo R^2 value is defined as $(L_0-L_p)/L_p$ where L_0 represents the log-likelihood of the model containing only the intercept and L_p the log-likelihood of the model with the intercept and 'p' covariates.[87]

To address the second primary objective, crude incidence rate ratios were derived for "at-fault" crash and traffic violation rates pre and post imposed driving restrictions.

Time series analyses were used to determine the effect of driving restriction imposition. Autoregressive, integrated, moving average (ARIMA) models were used for the time series analyses.[89] Time series analysis is the most appropriate method of analysis for this interventional situation, since "at-fault" crash and conviction rates pre and post driving restriction cannot be considered independent. In fact time series analysis focuses on the dependence of the observations which are autocorrelated. [89,90] Time series analysis has also been shown to be effective at demonstrating the impact of a specific intervention imposed at a common point in time.[77,89,90]

ARIMA modelling was completed using SAS® (V6.12) The intervention in each series model was represented by a dummy variable with 0 representing pre-intervention and 1 representing post intervention. Models were first studied with zero orders of differencing (no added terms: Model (0,0,0) where the first term represents autoregressive terms, the second differencing terms and the third represents moving average terms). If there was evidence of a trend in the time series plot or if the series had positive autocorrelations for a large number of lags, then differencing for the model was used. After differencing was applied to the model, the autocorrelation plots and partial autocorrelation plots were reviewed to determine the presence of AR or MA signatures which suggest the specific type of term that may be best to try in the model.[91] Using this technique models were developed where the best fitting models were those with highest lag 6 and lag 12 q statistics [89]. If the t ratio for the intervention parameter was associated with a significance level of less than 0.05 in the model, then restricted licensing was considered to be significantly associated with a change in the "at-fault" crash and/or convictions rates.

For this study, all drivers had an identified onset date for their driving restriction, however, this date obviously was different for each driver. The study length was divided into 380 weekly time intervals and the interval in which the driver received his or her restriction was identified, as well as the licensing start date and finish date. All drivers then had their driving history adjusted such that the imposition of the driving restriction fell in the 380th interval. Therefore the length of the time series was potentially for 760 weekly intervals (~14 years), however any one driver could only contribute up to between seven and eight years (380 intervals) of driving time.

2.7 Ethics Approval

The proposal was submitted to the Research Ethics Committee at The Rehabilitation Centre. Approval was granted on July 8, 1999. (See Appendix I)

Chapter 3: Results

3.1 Results Overview

Demographic information is presented in section 3.2. The remainder of the results section is organized in a manner to sequentially address the objectives of this study. (Table 5)

Table 5: Overview of results section organization

Objective	Outcome Measure	Type of Driving Restriction	IRR	M-H IRR*	Poisson Model	Time Series
Objective 1: To determine if Saskatchewan drivers who have been granted restricted driver licenses for medical impairments have "at-fault" crash rates or traffic violation rates comparable to Saskatchewan drivers of similar age, sex and residence who have unrestricted, class 5 (general) licenses	"At-fault" crash	All restrictions	3.3.1 Tab 7	3.3.3 Tab 9	3.4.1	N/A
		Driving restriction			App. J	
		Licensing Restriction			App. J	
	Conviction	All restrictions	3.3.2 Tab 8	3.3.4 Tab 10	App. J	N/A
		Driving restriction				
		Licensing Restriction				
Objective 2: To determine if initiation of a restricted driver license affects "at-fault" crash rates or traffic violation rates	"At-fault" crash	All restrictions	3.5.1 Tab 14	N/A	N/A	3.5.1 App. K
		Driving restriction				
		Licensing Restriction				
	Conviction	All restrictions	3.5 Tab 14	N/A	N/A	3.5.1 App. K
		Driving restriction				
		Licensing Restriction				

*M-H IRR- Stratified Mantel-Haenszel incidence rate ratios

3.2 Demographic Data

A total of 703,758 driving records were eligible for inclusion in this study. (Table 6) There were a total of 23,185 drivers who had a driving restriction identified. Of these drivers, 2010 had both a driving and licensing restriction, 20,074 had only a licensing restriction and 1101 had only a driving restriction imposed. The follow-up time for these driving records accounted for 3,792,479 person-years, where 72, 410 person-years represented time driven by persons with a restricted driver's license. Overall there are more female drivers represented in this study than male drivers. The data also indicate that drivers with restricted licenses are more likely to be male, to live in a rural location, to have an identified medical condition, and tend to be older.

Table 6: Descriptive data for independent variables comparing drivers with restrictions to drivers never having a restriction.

Independent Variables	Value	All Drivers (n=703758)	No Restriction (n=680573)	Restriction (n=23185)
Sex	Male	345701 (49%)	330812 (48.6%)	14259 (61.5%)
	Female	358686 (51%)	349760 (51.4%)	8926 (38.5%)
Residence	Rural	296417 (42%)	285386 (41.9%)	11031 (47.5%)
	Urban	407340 (57.9%)	395186 (58.1%)	12154 (52.4%)
Medical Condition	Yes	24442 (3.5%)	3579 (0.5%)	20863 (90.0%)
	No	679315 (96.5%)	676993 (99.5%)	2322 (10.0%)
Age Category	16-24	111221 (15.8%)	109722 (16.1%)	1499 (6.5%)
	25-34	135060 (19.2%)	133339 (19.6%)	1721 (7.4%)
	35-44	148116 (21.0%)	145525 (21.4%)	2591 (11.2%)
	45-54	107898 (15.3%)	105078 (15.4%)	2820 (12.2%)
	55-64	71395 (10.1%)	68152 (10.0%)	3243 (14.0%)
	65-74	65257 (9.3%)	60613 (8.9%)	4644 (20.0%)
	75-84	48360 (6.9%)	43534 (6.3%)	4826 (20.8%)
	>85	16450 (2.3%)	14609 (2.1%)	1841 (7.9%)

The distribution for the number of individual driver "at-fault" crashes and traffic violations demonstrates that most drivers have no crashes or convictions. (Figures 4 and 5) This distribution is consistent with the Poisson distribution [88]. The expected Poisson distribution was plotted against the observed distribution for "at-fault" crashes and traffic violations. The distributions were very similar for "at-fault" crashes, however the fit was not as good for traffic violations.

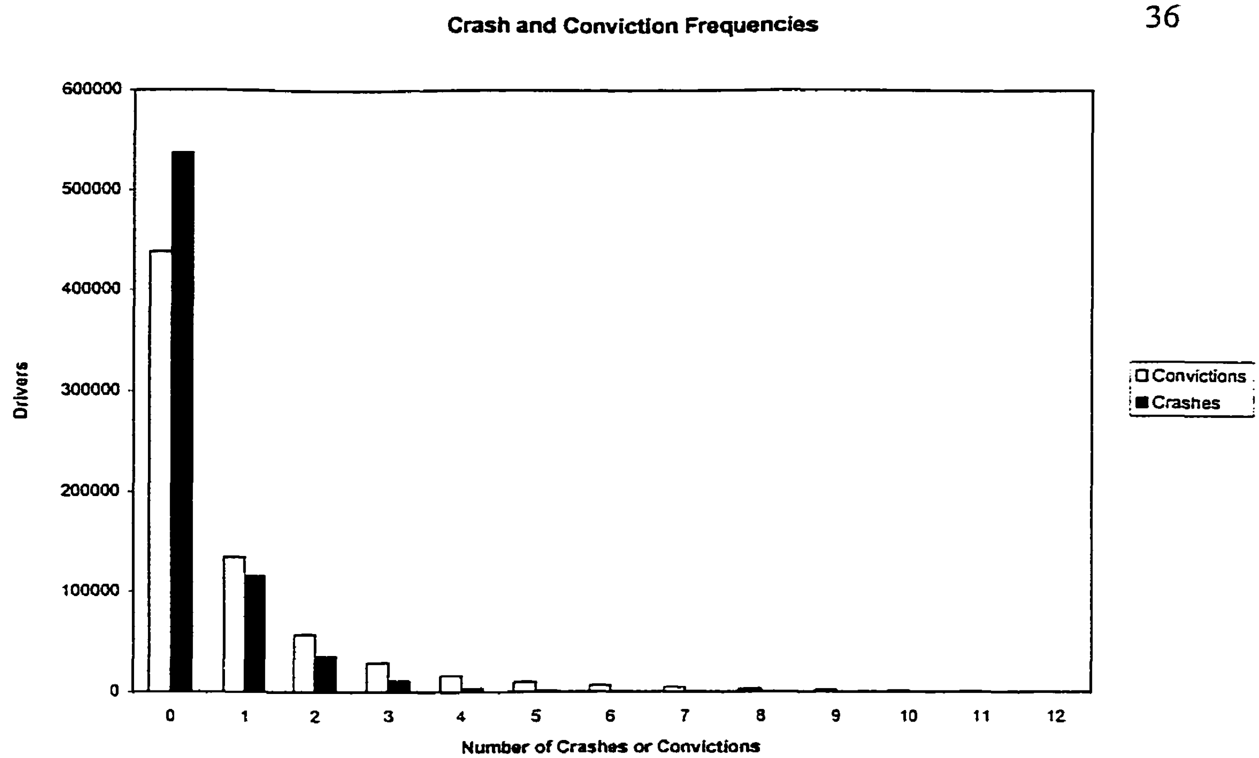


Figure 4: Frequency of "at-fault" crashes and traffic violations for all drivers

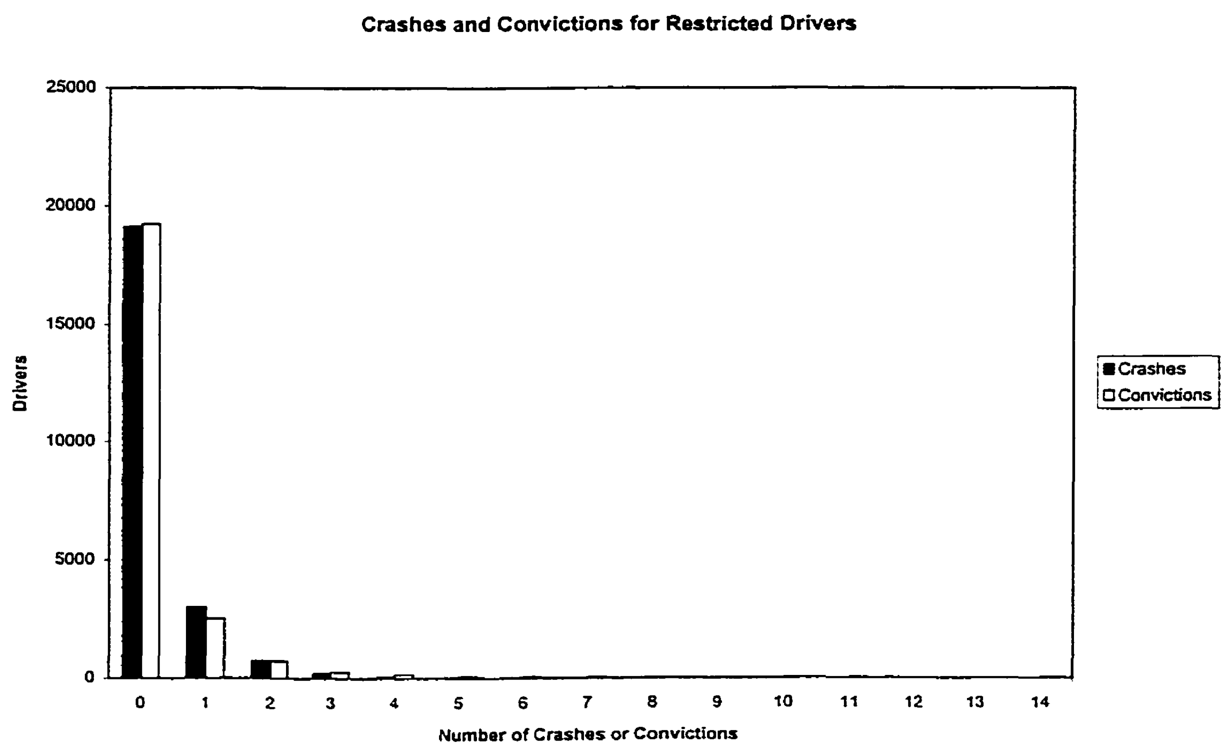


Figure 5: Frequency of "at-fault" crashes and convictions for drivers with a driving restriction

3.3 Incidence Rates for "At-fault" Crashes and Traffic Violations

3.3.1 "At-fault" Crash incidence rates

Drivers with any type of driving restriction have an incidence rate of 7.6 "at-fault" crashes per 100 person-years of driving compared to an incidence rate of 6.4 for drivers without restriction. (Table 7) Similar rates are seen for drivers with a driving or licensing restriction. The most striking contrast for "at-fault" crash rates occurs for male drivers who have double the rate of female drivers. Urban drivers and drivers with identified medical conditions also have increased crash rates. Age category does not demonstrate a specific pattern for crash rates.

Table 7: "At-fault" crash incidence rates and crude IRR's

Independent Variables	Value	Incidence Rates (per 100 person-years)	Crude Incidence Rate Ratios	95% Confidence Intervals
Restriction All	Yes	7.6	1.19	(1.16, 1.22)
	No	6.4		
Driving	Yes	7.8	1.20	(1.15, 1.33)
	No	6.5		
Licensing	Yes	7.8	1.20	(1.18, 1.24)
	No	6.5		
Sex	Female	4.4	0.50	(0.50, 0.50)
	Male	8.8		
Residence	Urban	7.3	1.38	(1.37, 1.40)
	Rural	5.3		
Medical Condition	Yes	8.1	1.27	(1.25, 1.29)
	No	6.4		
Age Category	16-24	7.2	1.00	
	25-34	5.9	0.82	(0.81, 0.84)
	35-44	6.8	0.94	(0.93, 0.96)
	45-54	7.3	1.01	(1.00, 1.03)
	55-64	5.3	0.74	(0.73, 0.75)
	65-74	5.6	0.78	(0.76, 0.79)
	75-84	6.7	0.93	(0.91, 0.95)
	>85	7.5	1.04	(1.00, 1.09)

3.3.2 Traffic Violation Incidence rates

Drivers with any type of driving restriction have a traffic violation incidence rate of 10.2 violations per 100 person-years of driving which is less than drivers without restriction (16.4 violations per 100 person-years) (Table 8). Male drivers have an incidence rate three times that of female drivers and urban dwelling drivers are also more likely to have traffic violations compared to rural residents. Similar to drivers with driving restrictions, drivers with identified medical conditions have a lower traffic violation rate than those without identified medical conditions. There is an evident trend of an inverse relationship between increasing age and a decreasing incidence of traffic violations.

Table 8: Traffic violation incidence rates and crude incidence rate ratios

Independent Variables	Value	Incidence Rates (per 100 person-years)	Crude Incidence rate ratios	95% Confidence Intervals
Restriction All	Yes	10.2	0.62	(0.61, 0.63)
	No	16.4		
Driving	Yes	14.5	0.90	(0.84, 0.94)
	No	16.3		
Licensing	Yes	9.4	0.57	(0.56, 0.59)
	No	16.4		
Sex	Female	8.3	0.33	(0.33, 0.33)
	Male	25.2		
Residence	Urban	17.9	1.26	(1.26, 1.27)
	Rural	14.2		
Medical Condition	Yes	10.9	0.66	(0.65, 0.67)
	No	16.5		
Age Category	16-24	38.3	1.00	
	25-34	21.7	0.57	(0.56, 0.57)
	35-44	13.0	0.34	(0.34, 0.34)
	45-54	9.5	0.25	(0.25, 0.25)
	55-64	5.7	0.15	(0.15, 0.15)
	65-74	3.5	0.09	(0.09, 0.09)
	75-84	2.7	0.07	(0.07, 0.07)
	>85	2.4	0.06	(0.06, 0.07)

3.3.3 Stratified Incidence Rate Ratios of "at-fault" crashes for restricted versus non-restricted drivers

Gender, residential location, or age category do not appear to influence the effect of license restriction (including driving and licensing) on "at-fault" crash rate. (Table 9) Presence or absence of an identified medical condition, however, does have a differential effect on the crash rate ratio. For all drivers with a medical condition, those with a restricted license actually have a lower crash IRR compared to those drivers without restriction. For drivers without identified medical conditions, those with a restricted license have a higher "at-fault" crash IRR.

Table 9: Stratified incidence rate ratios (IRR) comparing "at-fault" crash rates of drivers with and without restrictions

Stratification Variables	Value	M-H (Crude) IRR All Restrictions	95% CI	M-H (Crude) IRR Driving Restriction	95% CI	M-H (Crude) IRR Licensing Restriction	95% CI
Sex	Combined	1.09 (1.19)	1.06, 1.12	1.11 (1.24)	1.03, 1.19	1.10 (1.21)	1.07, 1.13
	Male	1.05	1.01, 1.08	1.06	0.97, 1.15	1.06	1.03, 1.09
	Female	1.22	1.16, 1.28	1.28	1.09, 1.48	1.23	1.16, 1.29
Residence	Combined	1.20 (1.19)	1.17, 1.24	1.31 (1.24)	1.22, 1.41	1.22 (1.21)	1.19, 1.25
	Rural	1.16	1.11, 1.21	1.25	1.13, 1.39	1.18	1.13, 1.23
	Urban	1.23	1.19, 1.27	1.39	1.25, 1.54	1.25	1.20, 1.29
Medical Condition	Combined	N/A (Heterogeneity)		1.08 (1.24)	1.01, 1.17	N/A (Heterogeneity)	
	Yes	0.89	0.85, 0.92	1.03	0.93, 1.14	0.90	0.87, 0.93
	No	1.29	1.19, 1.39	1.17	1.04, 1.31	1.43	1.31, 1.57
Age Category	Combined	1.22 (1.19)	1.19, 1.26	1.23 (1.24)	1.14, 1.32	1.25 (1.21)	1.21, 1.28
	16-24	1.18	1.08, 1.29	1.06	0.89, 1.25	1.28	1.16, 1.40
	25-34	1.23	1.11, 1.35	1.29	1.02, 1.60	1.23	1.12, 1.36
	35-44	1.20	1.11, 1.29	1.44	1.16, 1.77	1.22	1.13, 1.31
	45-54	1.22	1.14, 1.31	1.36	1.06, 1.73	1.21	1.13, 1.30
	55-64	1.32	1.23, 1.42	1.33	1.00, 1.75	1.34	1.25, 1.44
	65-74	1.23	1.16, 1.31	1.13	0.90, 1.40	1.25	1.17, 1.33
	75-84	1.16	1.08, 1.24	1.23	1.04, 1.45	1.20	1.12, 1.28
	>85	1.36	1.18, 1.57	1.20	0.91, 1.54	1.36	1.19, 1.57

3.3.4 Incidence Rate Ratios of traffic violations for restricted versus non-restricted drivers stratifying by independent variables

Drivers with a restricted license generally have lower traffic violation rates than drivers without restricted licenses. Residence location does not appear to affect the incidence rate ratio for drivers with and without restriction. (Table 10) There is a difference in the incidence rate ratio between genders; the effect of restriction appears larger in males. As with crashes, there is a trend for the medical condition status to influence traffic violation IRR's in restricted versus non-restricted drivers. This appears to be a more prominent effect when drivers with driving restrictions are considered whereas the effect is almost negligible for drivers with a licensing restriction. When age category is controlled, it is apparent that age category is a confounder since the crude and adjusted incidence rate ratios differed.

Table 10: Stratified Incidence rate ratios comparing conviction rates of drivers with and without restrictions

Stratified Variables	Value	M-H (Crude) IRR All Restrictions	95% CI	M-H (Crude) IRR Driving Restriction	95% CI	M-H (Crude) IRR Licensing Restriction	95% CI
Sex	Combined	0.54 (0.62)	0.53, 0.56	0.76 (0.89)	0.72, 0.80	0.50 (0.57)	0.49, 0.51
	Male	0.52	0.50, 0.53	0.71	0.67, 0.75	0.47	0.46, 0.49
	Female	0.67	0.63, 0.70	1.02	0.90, 1.15	0.62	0.59, 0.65
Residence	Combined	0.63 (0.62)	0.61, 0.64	0.93 (0.89)	0.88, 0.98	0.58 (0.57)	0.56, 0.59
	Rural	0.67	0.65, 0.69	0.88	0.82, 0.95	0.61	0.59, 0.63
	Urban	0.60	0.58, 0.61	1.00	0.92, 1.08	0.56	0.54, 0.57
Medical Condition	Combined	0.83 (0.62)	0.81, 0.86	N/A (Heterogeneity)		0.75 (0.57)	0.73, 0.77
	Yes	0.77	0.75, 0.80	0.81	0.74, 0.89	0.75	0.73, 0.77
	No	1.03	0.97, 1.08	1.32	1.23, 1.41	0.74	0.68, 0.80
Age Category	Combined	1.01 (0.62)	0.99, 1.03	1.04 (0.89)	0.98, 1.10	1.01 (0.57)	0.99, 1.03
	16-24	0.99	0.95, 1.04	0.96	0.89, 1.04	1.02	0.97, 1.06
	25-34	0.84	0.79, 0.89	1.02	0.90, 1.16	0.82	0.76, 0.87
	35-44	1.08	1.02, 1.14	1.37	1.17, 1.59	1.04	0.98, 1.11
	45-54	1.05	0.99, 1.12	1.16	0.91, 1.45	1.04	0.98, 1.11
	55-64	1.20	1.11, 1.28	1.06	0.77, 1.42	1.18	1.10, 1.27
	65-74	0.98	0.90, 1.07	1.05	0.78, 1.39	1.00	0.92, 1.08
	75-84	1.15	1.03, 1.28	1.16	0.87, 1.52	1.16	1.04, 1.28
	>85	1.19	0.90, 1.55	1.08	0.61, 1.72	1.10	0.83, 1.43

3.4 Multivariate Poisson regression models: Objective 1

3.4.1 Model to predict "at-fault" crash rate comparing drivers with and without any type of restricted driving license

Univariate Poisson regression analysis of independent variables was completed to determine the contribution of independent variables to predict "āt-fault" crash rates. (Table 11) The Pseudo R^2 value (defined as: $1\text{-}L_l/L_0$ where L_l represents the value of the log likelihood function with all included variables and L_0 only the constant[87]) is used to estimate the contribution of variables in predicting the model where 1 represents perfect prediction.

Table 11: Univariate Poisson regression analysis of independent variables and their association with "at-fault"crash rate.

Variable	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	Log Likelihood	P value	Pseudo R^2
Intercept	-2.7395	0.0020			-20486		0.0000
Restriction	0.1724	0.0136	1.188	(1.157, 1.220)	-20411	0.000	0.0037
Female Sex	-0.6920	0.0042	0.501	(0.496, 0.505)	-6357	0.000	0.6897
Urban residence	0.3262	0.0042	1.386	(1.374, 1.397)	-17429	0.000	0.1493
Medical Condition	0.2390	0.0095	1.270	(1.247, 1.294)	-20190	0.000	0.0145
Age category 16-24 (ref)			1.000		-18966		0.0742
25 – 34	-0.1918	0.0066	0.826	(0.815, 0.836)		0.000	
35 - 44	-0.0581	0.0063	0.944	(0.932, 0.955)		0.000	
45 –54	0.0153	0.0067	1.015	(1.002, 1.029)		0.022	
55 –64	-0.3044	0.0081	0.738	(0.726, 0.749)		0.000	
65 –74	-0.2544	0.0082	0.775	(0.763, 0.788)		0.000	
75 – 84	-0.0706	0.0097	0.932	(0.914, 0.950)		0.000	
85 - 100	0.0442	0.0225	1.043	(0.998, 1.090)		0.060	

All variable terms including sex, location of residence, absence or presence of a medical condition or driving restriction and age category appeared to be associated significantly with total crashes. Therefore each of these variables will be included in the multivariate Poisson regression model at this stage. Below are the results of the Stata® output for the main effects model which includes all independent variables. (Table 12)

Table 12: Main effects model for "at-fault" crash rate for drivers with or without any type of driving restriction

Variable	Incidence Rate Ratio	95% Confidence Interval
Any License Restriction	0.920	(0.890,0.952)
Female Gender	0.499	(0.495, 0.504)
Urban Location	1.378	(1.367, 1.390)
Medical Condition	1.280	(1.250, 1.311)
Age 16-24 (reference)	1.000	
Age 25-34	0.842	(0.832, 0.854)
Age 35-44	0.981	(0.969, 0.994)
Age 45-54	1.053	(1.039, 1.067)
Age 55-64	0.757	(0.745, 0.769)
Age 65-74	0.782	(0.770, 0.795)
Age 75-84	0.914	(0.897, 0.932)
Age Greater than 85	0.958	(0.916, 1.000)

All of the variables significantly contribute to the model. It was known from the stratified analysis, however, that there is likely effect modification at least by medical condition. To assess for interaction, there is a possibility of ten 2-way interaction terms given that there are 5 independent variables. Seven of these interaction terms were selected for possible inclusion in this model for the following reasons:

Restric*sex	-men who have a restriction may have their crash rate affected to a different degree than women with restriction, since "at-fault" crash rates vary greatly between these groups
Restric*age category	-the effect of age on restriction may affect crash rates differently-the elderly may be more affected than the young

Restric*locat	-the effect of restriction on crash rate may be different for rural and urban drivers, since specific driving restrictions and the effect of restriction may vary by location
Restric*medcond	-the effect of restriction on crash rate may be different for drivers with and without an identified medical condition, since drivers without an identified medical condition and driving restriction may have been identified for restriction in a different manner (eg poor driving record)
Sex*Age category	-the effect of age category on sex may affect crash rates since there is such a disparity in the crash rates between men and women
Medcond*Age category	-the effect of medical condition on crash rate may be different across age categories, since specific medical conditions would be more likely in certain age categories
Sex*medcond	-The effect of presence of a medical condition may affect crash rates differently, since men and women may have different types of medical conditions

Table 13: Effect of interaction terms, individually, on the main effects model for "at-fault" crash rate comparing drivers with and without any type of driving restriction

Interaction term	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	P value	Pseudo R^2
Main Effects						0.9256
Restric*sex	.13774	.03043	1.148	(1.081, 1.218)	0.000	0.9261
Restric*Age category (Reference=Ra1)						0.9259
Ra2	0.0174	0.0652	1.018	(0.895, 1.156)	0.789	
Ra3	-0.0368	0.0610	0.964	(0.855, 1.086)	0.546	
Ra4	-0.0511	0.0591	0.950	(0.846, 1.067)	0.387	
Ra5	-0.0032	0.0597	0.997	(0.887, 1.121)	0.957	
Ra6	-0.716	0.0571	0.931	(0.832, 1.041)	0.210	
Ra7	-0.114	0.0586	0.892	(0.796, 1.001)	0.052	
Ra8	0.0890	0.0865	1.093	(0.923, 1.295)	0.303	
Restric*locat	0.0570	0.0281	1.059	(1.002, 1.118)	0.043	0.9257
Restric*medcond	-0.3518	0.0435	0.7034	(0.645, 0.766)	0.000	0.9270
Sex*agecat (Reference=Sa1)						0.9357
Sa2	0.1444	0.0139	1.155	(1.124, 1.187)	0.000	
Sa3	0.1935	0.0131	1.214	(1.182, 1.250)	0.000	
Sa4	0.0084	0.0141	1.008	(0.981, 1.037)	0.552	
Sa5	-0.0385	0.0173	0.962	(0.930, 0.995)	0.026	
Sa6	0.0723	0.0177	1.075	(1.038, 1.113)	0.000	
Sa7	0.1198	0.0215	1.127	(1.081, 1.176)	0.000	
Sa8	0.2819	0.0561	1.325	(1.188, 1.480)	0.000	
Medcond*Age category (Reference=Ma1)						0.9263
Ma2	0.0388	0.0464	1.040	(0.949, 1.139)	0.402	
Ma3	0.0138	0.0424	1.014	(0.933, 1.102)	0.745	
Ma4	-0.0499	0.0416	0.951	(0.877, 1.032)	0.230	
Ma5	0.0497	0.0417	1.051	(0.969, 1.140)	0.233	
Ma6	0.0523	0.0398	1.054	(0.975, 1.139)	0.189	
Ma7	0.1026	0.0413	1.108	(1.022, 1.201)	0.013	
Ma8	0.2150	0.0674	1.240	(1.086, 1.415)	0.001	
Sex*medcond	0.9490	0.0210	1.100	(1.055, 1.146)	0.000	0.9261

By comparing models with added interaction terms, the interaction terms Restric*sex, Restric*locat, Restric*medcond, Sex*Age category, Sex*medcond and Medcond*Age category were found to be statistically significant. (Table 13) However, it should be noted that the Pseudo R^2 values do not change considerably with addition of these interaction terms except for Sex*Age category which increases the pseudo R^2 value by greater than 1% from 0.9256 to 0.9357. Therefore the most parsimonious model will include the main effects model with the interaction term Sex*Age category. (Table 14)

Table 14: Final model to predict "at-fault" crashes comparing drivers with any type of driving restriction to drivers without driving restrictions

Variable	Incidence Rate Ratio	95% Confidence Interval
Any License Restriction	0.921	(0.890, 0.952)
Female Gender	0.460	(0.451, 0.469)
Urban Location	1.379	(1.368, 1.391)
Medical Condition	1.277	(1.247, 1.308)
Age 16-24 (reference)	1.000	
Age 25-34	0.801	(0.788, 0.814)
Age 35-44	0.913	(0.899, 0.927)
Age 45-54	1.053	(1.036, 1.070)
Age 55-64	0.768	(0.753, 0.783)
Age 65-74	0.764	(0.749, 0.779)
Age 75-84	0.881	(0.861, 0.901)
Age Greater than 85	0.899	(0.856, 0.945)
Female Gender* Age 16-24 (reference)	1.000	
Female Gender* Age 25-34	1.155	(1.124,1.187)
Female Gender* Age 35-44	1.213	(1.183, 1.245)
Female Gender* Age 45-54	1.008	(0.981, 1.037)
Female Gender* Age 55-64	0.962	(0.930, 0.995)
Female Gender* Age 65-74	1.075	(1.038, 1.113)
Female Gender* Age 75-85	1.127	(1.081, 1.176)
Female Gender* Age >85	1.326	(1.188, 1.480)

3.4.2 Summary of Multivariate Poisson Regression Models

Six multivariate Poisson regression models, similar to the above, were constructed to explain "at-fault" crash rates and traffic violation rates for Saskatchewan drivers. For both the crash rate and traffic violation rate models, three models were developed where the type of driving license restriction was any type of restriction, a driving restriction or licensing restriction. (Multivariate Poisson regression models 2 to 6, Appendix J) From the univariate analysis with the independent variables, all independent variables were found to contribute significantly to each model and therefore all were included in the main effects models. For each conviction rate model, the pseudo R^2 value was greater than 99.5% and no interaction terms were found to contribute substantially to the models. (Table 15) For each of the "at-fault" crash rate models, the pseudo R^2 was again high at greater than 93.5%, however the interaction term combining sex and age category did contribute to the models by increasing the pseudo R^2 value by greater than 1%. Although the pseudo R^2 values for each model were large, the Chi square test for goodness of fit for all models of convictions and "at-fault" crashes remained significant for the final models, suggesting that a statistically important portion of the information remained unexplained for these models.

Table 15: Summary table of six multivariate Poisson regression models for "at-fault" crash rates and traffic violation rates of Saskatchewan drivers with and without different types of driving restrictions

Model Outcome Measure	Model Restriction variable	Independent variables	Interaction Terms	Adjusted IRR's (95% CI)	Pseudo R^2
1. Crash rate	All restrictions	Age category, driving restriction, sex, residence location, presence or absence of medical condition	Sex*Age category	0.92 (0.89, 0.95)	0.9357
3. Crash rate	Driving restriction	Age category, driving restriction, sex, residence location, presence or absence of medical condition	Sex*Age category	1.06 (0.98, 1.14)	0.9402
5. Crash rate	Licensing restriction	Age category, driving restriction, sex, residence location, presence or absence of medical condition	Sex*Age category	0.93 (0.90, 0.96)	0.9364
2. Traffic violation rate	All restrictions	Age category, driving restriction, sex, residence location, presence or absence of medical condition		0.87 (0.85, 0.90)	0.9951
4. Traffic violation rate	Driving restriction	Age category, driving restriction, sex, residence location, presence or absence of medical condition		0.94 (0.89, 1.00)	0.9955
6. Traffic violation rate	Licensing restriction	Age category, driving restriction, sex, residence location, presence or absence of medical condition		0.86 (0.83, 0.88)	0.9951

3.5 Time Series Analysis: Autoregressive Integrated Moving Average (ARIMA) Models: Objective 2

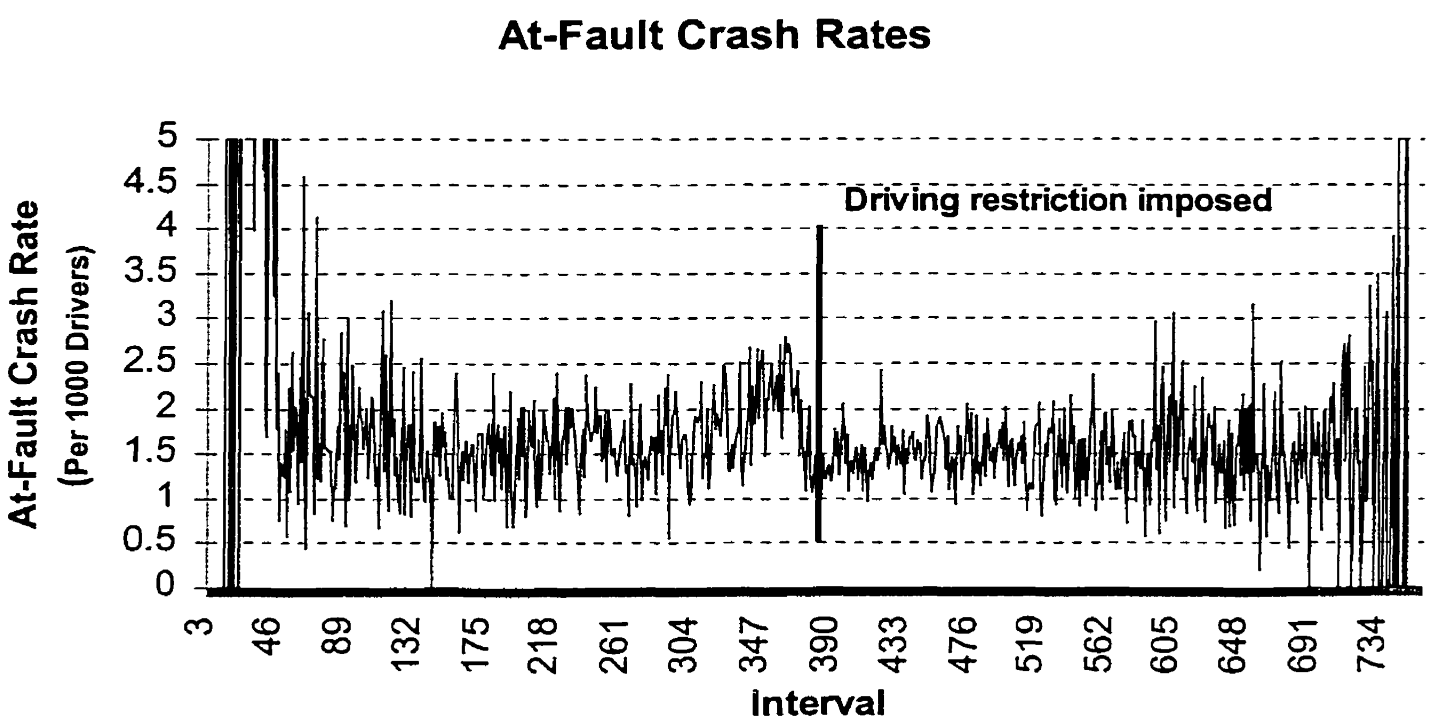
Crude comparisons of "at-fault" crash rates before and after the driving restriction interventions are presented in Table 16. Comparison of driving records for drivers pre and post imposition of a driving restriction demonstrated a decline in the incidence rate for both "at-fault" crash rate and traffic violation rate for each type of restriction imposed. It is inappropriate to conduct a test of statistical significance of these differences, because of the lack of independence between the before and after figures.

Table 16: The effect of imposition of a driving restriction on drivers determined by comparing pre and post "at-fault" crash and conviction rates

Restrictions	Incidence Rate Pre-Restriction (per 100 person-years)	Incidence Rate Post-Restriction (per 100 person - years)	Incidence Rate Ratio	95% Confidence Intervals
Crash / All Restrictions	9.2	7.6	0.828	(0.798, 0.860)
Crash / Driving Restrictions	12.5	8.0	0.637	(0.576, 0.7050
Crash/ Licensing Restrictions	9.1	7.8	0.850	(0.819, 0.883)
Convictions/ All Restrictions	11.7	10.2	0.867	(0.840, 0.8960
Convictions/ Driving Restrictions	18.9	14.5	0.769	(0.711, 0.832)
Convictions/ Licensing Restriction	11.1	9.4	0.845	(0.816, 0.874)

3.5.1 Interventional Time Series ARIMA model for "at-fault" crashes pre and post driving restrictions

The plot of the time series analysis for drivers with any type of restriction (Figure 6) demonstrates instability at the extremes of the plot, due to the small number of drivers in the denominator of the ratio. Due to this instability all ARIMA models were based only on interval 172 to 588 (8 year span). A gradual increase in "at-fault" crash rate is noticeable prior to the intervention point. A slight decrease in the crash rate occurs immediately before the intervention. The best ARIMA model (1,1,1) (Appendix L) provided a reasonably good description of the data. Differencing was implemented initially since a trend was noted prior to the intervention. A single MA term was added to the model since the lag 1 autocorrelation was negative. The lag 6 and lag 12 q statistics were not signficant (0.572 and 0.176 respectively) suggesting a reasonable fit of the model. The coefficient for the restriction variable was -0.505 with a t ratio of –3.63. This coefficient represents a significant decrease in the "at-fault" crash rate of 0.505 crashes per 1000 drivers per week or approximately 2.6 crashes per 100 person-years



driving.[92]

Figure 6: Time series plot of "at-fault" crash rates for drivers pre and post restriction over an 8 year time span

Time series ARIMA models were also constructed for drivers with driving and licensing restrictions specifically. (Appendix K) The same time interval were used for these models and once again as can be seen on the time series plots, the rates are unstable at the extremes of the intervals. The Model fit for driving restrictions was a (3-6,0,5) model and the fit was acceptable since the lag 6 and lag 12 *q* statistics were not significant. The coefficient for driving restriction was -0.76 with a *t* ratio of -4.53 once again demonstrating a significant drop in the "at-fault" crash rate. The licensing restriction model (0,1,1) had a better fit with no significant lag *q* statistics, however, the coefficient for licensing restriction was smaller at -0.45, but still significant (t =-2.44).

3.5.2 Interventional Time Series ARIMA model for convictions pre and post driving restrictions

The time series plot for driving conviction rates pre and post any restriction demonstrates a trend for decreased convictions after restriction. (Figure 7) The ARIMA model (5,0,1-2) provides a good fit of the data, as indicated by the lag 6 and lag 12 *q* statistics (0.613 and 0.343 respectively). The model coefficient (-0.20) reveals a significant decrease (*t* ratio -3.51) indicating that the conviction rate decreases by 1.0 convictions per 100 person-years driving.

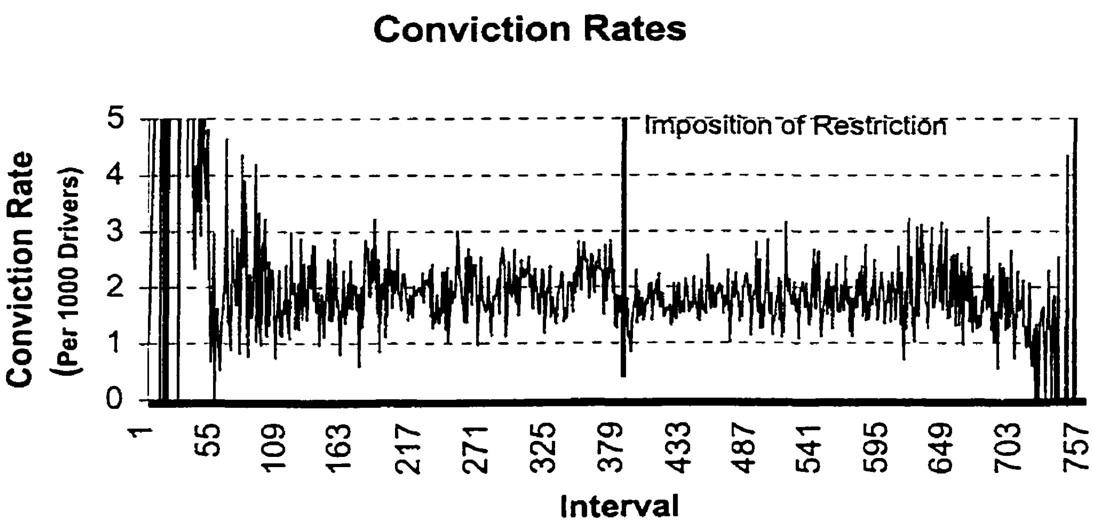


Figure 7: Time series plot of conviction rates for drivers pre and post restriction

The time series plot for those with driving restrictions does not reveal any obvious trends for conviction rate following implementation of the restriction. (Appendix K) However, on the time series plot for licensing restriction there is a noticeable decrease in the conviction rate after the intervention. The ARIMA models for driving restriction (3,0,2) and licensing restriction (5,0,1-2) were each satisfactory with non-significant lag 6 and lag 12 *q* statistics. The driving restriction intervention was not significant for reducing conviction rate (t ratio -1.09), however the licensing restriction intervention was significant (-3.49) for reducing conviction rate with an effect of 1 conviction per 100 person-years of driving.

Chapter 4: Discussion

4.1 Summary of Results

This retrospective cohort study revealed that drivers with either a driving or licensing restriction had unadjusted "at-fault" crash rates higher (7.6 per 100 person-years) than the general population with class 5 driver licenses (6.4 per 100 person-years). Unadjusted traffic violation rates for drivers with restrictions were lower (10.2 per 100 person-years) than the general population (16.4 per 100 person-years). However, when multivariate Poisson regression models were used to control for independent variables, drivers with either a driving or licensing restriction were found to have a lower relative risk for "at-fault" crashes (0.92, 95% confidence interval 0.89 to 0.95) compared to drivers without restrictions. The relative risk for traffic violations remained lower for drivers with restricted licenses (0.87, 95% confidence interval 0.85 to 0.90) after controlling for independent variables in multivariate Poisson regression models. Time series analysis demonstrated a significant reduction in "at-fault" crash and traffic violation rates following the imposition of driving or licensing restriction.

4.2 Demographics

Of the 703,758 Saskatchewan drivers who were eligible for this cohort study, 23, 185 of these drivers had a driving or licensing restriction at some point in the greater than 7 years of follow-up that this study spans. There are relatively more rural dwelling drivers with restricted licenses compared to urban dwelling residents. This may be due to the fact that public transportation systems are better developed in urban centres and therefore drivers who would require a restricted license to drive are more likely to access these systems to maintain community mobility. It may be expected that driving conditions in urban centres are more demanding due to complexity of routes and density of traffic, and that restricted licenses are therefore less likely to be granted for driving environments that would be at increased risk for drivers with limited capabilities.

For this study there were slightly more female drivers than male drivers in the general population, in contrast to restricted drivers where there was a preponderance of male drivers (61.5%). It might be expected that there are more male drivers than female drivers in the population, but in this study all drivers with a license class higher than a general license (120,808) were excluded from the comparison control population. Although the demographic of these excluded drivers was not examined, it is likely that the majority of these drivers were male since a higher class of license is required for commercial drivers and most commercial drivers are male. (Appendix A) For this study, these drivers were excluded, since driving and licensing restrictions would not be applicable to commercial (higher license class) drivers, and the "at-fault" crash and traffic violation rates has been shown to differ between class 1 and class 5 drivers in Saskatchewan [4].

The frequency of drivers by age category followed a predictable pattern for the reference population with more drivers in the 25 to 44 year old age range and fewer drivers in the younger and older age categories. As would be expected, restricted licenses are skewed toward the older age categories, and are in fact greatest (20.8%) for the 75 to 84 year old age category. The identification of a medical condition behaves similarly to age category with only 0.5% of the population without any type of restriction having an identified medical condition versus 90% of drivers with a driving or licensing restriction. This high rate of identified medical conditions is anticipated, since the driving and licensing restriction designations are based on the premise of medical conditions and associated physical and cognitive impairments that may affect driving ability.

The outcome measurements for this study were crash rate and traffic violation rates, which have been routinely used in the driving literature to compare driving populations and evaluate interventions designed to influence crash rates. [8,27,50,56,57,72-74,83,93-95] The frequency distributions of "at-fault" crashes and traffic violations for individual drivers appear to follow a Poisson distribution for the control population as well as for drivers with driving and licensing restrictions (Figures 4 and 5). The Poisson distribution is recommended for use to analyze data when the outcome variable is discrete as with the outcome measures "at-fault" crashes and traffic violations in our study. [87,88] In this study the basic assumptions required to use Poisson regression are met. Clearly "at-fault" crashes occur independently for different drivers and for the same driver at different points in time. The likelihood of an "at-fault" crash is proportional to the number of drivers studied and the risks for crash are relatively homogeneous across people and time. For example, a poor driver remains at the same risk of further crashes since driving ability is unlikely to change as a result of previous crashes or time. Traffic violations as an outcome measure, also meet these assumptions, however, the possibility of simultaneous violations as the result of one incident is greater than for crashes (eg. a driver may be charged with more than one offence for a single driving incident). Support for assuming a Poisson distribution comes from previous studies that have successfully used Poisson regression analysis to model crash rates and traffic violation rates. [27,62,74,75]

The unexposed population for this study appears to reflect a general population of drivers with class 5 (general licenses). The exposed population, drivers with driving and licensing restrictions, has anticipated differences in age category, gender, residence location and presence of identified medical conditions, supporting the need for control of these variables in order to make meaningful comparisons with regard to the effectiveness of restricted licensing.

4.3 Incidence Rates

4.3.1 "At-fault" Crash Rate

For drivers with either driving or licensing restrictions, the unadjusted "at-fault" crash rates were higher than those of the unrestricted population. Although driving and licensing restrictions are quite different in nature, in that a driving restriction puts direct limitations on the driving task compared to scheduled assessments for licensing restrictions, the incidence rates for any restriction, driving restriction and licensing restriction were quite similar. There was a marked difference in incidence rate for gender with males demonstrating twice the crash rate of females. The increased crash rate for males has been shown in previous studies [56,83,96] and holds even after increased driving exposure for males has been accounted for.[56] The incidence rate for rural drivers was lower than for urban drivers. This result is not unexpected since drivers in rural regions are likely to experience conditions quite distinct from urban drivers where there is a higher density of traffic and increased frequency of intersections. The increased incidence rate of "at-fault" crashes for drivers with identified medical conditions is consistent with previous literature identifying medical impairments as affecting the ability to drive.[7,42,48,50,62,66,97-99]

In this study age category and "at-fault" crash incidence rate does not demonstrate the typical "U"-shaped pattern where older and younger drivers have higher crash rates compared to middle aged drivers. [57,72,96] In fact, drivers in the 45 to 54 year old age group have an "at-fault" crash rate very similar to the youngest and oldest age groups. The increased crash rate for younger drivers has been explained by increased risk taking behaviors and inexperience, whereas for older drivers, increasing frequency of medical problems and physiologic changes related to aging have generally been proposed as explanations for increased crash rates. [72,100] The explanation for increased crash rate for drivers in the 45 to 54 year old age group in this dataset is not obvious. One explanation may be related to the likely increased amount of driving exposure for this group compared to the younger and older age groups which in other studies have been shown to drive less frequently. [101] Since this study is retrospective, actual driving exposure is not available and cannot be controlled for in any groups

4.3.2 Traffic Violation Rates

The incidence rate for traffic violations is actually lower for drivers with driving or licensing restrictions compared to the control population. The lower incidence rate is more marked for drivers with licensing restrictions than for those with driving restrictions. As with "at-fault" crash rate there is a striking difference in traffic violation incidence rates comparing men (25.2 per 100 person-years) and women (8.3 per 100 person-years). Driving exposure is again the most likely explanation for the difference in rates between men and women.[56] A second factor may be increased risk taking behaviour in men compared to women, which has been documented in relation to driving.[102]

Incidence rate trends for traffic violations were similar to those found for "at-fault" crash rates when residence location is considered. Rural drivers had a lower rate compared to urban drivers. Decreased complexity of driving as well as decreased likelihood of observation of violation may contribute to this lower rate. Presence of an identified medical condition also was associated with a lower traffic violation rate.

There is an evident inverse relationship between age and traffic violation rates. The most plausible explanation for this effect of age is due to increased risk taking behavior, which has been shown to be highest in young, single males. [102] Increased driving exposure is not a likely explanation for this trend, since younger drivers tend not to have the highest driving exposure compared to middle aged drivers.[56]

4.4 Comparison of restricted versus non-restricted drivers: Objective 1

4.4.1 "At-fault" crash rates

Stratified comparison of "at-fault" crash IRR's for restricted and non-restricted drivers by age category, gender, and residential location did not demonstrate substantial confounding or effect modification. However, effect modification was demonstrated when presence or absence of an identified medical condition was used. When all drivers with an identified medical condition are compared, the relative risk for drivers with a restricted license is actually lower (0.89; 95% confidence interval 0.85 to 0.92). In contrast, for all drivers without an identified medical condition the relative risk is significantly higher for those drivers with a restricted license (1.29; 95% confidence interval 1.19 to 1.39). This effect modification indicates that an interaction term containing restriction and medical condition needed to be considered for inclusion in further multivariate analysis. Although this term was statistically significant, it did not contribute much information to the final model and was therefore not included. It is possible that these drivers may have been identified in another manner, such as poor driving record, since unlike the majority of drivers with restricted licenses, these drivers have no identified medical condition.

Each of the three multivariate Poisson regression models included all independent variables in this study as well as the interaction term comprising age category and gender. For prediction of "at-fault" crash rate, all independent variables contributed significantly to each model except in the model for drivers with a driving restriction, where the relative risk for "at-fault" crash with a restricted license was not significant. (In fact, in the two models including either any restriction or only a licensing restriction, the relative risk for drivers with restriction is significantly lower compared to drivers without restriction.) Controlling for gender, age category, absence or presence of a medical condition and residential location changes the "at-fault" crash crude relative risk for any restriction from 1.19 (95% confidence interval 1.16 to 1.22) to a relative risk of 0.92 (95% confidence interval 0.89 to 0.95). The only interaction term providing a substantial contribution to the model was the term combining gender and age category. As postulated in the model building, this interaction term likely affects crash rate since there is a disparity in crash rate for male and female drivers and (although not shown in this study) older drivers are more likely to be male and have higher crash rates than middle aged drivers.

There is relatively little literature evaluating the impact of restricted licensing, and the few available studies all date back to the 1960's and early 1970's. One of the first studies to investigate chronic medical conditions and their effect on driving was a California based case control study completed by Waller et al[96]in 1965. In this study they were able to estimate driving exposure and provided crash and violation rates in relation to miles driven, versus person-years of driving as in our study. These authors found much higher crash and violation rates for drivers with chronic medical conditions compared to a sample from the general driving population. Due to reporting laws at that time, there was a bias towards including drivers with substance abuse problems and alcoholism, which were excluded from the current study. Epilepsy was also prevalent in the study population since it was the only mandatory reported medical condition at that time. A study by Trenton et al[93] in 1973 looked at accident and violation rates of drivers in Oklahoma. All disease categories in this study were found to have higher crash rates relative to other drivers in Oklahoma, however the only factor controlled for in this study was sex. These study results are in contrast to a more recent Canadian case control study that found elderly drivers with chronic medical conditions are not at increased risk of crashes.[58] Drivers in this case control study were identified through crashes and were then compared to controls of same sex, similar age and residence location.

Few studies, however, have directly addressed the effectiveness of restricted licensing programs.[4,83] Crancer et al[83]studied accident and violation rates of medically restricted drivers in Washington State retrospectively from 1961 to 1967. This study reviewed drivers with both driving and licensing restrictions. Licensing restrictions were reported by diagnosis and the authors found that those with heart disease and vision deterioration did not have increased crash or violation rates. Licensing restrictions for drivers with medical conditions including diabetes mellitus, epilepsy, fainting and other conditions did have higher crash and traffic violation rates than a control population, when age and sex were controlled for. Medical driving restrictions were also evaluated, and overall traffic violation and crash rates were increased compared to the control population. However, when stratified by age and sex, women drivers with driving restriction had a higher crash and violation rate whereas men actually had lower rates than controls. The authors were unable to explain their findings. For this study completed in the 1960's, there are likely differences in the restricted driver population compared to those in our current study. The reporting requirements have changed since the 1960's for Washington state[5] and as well disease prevalence has changed with more of a preponderance of chronic medical conditions such as Alzheimer's disease.[84] Also the driving restrictions identified in this study were different from those defined in Saskatchewan. Crancer et al[83] mention that the majority of driving restrictions are related to vehicle modifications, whereas in our study population the majority of driving restrictions involved modifications to driving conditions such as driving only during daylight hours or within a certain radius of the driver's home.

In 1994 Medgyesi and Koch[4] studied the effect of medical impairments on driving for Saskatchewan drivers from 1980 to 1989. This retrospective case control study demonstrated that drivers with licensing restriction for most medical conditions had higher "at-fault" crash rates compared to controls matched for age category, sex, class of license and residence location. Medical conditions associated with higher "at-fault" crash rates included alcohol/drug dependence, cardiovascular disease, cerebrovascular disease, disorders of co-ordination and muscular control, diabetes mellitus, essential hypertension, seizure disorders and visual disorders. These findings are in contrast to the current study findings which have demonstrated that overall Saskatchewan drivers with licensing restrictions (the only type of restriction studied by Medgyesi and Koch[4]) have a lower "at-fault" crash rate than non-restricted drivers, when age category, sex, presence or absence of an identified medical condition and residence location are controlled for.

One explanation for the differences in findings of these two studies is that for the study by Medgyesi and Koch[4] the Traffic Accident Information System (TAIS) dataset was used. (Appendix H) For our current study, the Claims dataset maintained by Saskatchewan Government Insurance was used instead of the TAIS dataset. As outlined in the methods section (section 2.2.7), we found that the TAIS dataset reported far fewer crashes than identified through the Claims dataset. A further limiting feature of the TAIS dataset was that fault was not clearly assigned. Fewer crashes are likely reported in the TAIS dataset due to the requirement of a minimum of $1000.00 damage as a result of a crash. Therefore it is possible that the crashes reported in the study by Medgyesi and Koch[4] would tend to be on average more severe than in our study, since the reporting threshold for the Claims database is lower. We did not rank crash severity in our study due to limitations of data available from the datasets provided. Claims costs were considered as a possible proxy for crash severity, but on discussion with representatives from SGI it became clear that cost is not a good indicator of severity. For instance, any type of claim where personal injury is involved would drive up claims costs regardless of other more pertinent indicators of severity such as fatalities.

Our study design also differed from Medgyesi and Koch[4] in that we used a retrospective cohort design in contrast to a case control design. Our study included all eligible restricted drivers as well as all eligible Saskatchewan drivers with class 5 (general licenses). From this design we were able to determine true relative risks while controlling for similar independent variables. Megdyesi and Koch[4] report "at-fault" and "not at-fault" crash rates, but do not provide odds ratios or relative risk estimates. These study differences suggest why the studies may have shown different results on a similar population with the primary difference being time period.

Although each of the multivariate Poisson regression models for estimating "at-fault" crash rates yielded a Pseudo R^2 value of at least 0.936, representing good explanatory power of the model[88], the Chi square test for goodness of fit for each model remained significant. This could possibly indicate that the data are not necessarily Poisson distributed. However we believe that in fact the data are largely Poisson distributed, but as a result of the large size of the dataset, small differences are statistically significant. Although further interaction terms could have been added to the models since they made a statistically significant contribution, they did not substantially change the Pseudo R^2 value.

4.4.2 Traffic Violation Rates

Stratified comparison of traffic violation rates for restricted and non-restricted drivers by gender and residential location did not demonstrate substantial confounding or effect modification. Age category is clearly a confounder when comparing traffic violation rates of restricted versus non-restricted drivers. When age category is controlled for the combined Mantel-Haentzel incidence rate ratio is 1.01 compared with a crude IRR of 0.62. The combined and crude estimates differ since younger age categories have higher violation rates, but are less likely to have restricted licenses. Waller et al demonstrated a similar trend for increased traffic violation rates for younger drivers, however, they showed that the rate actually increased for drivers over 60 when driving exposure was accounted for.[96] Age category was controlled for, as with all independent variables in the multivariate Poisson regression models.

The three multivariate Poisson regression models developed to describe traffic violation rates for drivers with driving restriction, licensing restrictions or either restriction represent an excellent fit to the data, with a Pseudo R^2 value of 0.995. Each model contains the independent variables used in this study including age category, gender, residence location, presence or absence of a medical condition and type of restricted driver's license. No interaction terms were found to contribute substantially to the models, since the Pseudo R^2 value did not change demonstrably. When independent variables are controlled for, the IRR increases from the crude/ unadjusted relative risk of 0.62 (95% confidence interval 0.61 to 0.63) to 0.87 (95% confidence interval 0.85 to 0.90). Drivers with a restricted license are thus less likely to have a traffic violation than drivers without restriction.

Traffic violation rates have been used as outcome measures in other studies assessing the impact of chronic medical conditions and restricted licenses on driving,[50,83,93,96] although, the usual primary outcome is crash rate. Traffic violations may not be as good a proxy measure of driving ability as "at-fault" crashes, since clearly all drivers wish to avoid a crash. Contrary to this, many drivers volitionally decide to break the law by speeding or completing driving infractions, which unless caught may not have negative consequences. This is reflective of risk taking behaviour, which although it has been shown to put a driver at increased crash risk[102], does not necessarily represent driving ability.

Most studies that have looked at traffic violation rates have shown an increased rate for drivers with chronic medical conditions.[83,93,96] As for crash rate, Waller [96]identified an increased traffic violation rate for drivers with chronic medical conditions when miles driven were controlled for. Trenton et al[93] published similar findings. Grancer et al[83] also found that Washington State drivers with licensing restrictions had increased traffic violation rates relative to controls. For drivers with driving restrictions men were found to have lower rates than a comparison population, but as with crash rate, women with driving restrictions had a higher traffic violation rate.

4.5 Impact of initiation of driving and licensing restrictions: Objective 2

4.5.1 Conviction and "At-fault" Crash rates

Objective 1 for this study investigated the "at-fault" crash and violation rates for drivers with restrictions compared to the general population. Although it is clear from the results that drivers with a restriction have either a decrease or no difference in relative risk for "at-fault" crashes, no information is provided with regards to the effect of the imposition of the driving or licensing restriction in individuals. When comparing the crude, pre and post conviction and "at-fault" crash rates, there appears to be a dramatic drop in crash rate, as well as conviction rate following the imposition of a restriction. The impact was largest for drivers with driving restrictions who prior to the restriction had a high "at-fault" crash rate of 12.5 per 100 person-years, which decreased to 8.0, however this change may certainly have been biased by events that led to the restriction.

Medgyesi and Koch[4] also studied "at-fault" crash rate for drivers with licensing restrictions in Saskatchewan from 1980 to 1989. In this case control study, they were able to demonstrate similar improvements in crash rates with imposition of a licensing restriction for medical impairments.

4.5.2 Time Series Analyses

Evaluation of the effect of restricted licensing as an intervention cannot be completed using multivariate regression methods or categorical analysis since these types of analyses require that the assumption of independence be met. However, in contrast to this, time series analysis actually is based on autocorrelation of sequential, dependent observations.[90] This dataset is especially suited for time series analysis since the time period analyzed is greater than seven years and, as well, time series analysis has frequently been used to evaluate community wide interventions.[77,90,103,104]

All ARIMA models demonstrated a significant impact of restricted licensing for reducing "at-fault" crash and conviction rates. On examination of the plots, there is a general tendency for increasing rates of "at-fault" crash and conviction rates as the intervention interval is approached. This is likely reflective of both an aging effect with advancing time as well as possible deterioration of physical and cognitive health which is the likely precursor to the need for a restricted license. Another possibility for the higher "at-fault" crash rate in the pre restriction group could have been that drivers were identified for restriction through their crash or traffic violation record. This could also account for higher crash rate trend. However, on discussion with personnel at SGI, it appears that most drivers with restrictions are not identified in this manner, but through personal medical information provided on annual renewal of driver licenses and through physician reporting.

The time series plots also show a reduction in crash and conviction rates just prior to the actual intervention interval. There may be several possible explanations for this. It is possible that either an acute illness or negative driving event may have caused drivers to refrain from driving and therefore decrease their exposure to risk. It is also possible that drivers may have been notified of their change in driving status prior to entry of information into the computer database.

Clearly, restricted licenses have an impact on crash and conviction rates for drivers with medical disability. From the analysis, however, drivers with a driving restriction have a more significant drop in the "at-fault" crash rate. This difference could be a result of the general difference between driving and licensing restrictions. For instance a driving restriction may actually limit the driving task to the true ability of the driver with limitations, whereas a licensing restriction serves only in a monitoring capacity, allowing drivers to continue to drive in higher risk situations. However, the method by which restricted licensing is effective in improving the "at-fault" crash and conviction rates could not be explored in this study. A likely possibility is that once drivers have been formally informed of a concern about their driving ability, they change their driving pattern either by driving more cautiously or by driving less frequently, which will decrease exposure risk to crashes.

No previous studies have examined restricted licensing using time series analysis methods. However, time series analysis has been used successfully to assess traffic violation and crash rates following introduction of new driving laws and programs.[77,103] Voas et al[103] successfully used time series analysis to evaluate a state level initiative to reduce unlicensed driving. This study used "zebra"/ striped stickers for licence plates of persons with suspended licenses. This study revealed the new program had significant effects on violation rates, which the authors believe to reflect behaviour, but crash rates did not change. Hagge and Romanowicz[77] evaluated the California driver license program using an interventional time series approach. In this well designed study, the authors found that the introduction of the driving program had no significant impact on crash rate. In contrast to our study, each of these studies had to contend with seasonality, since crashes are more likely to occur at different times of year. In this study, seasonal trend for crashes appears to have been averaged out since drivers would have individual start dates, which had to be adjusted for by setting all drivers to a common interval for restriction start date.

4.6 Study Strengths and Weaknesses

This study has a number of strengths that allow the results to be of value for evaluating the effectiveness of restricted licensing for drivers with medical impairments. The SGI datasets included all drivers in the province of Saskatchewan. The data provided seven years of follow-up for most Saskatchewan drivers and when the datasets were linked few errors or missing values were encountered. The data also clearly identified dates of violations and crashes so that pre and post driving and licensing restriction comparisons could be made by using interventional time series analysis. The province of Saskatchewan also provided an ideal setting for the evaluation of restricted licensing, since this practice is encouraged compared to other provinces such as Ontario where restricted licensing in not endorsed.[5]

Since the study design was a retrospective cohort study, relative risks for drivers could be determined. The discrete outcomes and the ability of the data to be converted to person-years of driving exposure, allowed for multivariate Poisson regression modelling to control for independent variables and their effect on "at-fault" crash rate and traffic violation rate.

As with any study, there were also significant limitations present. One of the primary weaknesses of this study was the inability to control for driving exposure which is likely to be less for drivers with restrictions. With regards to residence location, only the residence location on the date the datasets were created was available. It was therefore possible for a driver to have driven greater than 6 years in a rural location, only to have it attributed to urban driving as a result of a recent move. The severity of the "at-fault" crashes was also not available. Certainly the severity of the crash could influence the interpretation of the results of the study, since in essence these are the events of consequence which are most concerning to society. In this study, specific driving and licensing restrictions as well as specific medical diagnoses were not explored, since the objective was to evaluate the restricted licensing process for all conditions combined. Therefore, the effectiveness of restricted licensing at the individual level cannot be estimated.

The method of identification of drivers for medical conditions and restrictions is not known and this bias, as discussed above, may have influenced the results. Also, since compliance with restrictions was not monitored, we cannot be assured that the results are truly due to the imposed restrictions.

4.7 Implications for Future Research

Restricted licensing for medical impairments appears to be an effective intervention. However, the reasons why it is effective remain unproven. Further prospective study will be required to determine what specific factors lead to the decreased "at-fault" crash and traffic violation rates. A prospective study would also allow assessment of driving exposure, which would then provide a true, time-based estimate of crash and violation risk. Clearly the specific driving and licensing restrictions each need to be evaluated as well as specific medical diagnoses / impairments and their differing responses to restricted licensing. This was further supported by clear differences in rates between urban and rural dwelling residents. Since in our study we were able to show that "at-fault" crash rates and traffic violation rates were high prior to intervention, further study of the appropriate timing and methods of identification of who would benefit from restricted licensed is required.

Chapter 5: Conclusions

There has been little previous study of the effectiveness of restricted driver licensing for medical conditions, even though many jurisdictions in North America offer this solution for drivers who may have impaired driving ability. We have shown that Saskatchewan drivers with restricted licenses secondary to medical impairments have similar or decreased "at-fault" crash rates and traffic violation rates compared to other Saskatchewan drivers with class 5 (general licenses) when controlled for age category, gender, absence or presence of an identified medical condition or residence location. The imposition of a driving or licensing restriction results in a decreased rate for "at-fault" crashes and traffic violations. These results suggest that restricted licensing appears to be an effective intervention for allowing persons with medical conditions to continue driving under certain circumstances. Further study is required to determine what specific types of restrictions are most effective for various medical conditions and the point in time at which the restrictions should be implemented.

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Appendices

Appendix A: Classes of Driver's Licenses

Class	Driving Privileges
1	. motor vehicles in classes 1, 2, 3, 4 and 5;
2	. motor vehicles in classes 2, 3, 4 and 5; . motor vehicles in class 1 as a learner with endorsement 1;
3	. motor vehicles in classes 3, 4 and 5; . motor vehicles in classes 1 and 2 as a learner with endorsement 1 or 2 (resp.);
4	. motor vehicles in classes 4 and 5; . motor vehicles in classes 1, 2 and 3 as a learner with endorsement 1, 2 or 3 (resp.);
5	. motor vehicles in class 5; two–axle farm trucks which have a trailer(s) or a vehicle(s) in tow, where the gross weight of the towed unit(s) exceeds 4600 kg; three–axle farm trucks which have a trailer(s) or a vehicle(s) in tow, where the gross weight of the towed unit(s) does not exceed 4600 kg; . motor vehicles in classes 1, 2, 3 and 4 as a learner with endorsement 1, 2, 3 or 4 (resp.)
6	. motor vehicles in class 6 . motor vehicles in class 5 as a learner
7	. motor vehicles in class 5 as a learner . motor vehicles in class 6 under certain circumstances with appropriate endorsement

Appendix B: SGI Driver Summary Sheet (Restriction Codes)

CC APPEAL IND.

- b - No appeal
- A - Appeal withdrawn
- C - Crown won
- L - Lost
- P - Pending
- S - Sentence
- W - Won

DRIVER S/C APPEAL

- b - No appeal
- A - Appellant withdrew
- D - Dropped by SAF
- F - Forgiven (waived)
- P - Pending
- W - Appellant won
- L - Appellant lost

CANCELLATION REASONS

- 1 - No longer wishes to drive, or licence canceled or revoked due to age, illness or physical, mental or emotional disability
- 2 - Moved
- 3 - Death
- 4 - Other
- 5 - Licence Issued in error (full refund)
- 6 - Driver Noncompliance
- 7 - Restricted licence no longer required due to DWI course
- 8 - Driver Education Drop-out

CLAIMS A/R CODES

- 1 - Not responsible
- 2 - Over 50%
- 3 - Undecided
- 4 - Under 50%

CLAIMS TRANSACTION TYPES

- D350 - Add/Change accident (Claims)
- D351 - Delete accident (Claims)
- D352 - Change accident appeal indicator (SAF)

DRIVER INFORMATION

Class	Minimum Age	Eye Colour
1	18	1 - Blue
	18	2 - Brown
	18	3 - Green
4	18	4 - Grey
5	16	5 - Hazel
6	16	9 - Other
7	A. 16 with parental signature	
7	B. 15 with i) parental signature ii) principal signature iii) training code 'A'	

DRIVER STATUS CODES

- AA - Active
- AI - Renewal Issued
- AX - Renewal Issued/reassessment required
- AZ - Renewal Issued/new certificate required
- IC - Inactive canceled
- NI - Renewal not issued
- SR - Special restricted
- SC - Special restricted cancellation
- bb - No drivers licence

DRIVER SUSPENSION REASON CODES

- A - Judgment
- B - Consent and undertaking
- D - Habits and conduct
- E - Driver examination
- F - Medical
- G - Interview on driver record
- H - 24 Hour
- I - 30 day / Administrative Extension
- J - Out-of-province suspension
- M - Roadside Administrative
- N - Unpaid fine
- P - Maintenance Support
- Q - Addictions Screening (Roadside)
- R - Licence refusal
- S Recovery Program
- T Addictions Screening (CC)
- W - DWI (Driving Without Impairment)

EFFECTIVE DATE OF RATE CHANGES

- Dec. 1982 - Apr. 1985 10 - 15
- May. 1985 10 - 0
- Oct. 1987 20 - 0 $10. (Jan 1/88 and
- Apr. 1993 25 - 0 later)

ENDORSEMENT CODE

- A - Air brake
- M - Motorcycle
- S - School bus
- 1 - Learners for Class 1
- 2 - Learners for Class 2
- 3 - Learners for Class 3
- 4 - Learners for Class 4
- 6 - Learners for motorcycle

DRIVER RECORD TX TYPES

- D400 - Add VA, BL, OP, or HT
- D401 - Change VA, BL, OP, or HT
- D402 - Delete VA, BL, OP, or HT
- D410 - Add CC or CP
- D411 - Change CC or CP/Pending CC Appeal
- D412 - Delete CC or CP
- D420 - Add manual suspension
- D421 - Change manual suspension
- D422 - Delete manual suspension
- D430 - Add exam information
- D431 - Change exam information
- D432 - Delete exam information
- D440 - Add medical information
- D441 - Change medical information
- D442 - Delete medical information
- D443 - Add Medical History
- D444 - Change Medical History
- D450 - Add training information
- D451 - Change training information
- D452 - Delete training information

JURISDICTION CODES

Province	Code	Convert To
Alberta	A	AB
British Columbia	B	BC
Manitoba	M	MB
New Brunswick	N	NB
Newfoundland	F	NF
Nova Scotia	S	NS
N.W. Territories	T	NW
Ontario	O	ON
P.E.I.	P	PE
Quebec	Q	PQ
Yukon	Y	YU
United States	U	US
Other Country	Z	OS

LENGTH OF PROHIBITIONS

After Jan. 1/88

- 12 months - 25 rating units
- 13 - 36 months - 35 rating units
- 37 - 60 months - 45 rating units

APPLICATION TX TYPES

- D001 - New application/PIC assignment
- D003 - Reinstatement/Amended Renewal
- D005 - Advance issue
- D007 - Class change
- D009 - Endorsement change
- D011 - Restriction change
- D013 - Replacement/Retest
- D015 - Change master file
- D017 - Cancellation
- D025 - Restricted licence
- D036 - Create Master File/Int. Tx's
- D047 - Driver renewal
- D050 - Camera Card
- D600 - Driver tad
- D610 - Delete driver tad

PREMIUMS ACCORDING TO RATING UNITS

Rating Units	Classification	Premium ($)
3 or less	A	Nil
4 - 5	B	$25.
6 - 7	C	$35.
8 - 9	D	$55.
10 - 11	E	$75.
12 - 13	F	$95.
14 - 15	G	$115.
16 - 17	H	$135.
18 - 19	J	$155.
20 - 21	K	$175.
More than 21	M	$175+
Clear year reduces RU's by 33.3% (1/3)	$30. for each additional rating unit over 21	

QUESTIONS

- 1 Revoked or suspended (Y or N)
- 2 Hold valid licence (out of Sask.) (Y or N)
- 3 Physical or mental disability (Y or N)
- 4 Medical disability (Y or N)

RESTRICTION CODE

- A - When wearing prescribed corrective lenses
- B - During hours of full daylight only
- C - Within a 40 km radius of address shown on Lic.
- D - Within 80 km radius of address shown on Lic.
- E - Outside the limit of any city
- F - Equipped with two outside mirrors
- G - Under special conditions recorded on file
- H - Three-wheeled motorcycles only in Class 6
- J - Mopeds only in Class 6
- K - School buses with seating capacity less than 36 passengers
- L - Not to operate Class 2 or 4 vehicles
- M - Automatic transmission in class noted
- N - Automatic transmission in school bus
- X - Annual vision test required
- Y - Annual road test required
- Z - Annual medical examination required

SIGNATURES

- 1 - Applicant Y
- 2 - Parent Y (D001)
- 3 - Principal Y (D001)

TRAINING COURSE CODE

- A - Department of Education
- B - DWI (Driving Without Impairment)
- C - Saskatoon Pre-pilot Project
- D - Commercial
- E - Defensive Driving Course
- P - Probationary Driver
- Q - Addictions screening (Roadside)
- S - Recovery Program
- T - Addictions screening (CC)
- W - Probation Licence (old W restriction)

MISCELLANEOUS TRANSACTIONS

- P010 - 24 Hour Permit
- P020 - 7 Day Permit
- P030 - 14 Day T.I.C.
- P040 - 7 Day T.I.C.
- P050 - Special Use
- P060 - Bulk Permits
- R010 - Driver Test and Exam Receipt
- R020 - Other Receipt
- R030 - Abstract Receipts
- R040 - Add AutoPay Contract
- R050 - Change AutoPay Contract
- R060 - Returned Items Arrears (RIA) Payment
- M010 - Searches
- M020 - Dispute of Accident Surcharge
- M030 - E & H Tax
- * 50 - Snowmobile Application
- M070 - AutoPay Pennies

* code no longer used

Appendix C: Letter of Request to Saskatchewan Government Insurance (SGI)

April 22, 1999

David Koch
Saskatchewan Government Insurance
2260 11th Avenue
Regina, Saskatchewan
S4P 2N7

Dear Mr. Koch:

Re: Research Project - "Evaluation of restricted driver licensing for medical impairments in Saskatchewan"

I am writting this letter to request your co-operation in a research project I will soon be starting. It is designed to evaluate the practice of restricting driver licenses for people with medical impairments in Saskatchewan. This is an exciting project that will: 1) determine if medically impaired Saskatchewan residents granted restricted driver licences have crash and traffic violation rates similar to people with unrestricted driver licenses and 2) determine if initiation of a medical condition code or restricted driver's licence affects either crash or traffic violation rates of individuals with all categories of medical impairments. I believe that this study will benefit SGI since it will provide some feedback and evaluation of your restricted licensing program. For more details, please refer to the attached full research proposal.

I would first like to thank for your assistance in helping to develop this research project thus far. I am a specialist in Physical Medicine and Rehabilitation and I am a member of the Division of Physical Medicine and Rehabilitation in the Department of Medicine at the University of Ottawa. I am completing this research project as part of my requirements for completion of a Master of Science degree in Community Health and Epidemiology at the University of Ottawa. This research proposal has been approved by the Department Graduate Studies Committee. This letter identifies the data required for this study. I have reviewed the variables from your database and have listed the required variables below. I would appreciate your input both regarding these variables and the logistics regarding data transfer. I understand that there will be some preparation time for selecting and organizing the requested data and I appreciate your time and effort in this collaboration. I also understand that since I will be sharing all results as well as my completed thesis with SGI, that there will be no cost to acquire this data.

I am requesting data starting from November 1986, since this is the date when information on medical license restriction dates back to. I am requesting information/data for all persons who have ever had a medical license restriction and all persons who have had a medical indicator code. I would also request information/ data on all other Saskatchewan drivers so that I am able to complete population statistics for all drivers as a comparator as well as identifying matched cases for age, sex and residence location. I would also request that a list of all Saskatchewan drivers who have at some point held a driver's licence that is higher than a class 5 licence (Class 1, 2, 3, 4 or school bus driver endorsement). I understand that you will not be providing me with names, addresses or driver licence numbers, or any other information that would allow me to identify individual drivers; an alias will be included to replace driver's licence number and will allow linkage of all components of the driver's history. The data requested includes the following variables:

SGI Database:

Source Variable List	Variable	Comments
RCTYPE70	DH70MIND	Medical Indicator code
	DH_OCDAT	Occurrence date
	DH70REST	Restriction Code
Customer Database	BIRTHDT	Birth date
	POSTCODE	first 3 characters of the Postal Code
	SEX	Sex
VXCLM1-3	ACC_RESP	Accident Responsibility
	LSS_DATE	Loss date
	COVR_TYP	Type of claim
RCTYPE20	DH20CVCD	Conviction Code
	DH20FAMT	Fine Amount
	DH20OFDT	Offence Date
	DH_OCDAT	Occurrence Date
RCTYPE25	DH25CVCD	Conviction Code
	DH25FAMT	Fine Amount
	DH25JLTM	Jail Term
	DH25OFDT	Offence Date
	DH_OCDAT	Occurrence Date
DRREG	DCANCEL	Cancellation Code
	DEFFDATE	Effective Date
	DEXPDATE	Expiry Date

	DSTATUS	Driver Status
	DCLASS	Licence Class

TAIS Database:

Source Variable List	Variable	Comments
TAIS	Date of Accident	
	Time of accident	
	Number of vehicles	
	Number injured	
	Number killed	
	Accident Severity	
	Total Estimated Damages	
	Road Authority	
	Number of Occupants	
	Lighting	
	Weather Conditions	
	Road Surface conditions	
	Accident site	
	Road Character	
	Road Alignment	
	Traffic control	
	Vehicle identification	
	Pre-Collision Vehicle action	
	Major contributing factors	
	Vehicle damage	
	Location of damage	
	Charges Laid	
	Case Number	
	Vehicle Number	

I realize that this data preparation will take some time on the part of SGI and I appreciate your collaboration. I believe that this retrospective project will provide important preliminary information regarding restricted licensing for medical impairments.

If you have any questions, please do not hesitate to contact me.

Yours sincerely,

Shawn C. Marshall MD FRCPC

The Rēhabilitation Centre
505 Smyth Road
Ottawa, Ontario
K1H 8M2
Tel: 613-737-7350 ext 5590
Fax 613-737-9638
E-mail: smarshal@rohcg.on.ca
cc Cal Reece, Manager Training and Administration, SGI

Appendix D: Original Dataset Descriptions from SGI

```
                         The SAS System        17:22 Friday, April 23, 1999  6

                          CONTENTS PROCEDURE

Data Set Name: EXT_DATA.CUST                      Observations:          1176486
Member Type:   DATA                               Variables:             4
Engine:        V612                               Indexes:               0
Created:       12:49 Monday, April 19, 1999       Observation Length:    23
Last Modified: 12:51 Monday, April 19, 1999       Deleted Observations:  0
Protection:                                       Compressed:            NO
Data Set Type:                                    Sorted:                NO
Label:

              -----Engine/Host Dependent Information-----

           Data Set Page Size:         8192
           Number of Data Set Pages:   3333
           File Format:                607
           First Data Page:            1
           Max Obs per Page:           353
           Obs in First Data Page:     318
           File Name:                  /adhoc/extract/david/cust.ssd01
           Inode Number:               242053
           Access Permission:          rw-rw----
           Owner Name:                 AF5375
           File Size (bytes):          27312128

            -----Alphabetic List of Variables and Attributes-----

     #   Variable   Type   Len   Pos   Format       Informat     Label
     --------------------------------------------------------------------
     4   ALIAS      Num      8    15
     2   BIRTHDT    Num      8     1   YYMMDD10.    YYMMDD10.    birthdt
     3   POSTAL3    Char     6     9
     1   SEX        Char     1     0   $1.          $1.          sex
```

CONTENTS PROCEDURE

Data Set Name:	EXT_DATA.DRREG	Observations:	7234452
Member Type:	DATA	Variables:	6
Engine:	V612	Indexes:	0
Created:	12:48 Tuesday, April 20, 1999	Observation Length:	28
Last Modified:	13:08 Tuesday, April 20, 1999	Deleted Observations:	0
Protection:		Compressed:	NO
Data Set Type:		Sorted:	YES
Label:			

-----Engine/Host Dependent Information-----

Data Set Page Size:	8192
Number of Data Set Pages:	24947
File Format:	607
First Data Page:	1
Max Obs per Page:	290
Obs in First Data Page:	252
File Name:	/adhoc/extract/david/drreg.ssd01
Inode Number:	242060
Access Permission:	rw-rw----
Owner Name:	AF5375
File Size (bytes):	204374016

-----Alphabetic List of Variables and Attributes-----

#	Variable	Type	Len	Pos	Label
4	ALIAS	Num	8	4	
3	DCANCEL	Char	1	3	CANC CODE
2	DCLASS	Char	1	2	CLASS
5	DEFFDATE	Num	8	12	
6	DEXPDATE	Num	8	20	
1	DSTATUS	Char	2	0	STATUS

-----Sort Information-----

Sortedby:	ALIAS
Validated:	YES
Character Set:	ASCII

CONTENTS PROCEDURE

```
Data Set Name: EXT_DATA.CLAIMS                    Observations:         2053207
Member Type:   DATA                               Variables:            4
Engine:        V612                               Indexes:              0
Created:       14:52 Tuesday, April 20, 1999      Observation Length:   19
Last Modified: 14:55 Tuesday, April 20, 1999      Deleted Observations: 0
Protection:                                       Compressed:           NO
Data Set Type:                                    Sorted:               YES
Label:

            -----Engine/Host Dependent Information-----

            Data Set Page Size:         8192
            Number of Data Set Pages:   4809
            File Format:                607
            First Data Page:            1
            Max Obs per Page:           427
            Obs in First Data Page:     384
            File Name:                  /adhoc/extract/david/claims.ssd01
            Inode Number:               242064
            Access Permission:          rw-rw----
            Owner Name:                 AF5375
            File Size (bytes):          39403520

        -----Alphabetic List of Variables and Attributes-----

                #    Variable    Type    Len    Pos
                -----------------------------------
                2    ACC_RESP    Char      1      2
                4    ALIAS       Num       8     11      -
                1    COVR_TYP    Char      2      0
                3    LSS_DATE    Num       8      3

                     -----Sort Information-----

                       Sortedby:      ALIAS
                       Validated:     YES
                       Character Set: ASCII
```

CONTENTS PROCEDURE

Data Set Name:	EXT_DATA.TYPE25	Observations:	129529
Member Type:	DATA	Variables:	6
Engine:	V612	Indexes:	0
Created:	14:25 Monday, April 19, 1999	Observation Length:	43
Last Modified:	14:26 Monday, April 19, 1999	Deleted Observations:	0
Protection:		Compressed:	NO
Data Set Type:		Sorted:	YES
Label:			

-----Engine/Host Dependent Information-----

Data Set Page Size:	8192
Number of Data Set Pages:	686
File Format:	607
First Data Page:	1
Max Obs per Page:	189
Obs in First Data Page:	164
File Name:	/adhoc/extract/david/type25.ssd01
Inode Number:	242062
Access Permission:	rw-rw----
Owner Name:	AF5375
File Size (bytes):	5627904

-----Alphabetic List of Variables and Attributes-----

#	Variable	Type	Len	Pos	Label
5	ALIAS	Num	8	27	
2	DH25CVCD	Char	3	8	25-CONVICTION-CODE
3	DH25FAMT	Num	8	11	25-FINE-AMOUNT
4	DH25JLTM	Num	8	19	25-JAIL-TERM
6	DH25OFDT	Num	8	35	
1	DH_OCDAT	Num	8	0	OCCURRENCE-DATE

-----Sort Information-----

Sortedby:	ALIAS
Validated:	YES
Character Set:	ASCII

CONTENTS PROCEDURE

Data Set Name:	EXT_DATA.TYPE70	Observations:	360085
Member Type:	DATA	Variables:	4
Engine:	V612	Indexes:	0
Created:	13:18 Monday, April 19, 1999	Observation Length:	34
Last Modified:	13:19 Monday, April 19, 1999	Deleted Observations:	0
Protection:		Compressed:	NO
Data Set Type:		Sorted:	YES
Label:			

-----Engine/Host Dependent Information-----

Data Set Page Size:	8192
Number of Data Set Pages:	1507
File Format:	607
First Data Page:	1
Max Obs per Page:	239
Obs in First Data Page:	215
File Name:	/adhoc/extract/david/type70.ssd01
Inode Number:	242065
Access Permission:	rw-rw----
Owner Name:	AF5375
File Size (bytes):	12353536

-----Alphabetic List of Variables and Attributes-----

#	Variable	Type	Len	Pos	Label
4	ALIAS	Num	8	26	
3	DH70MIND	Char	8	18	70-MEDICAL-IND
2	DH70REST	Char	10	8	70-RESTRICTION
1	DH_OCDAT	Num	8	0	OCCURRENCE-DATE

-----Sort Information-----

Sortedby:	ALIAS
Validated:	YES
Character Set:	ASCII

CONTENTS PROCEDURE

```
Data Set Name: EXT_DATA.TYPE20                       Observations:         1024326
Member Type:   DATA                                  Variables:            5
Engine:        V612                                  Indexes:              0
Created:       14:48 Monday, April 19, 1999          Observation Length:   35
Last Modified: 14:51 Monday, April 19, 1999          Deleted Observations: 0
Protection:                                          Compressed:           NO
Data Set Type:                                       Sorted:               YES
Label:

            -----Engine/Host Dependent Information-----

           Data Set Page Size:         8192
           Number of Data Set Pages:   4416
           File Format:                607
           First Data Page:            1
           Max Obs per Page:           232
           Obs in First Data Page:     206
           File Name:                  /adhoc/extract/david/type20.ssd01
           Inode Number:               242059
           Access Permission:          rw-rw----
           Owner Name:                 AF5375
           File Size (bytes):          36184064

         -----Alphabetic List of Variables and Attributes-----

           #    Variable    Type    Len    Pos    Label
           --------------------------------------------------------
           4    ALIAS       Num       8     19
           2    DH20CVCD    Char      3      8    20-CONVICTION-CODE
           3    DH20FAMT    Num       8     11    20-FINE-AMOUNT
           5    DH20OFDT    Num       8     27
           1    DH_OCDAT    Num       8      0    OCCURRENCE-DATE

                    -----Sort Information-----

                      Sortedby:      ALIAS
                      Validated:     YES
                      Character Set: ASCII
```

Data Set Name:	EXT_DATA.TAIS	Observations:	395134
Member Type:	DATA	Variables:	32
Engine:	V612	Indexes:	0
Created:	11:39 Friday, April 23, 1999	Observation Length:	116
Last Modified:	11:40 Friday, April 23, 1999	Deleted Observations:	0
Protection:		Compressed:	NO
Data Set Type:		Sorted:	YES
Label:			

-----Engine/Host Dependent Information-----

Data Set Page Size:	16384
Number of Data Set Pages:	2823
File Format:	607
First Data Page:	1
Max Obs per Page:	140
Obs in First Data Page:	104
File Name:	/adhoc/extract/david/tais.ssd01
Inode Number:	242063
Access Permission:	rw-rw----
Owner Name:	AF5375
File Size (bytes):	46260224

-----Alphabetic List of Variables and Attributes-----

#	Variable	Type	Len	Pos	Format	Informat	Label
8	ACCCOST	Num	8	49	8.	8.	ACCCOST
2	ACCDATE	Num	8	8	MMDDYY8.	YYMMDD8.	ACCDATE
13	ACCSITE	Char	2	62	$2.	$2.	ACCSITE
3	ACCTIME	Num	8	16	8.	8.	ACCTIME
32	ALIAS	Num	8	108			
1	CASENO	Num	8	0	8.	8.	CASENO
30	CHARGES1	Char	2	104	$2.	$2.	CHARGES1
31	CHARGES2	Char	2	106	$2.	$2.	CHARGES2
19	CONTROLS	Char	2	83	$2.	$2.	CONTROLS
26	DAMAGE	Char	1	97	$1.	$1.	DAMAGE
27	DAMLOC1	Char	2	98	$2.	$2.	DAMLOC1
28	DAMLOC2	Char	2	100	$2.	$2.	DAMLOC2
29	DAMLOC3	Char	2	102	$2.	$2.	DAMLOC3
17	HOR	Char	1	81	$1.	$1.	HOR
22	MCF1	Char	2	89	$2.	$2.	MCF1
23	MCF2	Char	2	91	$2.	$2.	MCF2
24	MCF3	Char	2	93	$2.	$2.	MCF3
25	MCF4	Char	2	95	$2.	$2.	MCF4
10	NATLIGHT	Char	1	59	$1.	$1.	NATLIGHT
5	NOINJ	Num	8	32	8.	8.	NOINJ
6	NOKILLED	Num	8	40	8.	8.	NOKILLED
15	NOOCC	Num	8	72	8.	8.	NOOCC
4	NOVEH	Num	8	24	8.	8.	NOVEH

CONTENTS PROCEDURE

#	Variable	Type	Len	Pos	Format	Informat	Label
21	PRECOLL	Char	2	87	$2.	$2.	PRECOLL
9	ROADAUTH	Char	2	57	$2.	$2.	ROADAUTH
16	ROADCHAR	Char	1	80	$1.	$1.	ROADCHAR
12	ROADSURF	Char	1	61	$1.	$1.	ROADSURF
7	SEVERITY	Char	1	48	$1.	$1.	SEVERITY
14	VEHNO	Num	8	64	8.	8.	VEHNO
18	VERT	Char	1	82	$1.	$1.	VERT
20	VIDENT	Char	2	85	$2.	$2.	VIDENT
11	WEATHER	Char	1	60	$1.	$1.	WEATHER

-----Sort Information-----

Sortedby: ALIAS
Validated: YES
Character Set: ASCII

Appendix E: SGI Claim Codes

Clm Cov Desc
01-Weekly Indemnity
02-Death
03-Medical Expenses
04-Funeral
05-Permanent Disablity
07-Extd Weekly Indemnity
11-Bodily Inj to Passengers
12-Bodily Inj to Others
21-PD Auto
22-PD Real Property
23-Loss of Use
31-Collision
32-Comprehensive
33-Glass
41-Fire/Lightning/Explosion
42-Theft
43-Wind/Tornado/Cyclone
44-Hail
45-Flood/Rising Water
46-Water Damage
47-Malicious Mischief/Vandalism
48-Personal Effects
49-Other Comp
51-Upset
52-Falling/Flying Objects
53-Earthquake
54-Riot/Civil Commotion
55-Stranding/Sinking/Derailment
56-Conversion/Embezzlement/Unlawful Secretion
AD-Appeal Legal Disbursements
AL-Appeal Legal Costs
AM-Appeal Mediation Costs
AN-Appeal Mediation Disbursements
CC-Dependant Care
CD-Care of Other Dependant
CH-Home Care
CP-Personal Care
CQ-Personal Care/Out of Home
CZ-Care/No Determination
DA-Death
DB-Education
DC-Dependent Children
DD-Depend-2/Children

DE-Depend/Children/No Spouse
DF-Funeral Benefits
DN-Estate-No Dependents
DS-Spouse
DT-Spouse - 2
DV-Voc Rehab Spouse
IA-Youth/LSB/Elementary
IB-Youth/LSB/Secondary
IC-Reduction/Return to Work
ID-Determined Income-180 days
IE-Excess GYEI
IF-Full Time
IG-F/T Self - Actual
IH-F/T Self - Tables etc
II-10 % Unpaid
IL-Labour Replacement
IN-Non-Earner
IO-Determined Income-Residual
IP-Temp/Part Time
IQ-Temp P/T Self Actual
IR-Temp P/T Self Tables etc
IS-Student/Youth
IT-Student/IRB/IAW
IU-Student/LSB/Secondary
IV-Student/LSB/Post Secondary
IY-Youth
IZ-Youth/IRB/IAW
MA-Ambulance
MB-Vocational Rehab
MC-Chiro Rehab
MD-Drug Rehab
ME-Dental Rehab
MF-Clothing
MG-Secondary Care
MH-Home Renovation
MI-Out of Prov Medical
MJ-Jaws of Life
MK-Medical Funding
ML-Lodging/Meals
MM-Massage
MN-Conditioning Therapy
MO-Other
MP-Physio

Clm Cov Desc
MQ-Lost Wages/Appmts
MR-Medical Report
MS-Psychological Counseling
MT-Travel
MU-Global Fitness
MV-Vehicle Modification
MW-Mobility Aids
MZ-Prosthesis/Ortho/Glasses
PB-Brain Damage/Severe
PC-Brain Damage/Moderate
PF-Loss of Limb Function
PH-Loss of Hearing
PL-Loss of Limb
PO-Others
PP-Paraplegia
PQ-Quadriplegia
PS-Scarring
PV-Loss of Vision
PW-Whiplash
TD-Economic Loss-Death
TI-Economic Loss-IRB
TO-Economic Loss-Other
TL-Out of Prov Liability

Appendix F: SGI Conviction Code Chart

* Shaded ones are convictions which result in a suspension [CC or HTA 89(1) or 40(9)]

600	Operating Unregistered Vehicle
603	Hold More Than One Licence
604	Obscured Vision
606	Enter Prov Highway/Fail to Yield
607	Yield Sign
608	Stop Sign
609	Disobey Traffic Control Device
610	Fail to Stop for Railway Crossing
613	Fail to Stop Bus/Dangerous Goods Vehicle at Railway Crossing
614	Insufficient or No Signal
619	Allow Rider on Exterior of Vehicle
620	Overcrowded Steering Compartment
621	Insecure Load or Unmarked Overhanging Load
622	Headlamps not Illuminated
626	Exceed Speed Limit
628	Speed Too Fast For Conditions
629	Impede Traffic
630	Without Due Care/Reasonable Consideration
631	Following Too Close
634	Improper Lane Use
635	Passing on the Right
636	Cutting In
637	Speeding Up on Being Overtaken
639	Improper Turn
640	U-Turn at Traffic Lights
641	Failing to Yield to Vehicle on Right
642	Left Turn Across Traffic
643	Passing When Unsafe
644	Driving Left of Centre
645	Driving Contrary to Sign Direction
646	Fail To Yield To Pedestrian
647	Contest of Speed
648	Fail To Report Accident
649	Straddling Lanes
650	Cross Solid Lines
652	Drive Over Median
653	Enter or Leave Controlled Access Unlawfully
655	Amber Light
656	Red Light
657	Disobey traffic light Not at Intersection
658	Proceed Contrary To Arrow.

659	Fail to Yield On Green Arrow
661	Flashing Red Light or Proceed Before Safe
662	Flashing Red Light at Crosswalk
663	Improper Stopping On Highway or Street
664	Obstruct Intersection
665	Fail to Dim
670	Permit Attachment of Person/Device
671	Produce Other Persons Licence
672	Allowing Other Person to Use Licence
673	False Statement/Fail to Furnish Information
674	Disobey School Bus Signal
675	Glass or Other Litter on Highway
676	Cross Highway
678	Interfere With Funeral Procession
679	Fail to Obey Restriction/Endorsement
680	Inadequate Brakes
681	Improperly Equipped M/C Operator or Passenger
682	Inadequate/Improper Equipment
683	Improperly Equipped Vehicle
685	Improper Seating on Motorcycle
686	Disobey Emergency Vehicle Signal
688	Fail to Yield Leaving Lane or Alley
691	Drive Vehicle While Passenger Unrestrained
692	Fail to Extinquish Spotlight
693	Driving on Wrong Side of Divided Highway
694	Unlit Lamps or Obstruction
695	Deface or Alter Licence/Registration/Plate
696	Unauthorized Use of Plate/Registration
[redacted]	[redacted]
698	Fail to Produce Licence/Registration
699	Fail to Display Plate/Stickers/Permit
[redacted]	[redacted]
721	Backing Up When Unsafe
722	Illegal U-Turn

723	No Licence/Inappropriate Licence
725	Driver Fail to Wear Seat Belt
726	Motorcycle in Same Lane as Another Vehicle
727	Exceed 60 Km/Hr Passing Highway Worker
728	Fail to Obey Flag Person Directions
729	Stunting
730	Excessive Noise
731	Tampering With Flares/Hazard Lights
732	Motorcycles More Than Two Abreast
733	Fail to/Improperly Activate School Bus Signal
742	Dangerous Driving Causing Bodily Harm
743	Dangerous Driving Causing Death
744	Impaired Driving Causing Bodily Harm
745	Impaired Driving Causing Death
746	Driving While on 24 Hour Suspension
747	Driving While Suspended or Refused Issue Etc

MEDICAL CONDITION CODES

A) ALCOHOL & DRUG ABUSE

B) ORGANIC BRAIN DISORDERS
- alzheimer's disease / dementia
- brain tumor
- cerebral palsy
- craniotomy
- guillian-barre disease
- head injury / trauma

D) DIABETES & HYPOGLYCEMIA

E) SEIZURE DISORDER
- cataplexy
- epilepsy
- narcolepsy
- sleep apnea

H) CARDIAC / VASCULAR
- angina
- aortic aneurysm
- arrhythmias (abnormal heart rhythm)
- congestive heart failure
- coronary artery
- heart attack (M.I.)
- heart surgery (angioplasty, by-pass, implanted defibrillator
- pacemaker
- peripheral vascular disease
- rheumatic fever
- valve repleacement, transplant)
- valvular heart disease

I) HEARING IMPAIRMENT
- hearing loss
- meniere's disease
- vertigo

L) LOCOMOTOR PROBLEMS
- amputations
- arthritis
- lupus
- paraplegia
- polio
- quadriplegia

M) MALIGNANCY & NEOPLASTIC
- hodgkin's disease
- leukemia
- malignancies
- multiple myeloma

N) NEURAL DEGERERATION
- amyotrophic lateral sclerosis (AMLS)
- dystonia (muscle disorder)
- fibromyositis (muscle degeneration)
- huntington's chorea
- multiple sclerosis
- muscular dystrophy
- myasthenia gravis
- parkinsonism

O) OTHER
- aids (HIV)
- chronic pain syndrom
- fibromyalgia
- kidney failure (dialysis)
- kidney transplants
- liver disorder / failure
- renal failure / dialysis
- syncope (fainting)
- venereal disease
- Chronic Fatigue Syndrome

P) PSYCHIATRIC DISORDERS

R) RESPIRATORY DISORDERS
- chronic obstructive pulmonary disease (COPD)
- cystic fibrosis
- emphysema / asthma
- oxygen therapy
- tuberculosis

S) CEREBRAL VASCULAR DISORDER
- cerebral aneurysm
- cerebral ataxia
- cluster headaches
- dizziness
- stroke (CVA)
- transient ischemic attacks (TIA)

T) HYPERTENSION
- high / low blood pressure

V) VISUAL DISORDERS
- amblyopia (lazy eye)
- aphakia (cataracts)
- diplopia (double vision)
- monocular
- myopia (near sighted)
- nystagmus (eye constantly moving)
- restricted fields
- Strabismus (crossed eyes)

Appendix H: Definitions for the Traffic Accident Information System (TAIS) Dataset

The Traffic Accident Information System (TAIS) is a computer-based system that compiles information on traffic collisions occurring on Saskatchewan highways. This information is obtained from the motor vehicle accident (MVA) report form that is completed by Saskatchewan police agencies in accordance with Section 83 of The Highway Traffic Act.

TAIS provides valuable information for many traffic collision countermeasure programs and has done so since its inception in 1979. As a result of changing needs and improved technologies, a completely new TAIS was implemented in January 1991. The new TAIS consists of a personal computer-based system that provides more adaptability to "user" needs, a redesigned MVA report form, improved instructions and user documentation.

TAIS, the MVA report form, and various collision publications are administered by the Auto Fund, SGI. The collection of this valuable data is made possible by the efforts and dedication of the many police officers across the province who complete MVA forms from their collision investigations.

TAIS Definitions

REPORTABLE MOTOR VEHICLE COLLISION - an incident involving one or more motor vehicles in transport resulting in personal injury or a minimum of $1,000 in property damage, not including damage to cargo. TAIS only records reportable motor vehicle collisions which occur on public roadways. While legislation requires the reporting of private property collisions to police, they are not recorded on TAIS. The following is a list of words and terms used in reportable motor vehicle collisions:

INCIDENT - Any set of motor vehicle events, not under human control, that include at least one occurrence of injury or damage. It originates when human control of the vehicle is lost and terminates when control is regained, or in the absence of persons who are able to regain control, when all persons and property are at rest. This excludes events which are the result of deliberate intent, legal intervention or natural disasters. For example, if a vehicle catches fire due to mechanical failure and the driver is able to stop safely, a motor vehicle collision did not occur because control of the vehicle was never lost.

MOTOR VEHICLE - any motorized mechanically or electrically powered land vehicle not operated on rails. Collisions which involve only construction or maintenance equipment within the right-of-way are not reportable on TAIS.

IN TRANSPORT - means "in motion or being operated" on a roadway.

DAMAGE - harm to property that reduces the monetary value of that property. It includes harm to animals which have monetary value. It excludes mechanical failure during normal operation, such as a tire blowout.

PUBLIC ROADWAY - any highway, secondary road, rural road, street, avenue, parkway, lane, alley or bridge designed and intended for or used by the general public for the passage of motor vehicles. This includes sidewalks, boulevards and the immediate right-of-way adjacent to and parallel with the roadway. It does not include privately maintained roads, driveways or parking lots.

SNOWMOBILES AND OFF-HIGHWAY VEHICLES - collisions involving snowmobiles and off-highway vehicles that occur within the right-of-way of a public roadway are recorded as part of that roadway. If they occur outside of the right-of-way, they are on private property.

ROAD AUTHORITY - the jurisdiction responsible for the general maintenance and traffic safety of the road. The following is a list of Road Authorities and location breakdowns used in the MVA report:

URBAN LOCATION - any street, lane or back alley as defined in codes 01 and 02 below which is within the incorporated limits of a city, town, village or hamlet, except those streets recorded as a numbered highway.

01. STREET - any public road of an urban street system under the maintenance or jurisdiction of the municipal government. In the case where a road is maintained by a municipal government and would more easily be coded as a numbered highway, exceptions may be made.

02. LANE/BACK ALLEY - any alley or lane within an urban area intended for use by the public and maintained by the local government.

HIGHWAY LOCATION - any rural/urban highway, provincial road, community access or service road, or other highway as defined in codes 03, 04, and 05 below.

03. RURAL/URBAN HIGHWAY - any numbered provincial highway in a rural area or urban area with a population less than 1,000, that is maintained by Saskatchewan Highways and Transportation, and any roadways within urban limits that the police have been permitted to code as a highway for convenience (see street definitions).

04. PROVINCIAL ROADS (900 series highways) - any public highway with a highway number greater than 900.

05. COMMUNITY ACCESS, SERVICE ROAD/OTHER - roads built and maintained by Saskatchewan Highways and Transportation, providing access to communities, industrial plants, and/or land parcels.

RURAL ROAD LOCATION - Any designated grid, municipal or other road as defined in codes 06 and 07 below.

06. DESIGNATED GRID ROAD - A municipal road designated as a municipal grid or main farm access road on the Saskatchewan Municipal Road Inventory Maps and posted with customary grid road signs. Collisions on grid roads going through an Indian Reserve are coded to the Indian Reserve (code 09).

07. MUNICIPAL/OTHER RURAL ROAD - any rural municipal road not designated as a grid road. These will include trails, bladed and non-bladed roads, and local streets in unorganized hamlets. Collisions on municipal roads going through Indian Reserves are coded to the Indian Reserve (code 09).

OTHER LOCATIONS - any location not identified under urban, highway or rural road locations.

08. PRIVATE LAND/PARKING LOT - privately-owned property, both in rural and urban areas, such as parking lots, parkades, farmyards, private roads, driveways, service station lots, etc. Accidents coded to this Road Authority are not recorded on TAIS.

09. INDIAN RESERVES (Grid or Municipal Road) - any public road within an Indian Reserve boundary, other than a provincial highway, serving as an access or internal road for an Indian Reserve.

10. NORTHERN FOREST ROAD - roads in forested areas built and maintained with the primary intent of providing access to forestry operations.

11. FEDERAL/PROVINCIAL LANDS - any road other than a numbered provincial highway serving as a public access or internal road to federal or provincial land such as parks, federal community pastures, etc.

12. NOT KNOWN - this code is intended for use only when a general location is definitely not known.

PROPERTY DAMAGE ONLY COLLISION (Property Damage) - a motor vehicle collision resulting in total damages over the prescribed amount as defined in The Highway Traffic Act ($1,000) with no personal injuries or deaths.

TRAFFIC INJURY COLLISION (Personal Injury) - a motor vehicle collision resulting in a non-fatal injury to one or more persons. An injury is defined as any bodily harm resulting from the collision.

TRAFFIC FATALITY COLLISION (Fatal) - a motor vehicle collision resulting in death within 30 days to one or more involved persons.

Due to differences in reporting definitions, the numbers of collisions and associated casualties published in this report do not necessarily reflect the collision and injury claims experience of the Auto Fund. Collisions resulting in property damage only are reported by the police when the estimated repair costs for all vehicles exceed $1,000, whereas a collision claim may occur when the actual repair cost to one vehicle exceeds $500. Police estimates may not accurately reflect the actual repair costs and cases are excluded from TAIS when deemed to be under the reporting threshold. Private property and parking lot collisions as well as damage resulting from acts of vandalism or natural causes are also not recorded in TAIS.

The information presented in this publication reflects all police reports known to SGI as of Feb. 15, 1998. Since the TAIS is updated on a continual basis, information in future publications may vary from what is published in this report.

Appendix I: Ethics Approval

INSTITUTE FOR REHABILITATION RESEARCH AND DEVELOPMENT*
INSTITUT DE RECHERCHE ET DE DÉVELOPPEMENT EN RÉADAPTATION*

July 8, 1999

Shawn Marshall
The Rehabilitation Centre
505 Smyth Road
Ottawa, Ontario
K1H 8M2

Dear Shawn:

We are pleased to inform you that your research projects entitled "Development and Validation of the Physical Impairment Questionnaire" and "Evaluation of Restricted Driver Licensing for Medical Impairments in Saskatchewan" have been approved.

As per the IRRD's Research Reference Manual, primary investigators are required to submit a progress report on an annual basis to the Chair of the Research Ethics Committee. As well, any modifications to the protocol or adverse events must be reported immediately to the Chair of the Research Ethics Committee.

Congratulations and good luck with your project!

Sincerely,

Dan DeForge
Chair, Research Ethics Committee

J.C. MacDougall
Director of Research

Appendix J: Multivariate Poisson Regression Models 2 to 6

Model 2: Conviction Rate- Restriction represents drivers with any type of restriction

Univariate Poisson regression analysis of independent variables was completed to determine the contribution of independent variables for predicting conviction rates. (Table 1)

Table 1: Univariate Poisson regression analysis of independent variables and their association with conviction rate.

Variable	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	Log Likelihood	P value	Pseudo R^2
α	-1.8141	0.0013			-247948		0.0000
Restriction	0.4781	0.0117	0.6199	(0.6048, 0.6343)	-247000	0.0000	0.0039
Sex	-1.1039	0.0029	0.3316	(0.3297, 0.3334)	-163619	0.0000	0.3402
Residence location	0.2356	0.0026	1.2656	((1.2591, 1.2721)	-243895	0.0000	0.0165
Medical Condition	0.4191	0.0081	0.6577	(0.6473, 0.6681)	-246441	0.0000	0.0062
Age category 16 – 24			1.0			-88831	0.6418
Age category 25 – 34	-0.5658	0.0032	0.5679	(0.5644, 0.5715)	0.0000		
Age category 35 - 44	-1.0774	0.0037	0.3405	(0.3380, 0.3429)	0.0000		
Age category 45 –54	-1.3955	0.0048	0.2477	(0.2454, 0.2500)	0.0000		
Age category 55 –64	-1.91127	0.0067	0.1477	(0.1457, 0.1496)	0.0000		
Age category 65 –74	-2.3794	0.0088	0.0926	(0.0910, 0.0942)	0.0000		
Age category 75 – 84	-2.6664	0.0138	0.0695	(0.0676, 0.0714)	0.0000		
Age category 85 - 100	-2.7564	0.0387	0.06351	(0.0589, 0.0685)	0.0000		

All variable terms including sex, location of residence, absence or presence of a medical condition or driving restriction and age category appeared to be associated significantly with total convictions. Therefore each of these variables will be included in the multivariate Poisson regression model at this stage. Below is the Stata® output for the main effects model which includes all independent variables. (Figure 1)

All of the variables significantly contribute to the model. It was known form the stratified analysis, however, that there is likely confounding present as well as the possibility of effect modification. To assess for interaction, there is a possibility of 20 interaction terms given that there are 5 independent variables. The same arguments for interaction terms used in model 1 hold and therefore the same 7 interaction term effects were explored for this model.

```
. poisson conv_tot restric sex locat medcond a2-a8, exposure(py_tot) irr

Poisson regression, normalized by py_tot          Number of obs   =     128
Goodness-of-fit chi2(116)  =  1541.000            Model chi2(11)  =493511.00
> 0
Prob > chi2           =   0.0000                  Prob > chi2     = 0.0000
Log Likelihood        = -1222.500                 Pseudo R2       = 0.9951

------------------------------------------------------------------------------
conv_tot |     IRR      Std. Err.     z       P>|z|     [95% Conf. Interval]
---------+--------------------------------------------------------------------
 restric |   .872537    .0124425    -9.562   0.000     .8484879   .8972678
     sex |   .3263454   .0009364  -390.269   0.000     .3245153   .3281858
   locat |  1.112747    .0029358    40.492   0.000     1.107008   1.118516
 medcond |  1.089496    .010769      8.672   0.000     1.068592   1.110809
      a2 |   .5942019   .0019011  -162.699   0.000     .5904875   .5979397
      a3 |   .3621419   .0013316  -276.230   0.000     .3595414   .3647613
      a4 |   .2602939   .0012381  -282.961   0.000     .2578785   .2627319
      a5 |   .151052    .0010216  -279.463   0.000     .1490629   .1530677
      a6 |   .09151     .0008129  -269.198   0.000     .0899305   .0931172
      a7 |   .0656935   .0009085  -196.891   0.000     .0639369   .0674984
      a8 |   .053341    .0020629   -75.790   0.000     .0494473   .0575414
```

Figure 1: Stata® output of main effects model for conviction rate for drivers with or without any type of driving restriction

The interaction terms that have a statistically significant impact on the main effects model are restric*age category, restric*age category, restric*medcond, restric*medcond, sex*age category and medcond*age category. (Table 2) Sex*age category has the most impact of all the interaction terms, but as can be seen from the pseudo R^2 value, only 0.07% of information is contributed to the model through this interaction term. Since so little information is contributed by interaction terms, then the most parsimonious model for predicting conviction rates will not include interaction terms and will remain the main effects model.

Table 2: Effect of interaction terms on the main effects model for conviction rate comparing drivers with and without any type of driving restriction

Interaction term	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	Log Likelihood	P value	Pseudo R^2
Main effects model					-1222.5		0.9951
Restric*sex	-0.1445	0.0155	1.0392	(0.9829, 1.0989)	-1221.5	0.176	0.9951
Restric*Age category					-1194		0.9952
Ra1			1.0				
Ra2	-0.1980	0.0366	0.8203	(0.7636, 0.8813)		0.000	
Ra3	-0.0229	0.0357	1.0303	(0.9608, 1.1050)		0.402	
Ra4	-0.0386	0.0389	0.9622	(0.8916, 1.0384)		0.321	
Ra5	-0.0622	0.0419	1.0641	(0.9803, 1.1553)		0.137	
Ra6	-0.1312	0.0481	0.8771	(0.7981, 0.9638)		0.006	
Ra7	-0.0513	0.0579	1.0527	(0.9398, 1.1791)		0.375	
Ra8	-0.1328	0.1349	1.1420	(0.8766, 1.4877)		0.325	
Restric*locat	-0.1217	0.0236	0.8854	(0.8453, 0.9274)	-1209	0.000	0.9951
Restric*medcond	-0.1784	0.0319	0.8366	(0.7860, 0.8906)	-1207	0.000	0.9951
Sex*agecat (sa1)			1.0		-1036		0.9958
Sa2	0.0174	0.0072	1.0175	(1.0032, 1.0312)		0.016	
Sa3	0.1092	0.0081	1.1154	(1.0979, 1.1332)		0.000	
Sa4	0.0181	0.0106	1.0183	(0.9973, 1.0397)		0.087	
Sa5	-0.1520	0.0160	0.8590	(0.8324, 0.8863		0.000	
Sa6	-0.1256	0.0217	0.8820	(0.8452, 0.9204)		0.000	
Sa7	0.0218	0.0344	1.022	(0.9552, 1.0934)		0.527	
Sa8	0.0474	0.1186	1.0485	(0.8311, 1.3229)		0.689	
Medcond*Age category (ma1)			1.0		-1176		0.9953
Ma2	-0.1005	0.0247	0.9044	(0.8617, 0.9492)		0.000	
Ma3	0.0433	0.0251	1.0442	(0.9941, 1.0968		0.084	
Ma4	0.0029	0.0271	1.0029	(0.9511, 1.0575)		0.916	
Ma5	0.0205	0.0298	1.0207	(0.9628, 1.0821)		0.492	
Ma6	-0.0194	0.0328	0.9808	(0.9197, 1.0460)		0.556	
Ma7	0.2091	0.0414	1.2326	(1.1365, 1.3369)		0.000	
Ma8	0.5598	0.0970	1.7502	(1.4471, 2.1169)		0.000	
Sex*medcond	0.0364	0.0191	1.0371	(0.9990, 1.0767)	-1220.5	0.056	0.9951

Model 3: Crash Rate- Restriction represents drivers with Driving restriction

Univariate Poisson regression analysis of independent variables was completed to determine the contribution of independent variables for predicting “at-fault” rates comparing drivers with and without a driving restriction. (Table 3)

Table 3: Univariate Poisson regression analysis of independent variables and their association with "at-fault" crash rate.

Variable	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	Log Likelihood	P value	Pseudo R^2
α	-2.7395	0.0020			-20375		0.000
Restriction	0.2111	0.374	1.2351	(1,1478, 1.3289)	-20360	0.000	0.0007
Sex	-0.6920	0.0042	0.5006	(0.4965, 0.5047)	-6245	0.000	0.6935
Residence location	0.3262	0.0042	1.3856	(1.3742, 1.3972)	-17317	0.000	0.1501
Medical Condition	0.2390	0.0095	1.2699	(1.2466, 1.2937)	-20078.5	0.000	0.0146
Age category 16 – 24			1.0		-18854.8		0.0746
Age category 25 – 34	-0.1918	0.0066	0.8255	(0.8148, 0.8363)		0.000	
Age category 35 - 44	-0.5812	0.0063	0.9435	(0.9320, 0.9552)		0.000	
Age category 45 –54	0.01529	0.0067	1.0154	(1.0022, 1.0288)		0.022	
Age category 55 –64	-0.3044	0.0081	0.7376	(0.7260, 0.7493)		0.000	
Age category 65 –74	-0.2544	0.0082	0.7754	(0.7630, 0.7880)		0.000	
Age category 75 – 84	-0.0706	0.0097	0.9318	(0.9142, 0.9498)		0.000	
Age category 85 - 100	0.0422	0.0225	1.0431	(0.9982, 1.0901)		0.060	

All variable terms including sex, location of residence, absence or presence of a medical condition or driving restriction and age category appeared to be associated significantly with total "at-fault" crashes. Therefore each of these variables will be included in the multivariate Poisson regression model at this stage. This main effects model includes all independent variables which were shown to contribute information to the prediction of crash rate in the univariate analysis. The pseudo R^2 value indicates that this model explains 93% of the variance of the dataset. Although the Log likelihood remains statistically significant, this model appears to provide a reasonable representation of crash rate prediction for drivers with and without a driving license restriction. To further enhance this model, interaction terms will need to be explored.

All of the variables significantly contribute to the model. It was known form the stratified analysis, however, that there is likely confounding present as well as the possibility of effect modification. To assess for interaction, there is a possibility of 20 interaction terms given that there are 5 independent variables. The same arguments for interaction terms used in model 1 hold and therefore the same 7 interaction term effects were explored for this model.

Table 4: Effect of interaction terms on the main effects model for "at-fault" crash rate comparing drivers with and without a driving restriction

Interaction term	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	Log Likelihood	P value	Pseudo R^2
Main effects model					-1424		0.9301
Restric*sex	0.2070	0.0056	1.2300	(1.0385, 1.4569)	-1421	0.017	0.9302
Restric*Age category					-1421		0.9303
Ra1			1.0				
Ra2	0.1339	0.1405	1.1432	(0.8680, 1.5058)		0.341	
Ra3	0.2059	0.1347	1.2287	(0.9435, 1.6000)		0.126	
Ra4	0.0956	0.1495	1.1003	(0.8209, 1.4749)		0.522	
Ra5	0.0415	0.1633	1.0424	(0.7569, 1.4357)		0.799	
Ra6	-0.1193	0.1391	0.8876	(0.6758, 1.1658)		0.391	
Ra7	0.0315	0.1201	1.0320	(0.8156, 1.3059)		0.793	
Ra8	-0.0079	0.1559	0.9921	(0.7310, 1.3466)		0.959	
Restric*locat	0.0787	0.0748	1.0181	(0.9343, 1.2527)	-1423.5	0.293	0.9301
Restric*medcond	-0.1378	0.0765	0.8712	(0.7499, 1.0122)	-1422.5	0.072	0.9302
Sex*agecat (sa1)			1.0		-1217		0.9403
Sa2	0.1445	0.0139	1.1554	(1.1245, 1.1873)		0.000	
Sa3	0.1935	0.0131	1.2135	(1.1829, 1.2450)		0.000	
Sa4	0.0084	0.0141	1.0084	(0.9809, 1.0368)		0.553	
Sa5	-0.0386	0.0173	0.9621	(0.9302, 0 9953)		0.025	
Sa6	0.0725	0.0177	1.0752	(1.0385, 1.1133)		0.000	
Sa7	0.1203	0.0215	1.1278	(1.0813, 1.1763)		0.000	
Sa8	0.2833	0.0561	1.3276	(1.1893, 1.4819)		0.000	
Medcond*Age category (ma1)			1.0		-1410		0.9308
Ma2	0.0394	0.0464	1.0402	(0.9498, 1.1392)		0.395	
Ma3	0.0116	0.0424	1.0117	(0.9310, 1.0994)		0.784	
Ma4	-0.0537	0.0416	0.9478	(0.8736, 1.0282)		0.197	
Ma5	0.0464	0.0417	1.0475	(09654, 1.1367)		0.265	
Ma6	0.0478	0.0398	1.0490	(0.9703, 1.1340)		0.229	
Ma7	0.0926	0.0413	1.0971	(1.0118, 1.1895)		0.025	
Ma8	0.1943	0.0675	1.2144	(1.0640, 1.3862)		0.004	
Sex*medcond	0.0982	0.0210	1.1031	(1.0585, 1.1496)	-1413	0.000	0.9306

Different interaction terms appear to statistically contribute to the main effects model in explaining crashes. However, only for the interaction term combing sex and age category, is the pseudo R^2 value increased to a significant degree (0.9402) of more than 1%. Therefore, the most parsimonious model will include only the interaction term combining sex and age category added to the main effects model. (Figure 3)

```
. poisson  crsh_tot  restric sex locat medcond a2-a8 Sa2-Sa8, exposure( py_tot)
> irr

Poisson regression, normalized by py_tot          Number of obs =    128
Goodness-of-fit chi2(109)  =  1633.750            Model chi2(18)=38316.000
Prob > chi2=0.0000                                Prob > chi2 =  0.0000
Log Likelihood= -1217.125                         Pseudo R2=  0.9403

------------------------------------------------------------------------------
crsh_tot |      IRR      Std. Err.      z      P>|z|    [95% Conf. Interval]
---------+--------------------------------------------------------------------
 restric |   1.059653   .0400884     1.532   0.126     .9839234   1.141211
     sex |    .460203   .0044593   -80.093   0.000     .4515455   .4690266
   locat |   1.379629   .00588      75.508   0.000     1.368152   1.391202
 medcond |   1.229682   .0119626    21.253   0.000     1.206457   1.253353
      a2 |   .8009957   .00665     -26.728   0.000     .7880675   .8141361
      a3 |   .9132385   .0072025   -11.508   0.000     .8992304   .9274649
      a4 |   1.053241   .0087158     6.268   0.000     1.036297   1.070463
      a5 |   .7679001   .0075489   -26.865   0.000     .7532461   .7828393
      a6 |   .7637855   .0076729   -26.824   0.000     .748894    .7789731
      a7 |   .8797256   .0102574   -10.990   0.000     .8598494   .9000612
      a8 |   .8955183   .0226259    -4.368   0.000     .8522525   .9409805
     Sa2 |   1.155443   .0160203    10.421   0.000     1.124467   1.187273
     Sa3 |   1.213536   .0158472    14.821   0.000     1.18287    1.244996
     Sa4 |   1.008425   .0142553     0.593   0.553     .9808687   1.036756
     Sa5 |   .9621539   .0166061    -2.235   0.025     .9301509   .995258
     Sa6 |   1.075223   .0190793     4.087   0.000     1.038471   1.113276
     Sa7 |   1.12781    .0242174     5.601   0.000     1.08133    1.176289
     Sa8 |   1.327557   .0745105     5.048   0.000     1.189265   1.481931
```

Figure 3: Stata output of the model to predict "at-fault" crashes comparing drivers with or without driving restrictions

Model 4: Conviction Rate- Restriction represents drivers with Driving restriction

Univariate Poisson regression analysis of independent variables was completed to determine the contribution of independent variables for predicting conviction rates comparing drivers with and without a driving restriction. (Table 5)

Table 5: Univariate Poisson regression analysis of independent variables and their association with conviction rate

Variable	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	Log Likelihood	P value	Pseudo R^2
α	-1.8142	.0012			-247836.5		0.000
Restriction	-0.1160	0.0277	0.8905	(0.8434, 0.9401)	-247827.5	0.000	0.000
Sex	-1.1039	0.0015	0.3316	(0.3297, 0.3334)	-163478	0.000	0.3404
Residence location	0.2356	0.0026 -	1.2656	(1.2591, 1.2722)	-243754	0.000	0.0165
Medical Condition	-0.4191	0.0080	0.6577	(0.6473, 0.6682)	-246300	0.000	0.0062
Age category 16 – 24					-88689.5		0.6421
Age category 25 – 34	-0.5658	0.0032	0.5679	(0.5644, 0.5715)		0.000	
Age category 35 - 44	-1.0774	0.0037	0.3404	(0.3380, 0.3429)		0.000	
Age category 45 –54	-1.3955	0.0048	0.2477	(0.2454, 0.2500)		0.000	
Age category 55 –64	-1.9127	0.0067	0.1477	(0.1457, 0.1496)		0.000	
Age category 65 –74	-2.3794	0.0088	0.0926	(0.910, 0.0942)		0.000	
Age category 75 – 84	-2.6665	0.0138	0.0695	(0.0676, 0.0714)		0.000	
Age category 85 - 100	-2.7564	0.0020	0.0635	(0.0589, 0.0685)		0.000	

All variable terms including sex, location of residence, absence or presence of a medical condition or driving restriction and age category appeared to be associated significantly with total conviction rate. Therefore each of these variables will be included in the multivariate Poisson regression model at this stage. This main effects model includes all independent variables which were shown to contribute information to the prediction of conviction rate in the univariate analysis. The pseudo R^2 value indicates that this model explains 99.6% of the variance of the dataset. Although the Log likelihood remains statistically significant, this model appears to provide a reasonable representation of conviction rate prediction for drivers with and without a driving license restriction. To further enhance this model, interaction terms will need to be explored.

All of the variables significantly contribute to the model. It was known form the stratified analysis, however, that there is likely confounding present as well as the possibility of effect modification. To assess for interaction, there is a possibility of 20 interaction terms given that there are 5 independent variables. The same arguments for interaction terms used in model 1 hold and therefore the same 7 interaction term effects were explored for this model.

Table 6: Effect of interaction terms on the main effects model for conviction rate comparing drivers with and without a driving restriction

Interaction term	β	SE (β)	Incidence Rate Ratio	IRR 95%_CI	Log Likelihood	P value	Pseudo R^2
Main effects model					-1125.5		0.9955
Restric*sex	0.1276	0.0682	1.1361	(0.9939, 1.9385)	-1124	0.061	0.9955
Restric*Age category					-1120.5	-	0.9955
Ra2	0.0171	0.0759	1.0172	(0.8766, 1.1805)		0.822	
Ra3	0.2655	0.0861	1.3041	(1.1015, 1.5438)		0.002	
Ra4	0.0617	0.1227	1.0636	(0.8362, 1.3528)		0.615	
Ra5	0.0602	0.1559	0.9416	(0.6937, 1.2780)		0.699	
Ra6	0.0343	0.1470	0.9963	(0.2744, 1.2889)		0.815	
Ra7	0.1412	0.1423	1.1517	(0.8714, 1.5221)		0.321	
Ra8	0.0659	0.2420	1.0682	(0.6647, 1.7166)		0.785	
Restric*locat	-0.0457	0.0555	0.9554	(0.8569, 1.0652)	-1125	0.411	0.9955
Restric*medcond	-0.1034	0.0588	0.9018	(0.8036, 1.0120)	-1124	0.079	0.9955
Sex*agecat (sa1)					-939		0.9962
Sa2	0.0174	0.0072	1.0176	(1.0033, 1.0321)		0.015	
Sa3	0.1093	0.0081	1.1155	(1.0979, 1.1333)		0.000	
Sa4	0.0182	0.0106	1.0184	(0.9974, 1.0397)		0.086	
Sa5	-0.1519	0.0160	0.8590	(0.8325, 0.8864)		0.000	
Sa6	-0.1252	0.0217	0.8823	(0.8455, 0.9207)		0.000	
Sa7	0.0224	0.0344	1.0226	(0.9559, 1.0941)		0.516	
Sa8	0.0478	0.1186	1.0489	(0.8314, 1.3234)		0.687	
Medcond*Age category (ma1)					-1082.5		0.9956
Ma2	-0.0985	0.0247	0.9062	(0.8634, 0.9511)		0.000	
Ma3	0.0401	0.0251	1.0409	(0.9910, 1.0934)		0.110	
Ma4	-0.0035	0.0270	0.9965	(0.9451, 1.0508)		0.898	
Ma5	0.0149	0.0298	1.0150	(0.9574, 1.0760)		0.617	
Ma6	-0.0256	0.0328	0.9747	(0.9139, 1.0395)		0.435	
Ma7	0.1975	0.0414	1.2184	(1.134, 1.3214)		0.000	
Ma8	0.5441	0.0971	1.7231	(1.4245, 2.0842)		0.000	
Sex*medcond	0.0407	0.0191	1.0415	(1.0033, 1.0812)	-1123.5	0.033	0.9955

Different interaction terms appear to statistically contribute to the main effects model in explaining convictions. However, no interaction terms increase pseudo R^2 (0.9955) value by more than 1%. Therefore, only the main effects model, without interaction terms, will be used to describe convictions for drivers with driving restrictions, since this represents the most parsimonious model.

```
. poisson  conv_tot  restric sex locat medcond a2-a8, exposure ( py_tot) irr

Poisson regression, normalized by py_tot        Number of obs    =     128
Goodness-of-fit chi2(116)  =  1452.000         Model chi2(11)   =493422.00
> 0
Prob > chi2                 =   0.0000              Prob > chi2      = 0.0000
Log Likelihood              = -1125.500             Pseudo R2        = 0.9955

------------------------------------------------------------------------------
conv_tot |      IRR    Std. Err.       z     P>|z|     [95% Conf. Interval]
---------+--------------------------------------------------------------------
 restric |   .9444498   .0262939    -2.053   0.040     .8942954    .9974169
     sex |   .3263987   .0009365  -390.213   0.000     .3245682    .3282394
   locat |   1.112803   .0029362    40.508   0.000     1.107063    1.118573
 medcond |   1.03224    .0084558     3.874   0.000     1.015799    1.048947
      a2 |   .5942746   .0019014  -162.656   0.000     .5905597    .5980129
      a3 |   .3621483   .0013317  -276.207   0.000     .3595475    .3647679
      a4 |   .2602599   .0012381  -282.966   0.000     .2578447    .2626978
      a5 |   .1510132   .0010214  -279.485   0.000     .1490244    .1530285
      a6 |   .0914566   .0008124  -269.259   0.000     .0898781    .0930629
      a7 |   .0655917   .000907   -197.008   0.000     .0638378    .0673938
      a8 |   .0532056   .0020578   -75.852   0.000     .0493216    .0573956
------------------------------------------------------------------------------
```

Figure 4: Stata output of the model to predict convictions comparing drivers with or without driving restrictions

Model 5: Crash Rate- Restriction represents drivers with Licensing restriction

Univariate Poisson regression analysis of independent variables was completed to determine the contribution of independent variables for predicting "at-fault" rates comparing drivers with and without a licensing restriction. (Table 7)

Table 7: Univariate Poisson regression analysis of independent variables and their association with "at-fault" crash rate

Variable	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	Log Likelihood	P value	Pseudo R^2
α	-2.7395	0.0020			-20468	0.000	0.0000
Restriction	0.1883	0.0136	1.2071	(1.1754, 1.2397)	-20378	0.000	0.0044
Sex	-0.6920	0.0042	0.5006	(0.4965, 0.5407)	-6338	0.000	0.6903
Residence location	0.3262	0.0042	1.3856	(1.3742, 1.3972)	-17411	0.000	0.1494
Medical Condition	0.2390	0.0095	1.2699	(1.2466, 1.2937)	-20172	0.000	0.0145
Age category 16 – 24					-18948		0.0743
Age category 25 – 34	-0.1918	0.0066	0.8255	(0.8148, 0.8363)		0.000	
Age category 35 - 44	-0.0581	0.0063	0.9435	(0.9320, 0,9552)		0.000	
Age category 45 –54	0.0153	0.0070	1.0154	(1.0021, 1.0288)		0.022	
Age category 55 –64	-0.3044	0.0081	0.7376	(0.7260, 0.7493)		0.000	
Age category 65 –74	-0.2544	0.0082	0.7754	(0.7630, 0.7880)		0.000	
Age category 75 – 84	-0.0706	0.0097	0.9318	(0.9142, 0.9498)		0.000	
Age category 85 - 100	0.0422	0.225	1.0431	(0.9992, 1.0901)		0.066	

All of the independent variables appear to contribute significantly to the model. Since all of these variables make biologic sense, they will each be included in the main effects model. From this data, sex appears to exert the most influence on crash rate for drivers with licensing restrictions. The pseudo R^2 value indicates that this model explains 92.6% of the variance of the dataset. Although the Log likelihood remains statistically significant, this model appears to provide a reasonable representation of "at-fault" crash rate prediction for drivers with and without a licensing restriction. To further enhance this model, interaction terms will need to be explored.

All of the variables significantly contribute to the model. It was known form the stratified analysis, however, that there is likely confounding present as well as the possibility of effect modification. To assess for interaction, there is a possibility of 20 interaction terms given that there are 5 independent variables. The same arguments for interaction terms used in model 1 hold and therefore the same 7 interaction term effects were explored for this model.

Table 8: Effect of interaction terms on the main effects model for "at-fault" crash rate comparing drivers with and without a licensing restriction

Interaction term	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	Log Likelihood	P value	Pseudo R^2
Main effects model					-1510		0.9263
Restric*sex	0.1230	0.0307	1.1308	(1.0648, 1.2009)	-1502	0.000	0.9266
Restric*Age category				-	-1504		0.9265
Ra2	-0.0681	0.0694	0.9341	(0.8153, 1.0702)		0.326	
Ra3	-0.0851	0.0617	0.9184	(0.8138, 1.0364)		0.168	
Ra4	-0.1144	0.0596	0.8919	(0.7936, 1.0024)		0.055	
Ra5	-0.0426	0.0598	0.9583	(0.8522, 1.0775)		0.476	
Ra6	-0.1126	0.0571	0.8935	(0,7988, 0.9993)		0.049	
Ra7	-0.1399	0.0582	0.8694	(0.7756, 0.9746)		0.016	
Ra8	0.0362	0.0848	1.0368	(0.8780, 1.2244)		0.670	
Restric*locat	0.0681	0.0282	1.0705	(1.0130, 1.1313)	-1507	0.016	0.9264
Restric*medcond	-0.4161	0.0491	0.6596	(0.5991, 0.7262)	-1477	0.000	0.9278
Sex*agecat (sa1)					-1303		0.9364
Sa2	1.4443	0.0139	1.1554	(1.1244, 1.1872)		0.000	
Sa3	0.1935	0.0131	1.2135	(1.1828, 1.2450)		0.000	
Sa4	0.0084	0.0141	1.0084	(099809, 1.0368)		0.552	
Sa5	-0.0386	0.0173	0.9622	(0.9302, 0.9953)		0.025	
Sa6	0.0723	0.0177	1.0750	(1.0382, 1.113)		0.000	
Sa7	0.1196	0.0215	1.1270	(1.0806, 1.1755)		0.000	
Sa8	0.2816	0.0561	1.3253	(1.1872, 1.4794)		0.000	
Medcond*Age category (ma1)					-1493		0.9270
Ma2	0.0387	0.0464	1.0394	(0.9491, 1.1383)		0.404	
Ma3	0.0138	0.0424	1.0139	(0.9330, 1.1018)		0.745	
Ma4	-0.0499	0.0416	0.9513	(0.8679, 1.0321)		0.230	
Ma5	0.0500	0.0417	1.0513	(0.9688, 1.1408)		0.230	
Ma6	0.0532	0,0398	1.0546	(0,9755, 1.1402)		0.181	
Ma7	0.1045	0.0413	1.1101	(1.0238, 1.2038)		0.011	
Ma8	0.2176	0.0674	1.2431	(1.0893, 1.4188)		0.001	
Sex*medcond	0.0949	0.0210	1.0995	(1.0551, 1.1458)	-1500	0.000	0.9267

Different interaction terms appear to statistically contribute to the main effects model in explaining crashes. (Table 8) However, only for the interaction term combing sex and age category, is the pseudo R^2 value increased to a significant degree of more than 1% from 92.6% to 93.6%. Therefore, the most parsimonious model will include only this interaction term added to the main effects model. (Figure 5)

```
. poisson  crsh_tot  restric sex locat medcond a2-a8  Sa2-Sa8, exposure( py_to
> t) irr

Poisson regression, normalized by py_tot         Number of obs   =    128
Goodness-of-fit chi2(109)  =  1712.250              Model chi2(18)  =38331.250
Prob > chi2                =   0.0000               Prob > chi2     =  0.0000
Log Likelihood             = -1302.750              Pseudo R2       =  0.9364

------------------------------------------------------------------------------
crsh_tot |       IRR    Std. Err.       z     P>|z|     [95% Conf. Interval]
---------+--------------------------------------------------------------------
 restric |   .9294604   .0163702     -4.153   0.000     .8979228    .9621056
     sex |   .4601547   .0044588    -80.104   0.000     .4514981    .4689773
   locat |   1.379507   .0058786     75.498   0.000     1.368033    1.391078
 medcond |   1.273175   .0157135     19.568   0.000     1.242746    1.304348
      a2 |   .8009247   .0066493    -26.739   0.000     .7879978    .8140637
      a3 |   .9131843   .0072018    -11.516   0.000     .8991775    .9274093
      a4 |   1.053189   .0087149      6.263   0.000     1.036246    1.070409
      a5 |   .7678634   .0075481    -26.871   0.000     .7532109    .7828009
      a6 |   .7640244   .0076753    -26.792   0.000     .7491282    .7792169
      a7 |   .8811457   .0102766    -10.849   0.000     .8612325    .9015194
      a8 |   .899316    .022712      -4.202   0.000     .855885     .9449508
     Sa2 |   1.155383   .0160194     10.417   0.000     1.124408    1.187211
     Sa3 |   1.213505   .0158468     14.819   0.000     1.18284     1.244965
     Sa4 |   1.008441   .0142555      0.595   0.552     .9808845    1.036772
     Sa5 |   .9621546   .0166061     -2.235   0.025     .9301516    .9952588
     Sa6 |   1.074957   .0190746      4.073   0.000     1.038214    1.113
     Sa7 |   1.127021   .0242008      5.569   0.000     1.080572    1.175466
     Sa8 |   1.32527    .0743786      5.018   0.000     1.187222    1.479369
```

Figure 5: Stata output of the model to predict "at-fault" crashes comparing drivers with or without licensing restrictions

Model 6: Conviction Rate- Restriction represents drivers with Licensing restriction

Univariate Poisson regression analysis of independent variables was completed to determine the contribution of independent variables for predicting conviction rates comparing drivers with and without a licensing restriction. (Table 9)

Table 9: Univariate Poisson regression analysis of independent variables and their association with conviction rate

Variable	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	Log Likelihood	P value	Pseudo R^2
α	-1.8141	0.0013			-247971	0.000	0.000
Restriction	-0.5572	0.0123	0.5728	(0.5592, 0.5868)	-265727	0.000	0.0050
Sex	-1.1039	0.0029	0.3316	(0.3287, 0.3334)	-163612	0.000	0.3402
Residence location	0.2356	0.0026	1.2656	(1.2591, 1.2792)	-243889	0.000	0.0165
Medical Condition	-0.4191	0.0081	0.6577	(0.6473, 0.6682)	-246435	0.000	0.0062
Age category					-88824	0.000	0.6413
Age category 25 – 34	-0.5675	0.0032	0.5679	(0.5644, 0.5715)		0.000	
Age category 35 - 44	-1.0774	0.0037	0.3405	(0.3380, 0.3429)		0.000	
Age category 45 –54	-1.3955	0.0048	0.2477	(0.2454, 0.2500)		0.000	
Age category 55 –64	-1.9127	0.0067	0.1477	(0.1457, 0.1496)		0.000	
Age category 65 –74	-2.3794	0.0088	0.0926	(0.0910, 0.0942)		0.000	
Age category 75 – 84	-2.6665	0.0138	0.0695	(0.0676, 0.0714)		0.000	
Age category 85 - 100	-2.7564	0.0020	0.0635	(0.0589, 0.0685)		0.000	

All of the independent variables appear to contribute significantly to the model. (Table 9) Since all of these variables make biologic sense, they will each be included in the main effects model. (Figure 6) The value for the pseudo R2 is 99.5%. Although the Log likelihood remains statistically significant, this model appears to provide a reasonable representation of conviction rate prediction for drivers with and without a licensing restriction. To further enhance this model, interaction terms will need to be explored.

All of the variables significantly contribute to the model. It was known form the stratified analysis, however, that there is likely confounding present as well as the possibility of effect modification. To assess for interaction, there is a possibility of 20 interaction terms given that there are 5 independent variables. The same arguments for interaction terms used in model 1 hold and therefore the same 7 interaction term effects were explored for this model. (Table 10)

```
. poisson conv_tot  restric  sex  locat  medcond  a2-a8, exposure ( py_tot) i
> rr

Poisson regression, normalized by py_tot        Number of obs   =    128
Goodness-of-fit chi2(116)  =  1528.000          Model chi2(11)   =493524.00
> 0
Prob > chi2          =   0.0000                 Prob > chi2      =  0.0000
Log Likelihood       = -1209.000                Pseudo R2        =  0.9951

conv_tot |     IRR       Std. Err.       z       P>|z|     [95% Conf. Interval]
---------+-------------------------------------------------------------
 restric |    .855274    .013065     -10.234   0.000     .8300466    .8812681
     sex |    .3263472   .0009364   -390.269   0.000     .324517     .3281876
   locat |   1.11286     .0029361     40.531   0.000    1.10712     1.118629
 medcond |   1.098466    .0110892      9.303   0.000    1.076946    1.120417
      a2 |    .5942828   .0019013   -162.659   0.000     .5905679    .598021
      a3 |    .3622135   .0013319   -276.176   0.000     .3596124    .3648334
      a4 |    .2603603   .0012385   -282.905   0.000     .2579443    .262799
      a5 |    .1510993   .001022    -279.413   0.000     .1491096    .1531157
      a6 |    .09156     .0008134   -269.129   0.000     .0899797    .0931681
      a7 |    .0657693   .0009096   -196.790   0.000     .0640105    .0675765
      a8 |    .0534395   .0020667    -75.740   0.000     .0495385    .0576477
```

Figure 6: Stata output of the main effects model to predict convictions comparing drivers with or without licensing restrictions

Table 10: Effect of interaction terms on the main effects model for conviction rate comparing drivers with and without a licensing restriction

Interaction term	β	SE (β)	Incidence Rate Ratio	IRR 95% CI	Log Likelihood	P value	Pseudo R^2
Main effects model					-1209		0.9951
Restric*sex	-0.6103	0.0027	1.0314	(0.9726, 1.0938)	-1209	0.302	0.9951
Restric*Age category					-1179		0.9952
Ra2	-0.2481	0.0396	0.7803	(0.7220, 0.8432)		0.000	
Ra3	-0.0139	0.0380	0.9861	(0.9154, 1.0623)		0.713	
Ra4	-0.0563	0.0404	0.9452	(0,8732, 1.0232)		0.164	
Ra5	0.0383	0.0433	1.0390	(0,9545, 1.1310)		0.376	
Ra6	-0.1270	0.0485	0.8807	(0.8008, 0.9685)		0.009	
Ra7	0.0392	0.0575	1.0400	(0.9291, 1.1641)		0.495	
Ra8	0.0412	0.1353	1.0420	(0.7992, 1.3585)		0.761	
Restric*locat	-0.1257	0.0248	0.8819	(0.8340, 0.9259)	-1196	0.000	0.9952
Restric*medcond	-0.1831	0.0426	0.8327	(0.7659, 0.9052)	-1200	0.000	0.9952
Sex*agecat (sa1)					-1022		0.9959
Sa2	0.0174	0.0072	1.0175	(1.0032, 1.0320)		0.016	
Sa3	0.1092	0.0081	1.1154	(1.0979, 1.1332)		0.000	
Sa4	0.0181	0.0106	1.0183	(0.9973, 1.0397)		0.088	
Sa5	-0.1521	0.0160	0.8589	(0.8323, 0.8862)		0.000	
Sa6	-0.1258	0.0217	0.8818	(0.8450, 0.9201)		0.000	
Sa7	0.0210	0.0344	1.0213	(0.9546, 1.0926)		0.542	
Sa8	0.0465	0.1186	1.0476	(0.8304, 1.3217)		0.695	
Medcond*Age category (ma1)					-1161		0.9953
Ma2	-0.1013	0.0247	0.9036	(0.8610, 0.9484)		0.000	
Ma3	0.0440	0.0251	1.0450	(0.9948, 1,0976)		0.079	
Ma4	0.0045	0.0271	1.0045	(0.9526, 1.0592)		0.869	
Ma5	0.0225	0.0298	1.0227	(0.9647, 1.0842)		0.451	
Ma6	-0.0158	0.0328	0.9843	(0.9229, 1.0497)		0.630	
Ma7	0.2166	0.0415	1.2418	(1.1449, 1.3469)		0.000	
Ma8	0.5717	0.0971	1.7714	(1.4645, 2.1426)		0.000	
Sex*medcond	0.0357	0.0027	1.0363	(0.9982, 1. 0758)	-1207	0.062	0.9951

Different interaction terms appear to statistically contribute to the main effects model in explaining convictions. However, none of the interaction terms contribute significantly (by at least 1%) to the pseudo R^2 value. Therefore, the most parsimonious model will remain the main effects model (Figure 6) with all independent variables.

Appendix K: Time Series Analysis Plots

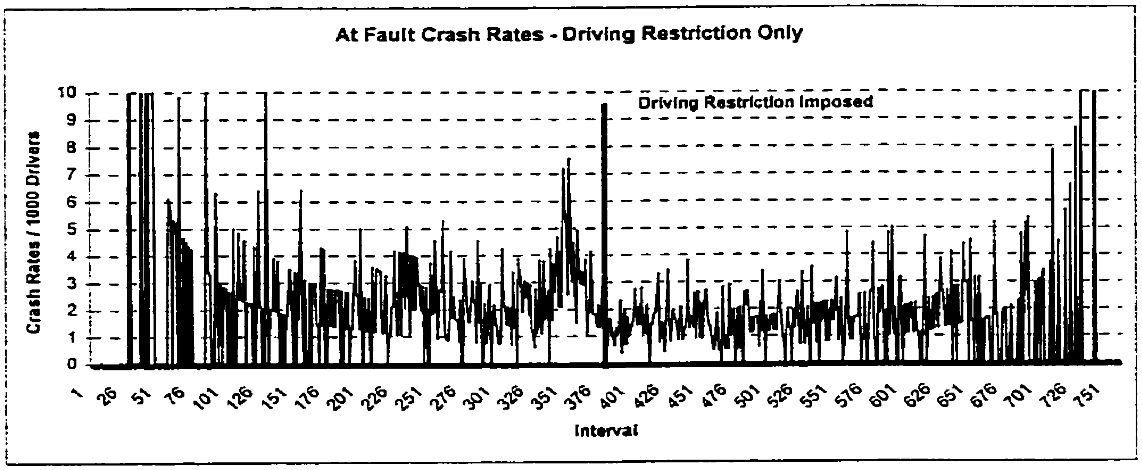

Figure K1: Time series plot of "at-fault" crash rates for drivers pre and post driving restriction over an 8 year time span

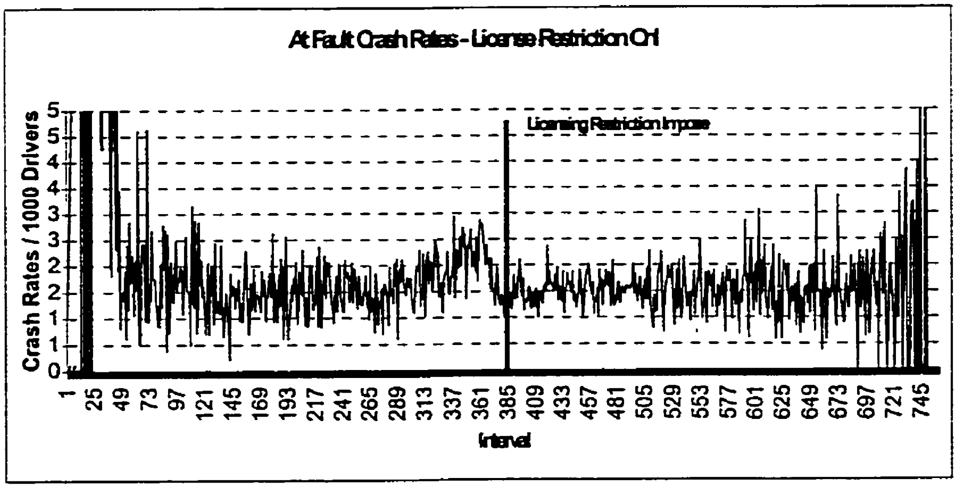

Figure K2: Time series plot of "at-fault" crash rates for drivers pre and post licensing restriction over an 8 year time span

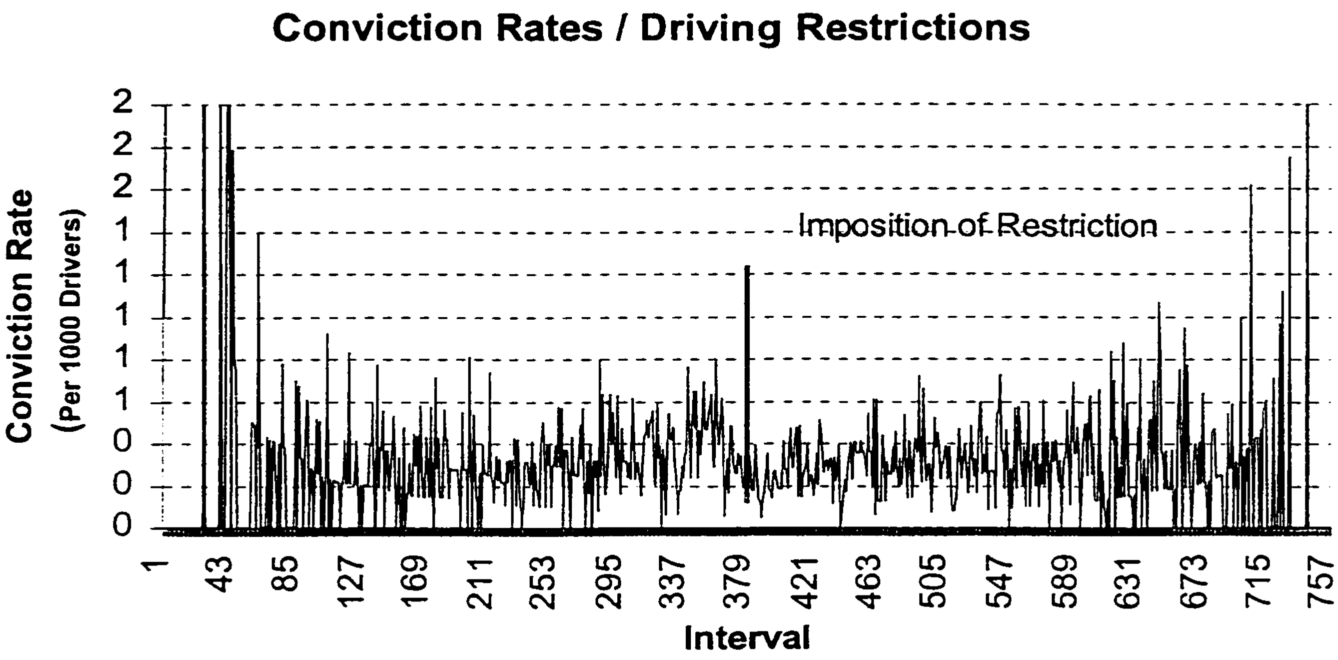

Figure K3: Time series plot of conviction rates pre and post driving restriction

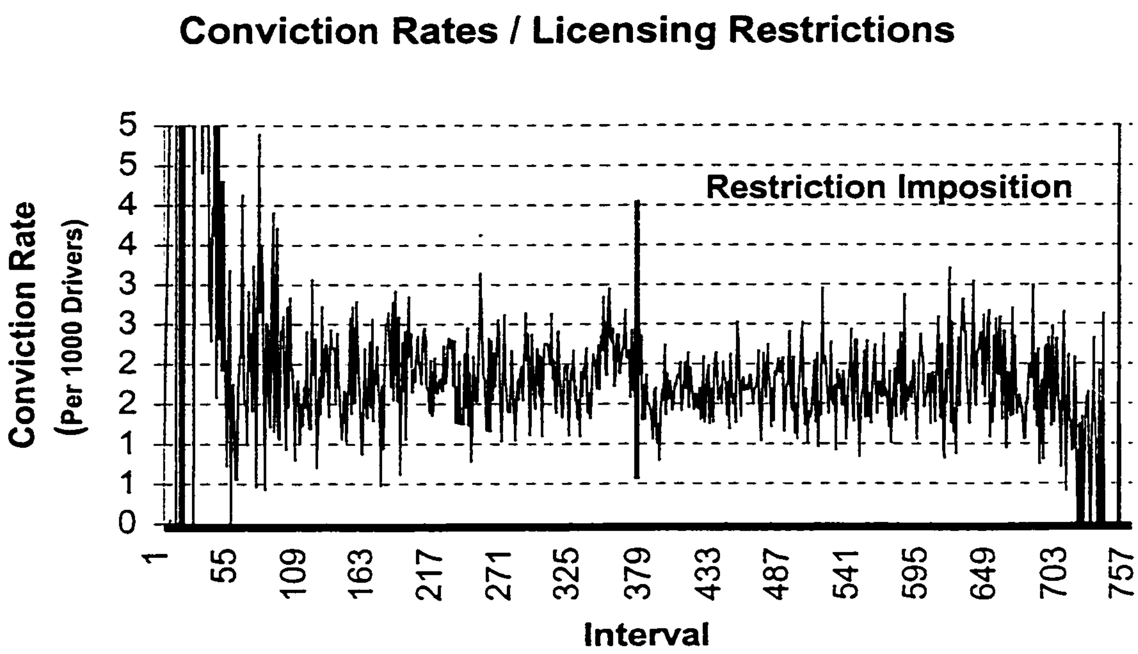

Figure K4: Time series plot of conviction rates pre and post licensing restriction

Appendix L: Interventional Time Series Analysis ARIMA Models (Models 1 to 6)

Model 1: "At-fault" Crash Rate-All Restrictions

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ARIMA Procedure

Maximum Likelihood Estimation

Parameter	Estimate	Approx. Std Error	T Ratio	Lag	Variable	Shift
MU	0.0011227	0.0010481	1.07	0	CRASH_AL	0
MA1,1	0.95704	0.01634	58.55	1	CRASH_AL	0
AR1,1	0.12776	0.05171	2.47	1	CRASH_AL	0
NUM1	-0.50492	0.13895	-3.63	0	RESTRICT	0

Constant Estimate = 0.00097923

Variance Estimate = 0.14407747
Std Error Estimate = 0.37957538
AIC = 380.809123
SBC = 396.931864
Number of Residuals= 416

Correlations of the Estimates

Variable	Parameter	CRASH_AL MU	CRASH_AL MA1,1	CRASH_AL AR1,1	RESTRICT NUM1
CRASH_AL	MU	1.000	0.163	0.045	-0.374
CRASH_AL	MA1,1	0.163	1.000	0.329	-0.279
CRASH_AL	AR1,1	0.045	0.329	1.000	-0.071
RESTRICT	NUM1	-0.374	-0.279	-0.071	1.000

Autocorrelation Check of Residuals

To Lag	Chi Square	DF	Prob	Autocorrelations					
6	2.91	4	0.572	-0.002	0.009	0.022	-0.024	0.021	0.073
12	13.94	10	0.176	0.033	0.089	0.039	-0.108	-0.001	0.060
18	20.43	16	0.202	-0.073	0.015	0.023	-0.074	0.002	-0.059
24	23.28	22	0.386	-0.041	-0.011	-0.068	0.006	0.004	0.008
30	29.71	28	0.377	0.070	-0.041	-0.085	0.006	-0.022	0.008
36	33.85	34	0.475	-0.020	-0.023	0.029	0.019	-0.067	-0.050
42	38.12	40	0.555	0.037	0.014	-0.003	0.011	0.026	-0.083
48	52.81	46	0.228	0.011	-0.049	0.121	-0.058	0.048	-0.092

ARIMA Procedure

Autocorrelation Plot of Residuals

```
Lag Covariance Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1   Std
  0   0.144077    1.00000  |                    |********************|   0
  1 -0.0003592   -0.00249  |                  . | .                  |   0.049029
  2  0.0013375    0.00928  |                  . | .                  |   0.049029
  3  0.0031567    0.02191  |                  . | .                  |   0.049034
  4 -0.0034312   -0.02381  |                  . | .                  |   0.049057
  5  0.0029645    0.02058  |                  . | .                  |   0.049085
  6   0.010507    0.07292  |                  . |*.                  |   0.049106
  7  0.0047485    0.03296  |                  . |*.                  |   0.049365
  8   0.012792    0.08878  |                  . |**                  |   0.049418
  9  0.0055782    0.03872  |                  . |*.                  |   0.049800
 10  -0.015599   -0.10827  |                  **| .                  |   0.049872
 11 -0.0001869   -0.00130  |                  . | .                  |   0.050434
 12  0.0086359    0.05994  |                  . |*.                  |   0.050434
 13  -0.010470   -0.07267  |                  .*| .                  |   0.050605
 14  0.0022091    0.01533  |                  . | .                  |   0.050855
 15  0.0033293    0.02311  |                  . | .                  |   0.050867
 16  -0.010646   -0.07389  |                  .*| .                  |   0.050892
 17 0.00021737    0.00151  |                  . | .                  |   0.051149
 18 -0.0084297   -0.05851  |                  .*| .                  |   0.051149
 19 -0.0058534   -0.04063  |                  .*| .                  |   0.051310
 20 -0.0015905   -0.01104  |                  . | .                  |   0.051387
 21 -0.0097561   -0.06771  |                  .*| .                  |   0.051393
 22 0.00091542    0.00635  |                  . | .                  |   0.051607
 23 0.00055055    0.00382  |                  . | .                  |   0.051609
 24  0.0012058    0.00837  |                  . | .                  |   0.051609

                          "." marks two standard errors
```

```
                                   (1,1,1)              08:58 Friday,
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                                ARIMA Procedure

                            Inverse Autocorrelations

         Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
           1    0.00751   |                 . | .                 |
           2   -0.01675   |                 . | .                 |
           3    0.01441   |                 . | .                 |
           4    0.00741   |                 . | .                 |
           5   -0.02286   |                 . | .                 |
           6   -0.05566   |                 .*| .                 |
           7   -0.03835   |                 .*| .                 |
           8   -0.09121   |                 **| .                 |
           9   -0.04280   |                 .*| .                 |
          10    0.09682   |                 . |**                 |
          11   -0.00188   |                 . | .                 |
          12   -0.07325   |                 .*| .                 |
          13    0.05812   |                 . |*.                 |
          14   -0.00399   |                 . | .                 |
          15   -0.02091   |                 . | .                 |
          16    0.06789   |                 . |*.                 |
          17    0.00728   |                 . | .                 |
          18    0.04322   |                 . |*.                 |
          19    0.02459   |                 . | .                 |
          20    0.03055   |                 . |*.                 |
          21    0.05669   |                 . |*.                 |
          22   -0.02915   |                 .*| .                 |
          23    0.00615   |                 . | .                 |
          24   -0.02421   |                 . | .                 |
```

ARIMA Procedure

Partial Autocorrelations

```
Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
  1   -0.00249  |                  . | .                  |
  2    0.00928  |                  . | .                  |
  3    0.02196  |                  . | .                  |
  4   -0.02380  |                  . | .                  |
  5    0.02008  |                  . | .                  |
  6    0.07308  |                  . |*.                  |
  7    0.03421  |                  . |*.                  |
  8    0.08687  |                  . |**                  |
  9    0.03775  |                  . |*.                  |
 10   -0.10885  |                  **| .                  |
 11   -0.00874  |                  . | .                  |
 12    0.05930  |                  . |*.                  |
 13   -0.07653  |                  **| .                  |
 14   -0.00699  |                  . | .                  |
 15    0.01718  |                  . | .                  |
 16   -0.06676  |                  .*| .                  |
 17   -0.00391  |                  . | .                  |
 18   -0.04448  |                  .*| .                  |
 19   -0.02584  |                  .*| .                  |
 20   -0.03146  |                  .*| .                  |
 21   -0.06003  |                  .*| .                  |
 22    0.03139  |                  . |*.                  |
 23   -0.00672  |                  . | .                  |
 24    0.02543  |                  . |*.                  |
```

```
Model for variable CRASH_AL

Estimated Intercept = 0.00112265
Period(s) of Differencing = 1.

Autoregressive Factors
Factor 1: 1 - 0.12776 B**(1)


Moving Average Factors
Factor 1: 1 - 0.95704 B**(1)


Input Number 1 is RESTRICT.
Period(s) of Differencing = 1.
Overall Regression Factor  = -0.50492
```

Model 2: Conviction Rate-All Restrictions

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ARIMA Procedure

Maximum Likelihood Estimation

Parameter	Estimate	Approx. Std Error	T Ratio	Lag	Variable	Shift
MU	1.98299	0.04046	49.02	0	CON_ALL	0
MA1,1	-0.14028	0.04853	-2.89	1	CON_ALL	0
MA1,2	-0.14711	0.04883	-3.01	2	CON_ALL	0
AR1,1	0.10179	0.04923	2.07	5	CON_ALL	0
NUM1	-0.19996	0.05700	-3.51	0	RESTRICT	0

Constant Estimate = 1.78115204

Variance Estimate = 0.16739608
Std Error Estimate = 0.40914067
AIC = 443.135429
SBC = 463.30086
Number of Residuals= 417

Correlations of the Estimates

Variable	Parameter	CON_ALL MU	CON_ALL MA1,1	CON_ALL MA1,2	CON_ALL AR1,1	RESTRICT NUM1
CON_ALL	MU	1.000	-0.003	-0.002	-0.015	-0.706
CON_ALL	MA1,1	-0.003	1.000	0.118	0.011	0.004
CON_ALL	MA1,2	-0.002	0.118	1.000	-0.015	0.004
CON_ALL	AR1,1	-0.015	0.011	-0.015	1.000	0.026
RESTRICT	NUM1	-0.706	0.004	0.004	0.026	1.000

Autocorrelation Check of Residuals

To Lag	Chi Square	DF	Prob	Autocorrelations					
6	1.81	3	0.613	-0.009	-0.011	-0.057	-0.007	-0.014	-0.024
12	10.10	9	0.343	0.043	0.014	-0.021	0.118	-0.019	0.052
18	19.14	15	0.207	-0.006	-0.094	-0.028	0.022	-0.066	0.078
24	26.43	21	0.191	-0.058	-0.011	-0.008	0.021	0.074	-0.084
30	34.13	27	0.162	0.004	-0.044	-0.005	-0.074	-0.080	-0.057
36	37.85	33	0.258	-0.032	0.012	-0.049	-0.025	0.016	-0.061
42	46.54	39	0.190	-0.050	0.044	0.025	-0.059	0.090	-0.045
48	51.19	45	0.244	0.037	-0.020	0.039	-0.006	-0.004	0.081

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ARIMA Procedure

Autocorrelation Plot of Residuals

```
Lag Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1   Std
  0  0.167396     1.00000   |                    |********************|  0
  1 -0.0015768   -0.00942   |                  . | .                  |  0.048970
  2 -0.0018398   -0.01099   |                  . | .                  |  0.048975
  3 -0.0095504   -0.05705   |                  .*| .                  |  0.048980
  4 -0.0011115   -0.00664   |                  . | .                  |  0.049140
  5 -0.0022752   -0.01359   |                  . | .                  |  0.049142
  6 -0.0040668   -0.02429   |                  . | .                  |  0.049151
  7  0.0071544    0.04274   |                  . |*.                  |  0.049180
  8  0.0024178    0.01444   |                  . | .                  |  0.049269
  9 -0.0034803   -0.02079   |                  . | .                  |  0.049279
 10   0.019671    0.11751   |                  . |**                  |  0.049300
 11 -0.0032047   -0.01914   |                  . | .                  |  0.049967
 12  0.0086398    0.05161   |                  . |*.                  |  0.049984
 13 -0.0010869   -0.00649   |                  . | .                  |  0.050112
 14  -0.015801   -0.09439   |                  **| .                  |  0.050114
 15 -0.0047565   -0.02841   |                  .*| .                  |  0.050539
 16  0.0036342    0.02171   |                  . | .                  |  0.050577
 17  -0.011104   -0.06633   |                  .*| .                  |  0.050599
 18   0.013104    0.07828   |                  . |**                  |  0.050807
 19 -0.0096568   -0.05769   |                  .*| .                  |  0.051096
 20 -0.0018854   -0.01126   |                  . | .                  |  0.051252
 21 -0.0013251   -0.00792   |                  . | .                  |  0.051258
 22  0.0034451    0.02058   |                  . | .                  |  0.051261
 23   0.012408    0.07412   |                  . |*.                  |  0.051280
 24  -0.014017   -0.08373   |                  **| .                  |  0.051537

                               "." marks two standard errors
```

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ARIMA Procedure

Inverse Autocorrelations

```
Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
  1   -0.03314   |                  .*| .                  |
  2    0.01967   |                  . | .                  |
  3    0.08860   |                  . |**                  |
  4   -0.05073   |                  .*| .                  |
```

```
  5     0.03347  |                    .  |* .                  |
  6     0.03259  |                    .  |* .                  |
  7    -0.09290  |                   **  | .                   |
  8     0.00945  |                    .  | .                   |
  9    -0.00269  |                    .  | .                   |
 10    -0.12664  |                  ***  | .                   |
 11     0.05386  |                    .  |* .                  |
 12    -0.06292  |                    .* | .                   |
 13     0.00044  |                    .  | .                   |
 14     0.09754  |                    .  |**                   |
 15     0.01168  |                    .  | .                   |
 16    -0.01302  |                    .  | .                   |
 17     0.08338  |                    .  |**                   |
 18    -0.07632  |                   **  | .                   |
 19     0.06112  |                    .  |* .                  |
 20     0.02994  |                    .  |* .                  |
 21    -0.01381  |                    .  | .                   |
 22     0.00214  |                    .  | .                   |
 23    -0.06505  |                    .* | .                   |
 24     0.04996  |                    .  |* .                  |
                          (5,0,1-2)            21:03 Thursday,
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                          ARIMA Procedure

                      Partial Autocorrelations

Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
  1    -0.00942  |                    .  | .                   |
  2    -0.01108  |                    .  | .                   |
  3    -0.05727  |                    .* | .                   |
  4    -0.00791  |                    .  | .                   |
  5    -0.01509  |                    .  | .                   |
  6    -0.02814  |                    .* | .                   |
  7     0.04117  |                    .  |* .                  |
  8     0.01305  |                    .  | .                   |
  9    -0.02287  |                    .  | .                   |
 10     0.12257  |                    .  |**                   |
 11    -0.01649  |                    .  | .                   |
 12     0.05345  |                    .  |* .                  |
 13     0.01094  |                    .  | .                   |
 14    -0.09820  |                   **  | .                   |
 15    -0.02263  |                    .  | .                   |
 16     0.02727  |                    .  |* .                  |
 17    -0.09226  |                   **  | .                   |
 18     0.07983  |                    .  |**                   |
 19    -0.06152  |                    .* | .                   |
 20    -0.04434  |                    .* | .                   |
 21     0.02025  |                    .  | .                   |
 22     0.00083  |                    .  | .                   |
 23     0.06875  |                    .  |* .                  |
 24    -0.05354  |                    .* | .                   |

      Model for variable CON_ALL

      Estimated Intercept = 1.98299493

      Autoregressive Factors
      Factor 1: 1 - 0.10179 B**(5)

      Moving Average Factors
      Factor 1: 1 + 0.14028 B**(1) + 0.14711 B**(2)


      Input Number 1 is RESTRICT.
      Overall Regression Factor  = -0.1999
```

Model 3: "At-fault" Crash Rate-Driving Restrictions

(3-6,0,5) 08:58 Friday, May 12, 2000 220

ARIMA Procedure

Maximum Likelihood Estimation

Parameter	Estimate	Approx. Std Error	T Ratio	Lag	Variable	Shift
MU	2.25780	0.11962	18.88	0	CRASHD	0
MA1,1	-0.08335	0.04963	-1.68	5	CRASHD	0
AR1,1	0.13413	0.04880	2.75	3	CRASHD	0
AR1,2	0.15661	0.04912	3.19	6	CRASHD	0
NUM1	-0.75907	0.16765	-4.53	0	RESTRICT	0

Constant Estimate = 1.60138889

Variance Estimate = 1.31094156
Std Error Estimate = 1.14496356
AIC = 1301.52615
SBC = 1321.69158
Number of Residuals= 417

Correlations of the Estimates

Variable	Parameter	CRASHD MU	CRASHD MA1,1	CRASHD AR1,1	CRASHD AR1,2	RESTRICT NUM1
CRASHD	MU	1.000	-0.001	0.002	-0.005	-0.702
CRASHD	MA1,1	-0.001	1.000	0.037	0.064	0.000
CRASHD	AR1,1	0.002	0.037	1.000	-0.163	-0.011
CRASHD	AR1,2	-0.005	0.064	-0.163	1.000	0.007
RESTRICT	NUM1	-0.702	0.000	-0.011	0.007	1.000

Autocorrelation Check of Residuals

To Lag	Chi Square	DF	Prob	Autocorrelations					
6	2.13	3	0.547	0.053	0.045	-0.007	0.009	0.006	-0.010
12	8.58	9	0.476	0.086	-0.025	0.042	0.063	-0.033	0.016
18	13.79	15	0.541	0.041	0.011	-0.031	0.034	0.048	0.075
24	24.90	21	0.252	0.050	-0.031	-0.107	-0.076	-0.010	-0.065
30	29.96	27	0.316	0.040	0.053	-0.046	0.065	-0.015	-0.016
36	34.59	33	0.392	-0.063	0.003	-0.072	0.012	-0.011	-0.028
42	38.74	39	0.482	0.012	-0.037	-0.005	-0.072	0.048	-0.006
48	40.08	45	0.680	0.005	-0.011	0.006	-0.033	-0.019	0.035

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ARIMA Procedure

Autocorrelation Plot of Residuals

```
Lag Covariance   Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1     Std
  0  1.310942      1.00000   |                    |********************|   0
  1  0.069539      0.05304   |                  . |* .                 |   0.048970
  2  0.058376      0.04453   |                  . |* .                 |   0.049108
  3 -0.0094191    -0.00718   |                  . |  .                 |   0.049205
  4  0.011426      0.00872   |                  . |  .                 |   0.049207
  5  0.0072618     0.00554   |                  . |  .                 |   0.049211
  6 -0.013114     -0.01000   |                  . |  .                 |   0.049212
  7  0.112622      0.08591   |                  . |**                  |   0.049217
  8 -0.033260     -0.02537   |                  .*|  .                 |   0.049575
  9  0.055153      0.04207   |                  . |* .                 |   0.049607
 10  0.082479      0.06292   |                  . |* .                 |   0.049692
 11 -0.043521     -0.03320   |                  .*|  .                 |   0.049883
 12  0.020594      0.01571   |                  . |  .                 |   0.049936
 13  0.053882      0.04110   |                  . |* .                 |   0.049948
 14  0.014512      0.01107   |                  . |  .                 |   0.050029
 15 -0.041128     -0.03137   |                  .*|  .                 |   0.050034
 16  0.045148      0.03444   |                  . |* .                 |   0.050082
 17  0.062398      0.04760   |                  . |* .                 |   0.050138
 18  0.098854      0.07541   |                  . |**                  |   0.050247
 19  0.065847      0.05023   |                  . |* .                 |   0.050517
 20 -0.040848     -0.03116   |                  .*|  .                 |   0.050637
 21 -0.140689     -0.10732   |                  **|  .                 |   0.050683
 22 -0.100102     -0.07636   |                  **|  .                 |   0.051225
 23 -0.012815     -0.00978   |                  . |  .                 |   0.051497
 24 -0.084922     -0.06478   |                  .*|  .                 |   0.051502

                     "." marks two standard errors
```

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ARIMA Procedure

Inverse Autocorrelations

```
Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
  1   -0.02908   |                  .*|  .                 |
```

```
  2   -0.03967   |                    .*| .                   |
  3    0.02401   |                    . | .                   |
  4   -0.02828   |                    .*| .                   |
  5   -0.00664   |                    . | .                   |
  6    0.02140   |                    . | .                   |
  7   -0.08976   |                    **| .                   |
  8    0.02998   |                    . |*.                   |
  9   -0.02111   |                    . | .                   |
 10   -0.06235   |                    .*| .                   |
 11    0.04202   |                    . |*.                   |
 12   -0.01613   |                    . | .                   |
 13   -0.04716   |                    .*| .                   |
 14   -0.01241   |                    . | .                   |
 15    0.02027   |                    . | .                   |
 16   -0.02031   |                    . | .                   |
 17   -0.03636   |                    .*| .                   |
 18   -0.07100   |                    .*| .                   |
 19   -0.04229   |                    .*| .                   |
 20    0.03135   |                    . |*.                   |
 21    0.09347   |                    . |**                   |
 22    0.05692   |                    . |*.                   |
 23    0.00265   |                    . | .                   |
 24    0.05671   |                    . |*.                   |
```


ARIMA Procedure

Partial Autocorrelations

```
Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
  1    0.05304   |                    . |*.                   |
  2    0.04183   |                    . |*.                   |
  3   -0.01172   |                    . | .                   |
  4    0.00785   |                    . | .                   |
  5    0.00554   |                    . | .                   |
  6   -0.01143   |                    . | .                   |
  7    0.08712   |                    . |**                   |
  8   -0.03378   |                    .*| .                   |
  9    0.03798   |                    . |*.                   |
 10    0.06395   |                    . |*.                   |
 11   -0.04639   |                    .*| .                   |
 12    0.01592   |                    . | .                   |
 13    0.04694   |                    . |*.                   |
 14   -0.00652   |                    . | .                   |
 15   -0.02850   |                    .*| .                   |
 16    0.03378   |                    . |*.                   |
 17    0.03651   |                    . |*.                   |
 18    0.07826   |                    . |**                   |
 19    0.03231   |                    . |*.                   |
 20   -0.05061   |                    .*| .                   |
 21   -0.10291   |                    **| .                   |
 22   -0.06566   |                    .*| .                   |
 23   -0.00763   |                    . | .                   |
 24   -0.05969   |                    .*| .                   |
```

Model for variable CRASHD

Estimated Intercept = 2.25780249

Autoregressive Factors
Factor 1: 1 - 0.13413 B**(3) - 0.15661 B**(6)

```
Moving Average Factors
Factor 1: 1 + 0.083346 B**(5)


Input Number 1 is RESTRICT.
Overall Regression Factor  = -0.75907


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                          ARIMA Procedure

                     Partial Autocorrelations

Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
  1    0.05675  |                    . |*.                  |
  2   -0.01668  |                    . | .                  |
  3   -0.00071  |                    . | .                  |
  4   -0.05352  |                    .*| .                  |
  5   -0.01859  |                    . | .                  |
  6    0.02868  |                    . |*.                  |
  7    0.07625  |                    . |**                  |
  8    0.05689  |                    . |*.                  |
  9    0.07578  |                    . |**                  |
 10   -0.10969  |                    **| .                  |
 11   -0.02647  |                    .*| .                  |
 12    0.01041  |                    . | .                  |
 13   -0.09758  |                    **| .                  |
 14    0.03676  |                    . |*.                  |
 15    0.00037  |                    . | .                  |
 16   -0.07323  |                    .*| .                  |
 17   -0.07183  |                    .*| .                  |
 18    0.01238  |                    . | .                  |
 19   -0.01371  |                    . | .                  |
 20   -0.04021  |                    .*| .                  |
 21   -0.03737  |                    .*| .                  |
 22    0.02179  |                    . | .                  |
 23    0.00064  |                    . | .                  |
 24    0.00302  |                    . | .                  |


Model for variable CRASHL


Estimated Intercept = 0.00098226

Period(s) of Differencing = 1.


Moving Average Factors

Factor 1: 1 - 0.9132 B**(1)

Input Number 1 is RESTRICT.

Period(s) of Differencing = 1.

Overall Regression Factor  =   -0.448
```

Model 4: Conviction Rate-Driving Restrictions

ARIMA Procedure

Maximum Likelihood Estimation

Parameter	Estimate	Approx. Std Error	T Ratio	Lag	Variable	Shift
MU	0.32207	0.01283	25.11	0	CON_DRIV	0
MA1,1	-0.07046	0.04923	-1.43	2	CON_DRIV	0
AR1,1	0.07964	0.04934	1.61	3	CON_DRIV	0
NUM1	-0.01862	0.01810	-1.03	0	RESTRICT	0

Constant Estimate = 0.29642148

Variance Estimate = 0.02539618
Std Error Estimate = 0.15936179
AIC = -344.30177
SBC = -328.16942
Number of Residuals= 417

Correlations of the Estimates

Variable	Parameter	CON_DRIV MU	CON_DRIV MA1,1	CON_DRIV AR1,1	RESTRICT NUM1
CON_DRIV	MU	1.000	-0.001	-0.003	-0.707
CON_DRIV	MA1,1	-0.001	1.000	0.011	0.002
CON_DRIV	AR1,1	-0.003	0.011	1.000	0.008
RESTRICT	NUM1	-0.707	0.002	0.008	1.000

Autocorrelation Check of Residuals

To Lag	Chi Square	DF	Prob	Autocorrelations					
6	1.91	4	0.752	-0.002	0.005	-0.001	0.061	0.028	0.004
12	11.33	10	0.332	0.024	0.011	0.096	0.025	0.056	0.091
18	19.34	16	0.251	0.071	0.062	0.060	-0.013	-0.047	0.061
24	22.81	22	0.412	-0.030	-0.060	-0.023	0.046	0.018	0.019
30	24.12	28	0.675	0.004	0.012	0.010	0.004	-0.039	0.032
36	31.49	34	0.591	0.021	0.011	-0.096	0.073	0.026	0.020
42	35.68	40	0.665	-0.017	-0.060	0.061	-0.011	0.024	-0.027
48	39.22	46	0.750	-0.002	-0.013	0.007	0.047	0.067	0.024

ARIMA Procedure

Autocorrelation Plot of Residuals

```
                Lag Covariance Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
Std
                  0   0.025396    1.00000  |                    |********************|
0
                  1 -0.0000389   -0.00153  |                  . | .                  |
0.048970
                  2 0.00011664    0.00459  |                  . | .                  |
0.048970
                  3 -0.0000227   -0.00089  |                  . | .                  |
0.048971
                  4  0.0015476    0.06094  |                  . |*.                  |
0.048971
                  5 0.00070105    0.02760  |                  . |*.                  |
0.049153
                  6 0.00010639    0.00419  |                  . | .                  |
0.049190
                  7 0.00061005    0.02402  |                  . | .                  |
0.049191
                  8 0.00028565    0.01125  |                  . | .                  |
0.049219
                  9  0.0024385    0.09602  |                  . |**                  |
0.049225
                 10 0.00063645    0.02506  |                  . |*.                  |
0.049672
                 11  0.0014198    0.05591  |                  . |*.                  |
0.049703
                 12  0.0023050    0.09076  |                  . |**                  |
0.049853
                 13  0.0017913    0.07053  |                  . |*.                  |
0.050248
                 14  0.0015641    0.06159  |                  . |*.                  |
0.050485
                 15  0.0015337    0.06039  |                  . |*.                  |
0.050665
                 16 -0.0003249   -0.01279  |                  . | .                  |
0.050837
                 17 -0.0011903   -0.04687  |                  .*| .                  |
0.050845
                 18  0.0015365    0.06050  |                  . |*.                  |
0.050948
                 19 -0.0007532   -0.02966  |                  .*| .                  |
0.051120
                 20 -0.0015231   -0.05997  |                  .*| .                  |
0.051161
                 21 -0.0005952   -0.02344  |                  . | .                  |
0.051330
                 22  0.0011808    0.04649  |                  . |*.                  |
0.051355
                 23 0.00045896    0.01807  |                  . | .                  |
0.051456
                 24 0.00047339    0.01864  |                  . | .                  |
0.051471
                                                   "." marks two standard errors

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                                              ARIMA Procedure

                                             Inverse Autocorrelations

                      Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
                       1     0.05612  |                  . |*.                  |
                       2     0.03427  |                  . |*.                  |
                       3     0.04668  |                  . |*.                  |
                       4    -0.02873  |                  .*| .                  |
                       5    -0.02064  |                  . | .                  |
```

```
  6   -0.00732  |                   . | .                  |
  7   -0.03613  |                   .*| .                  |
  8   -0.03114  |                   .*| .                  |
  9   -0.09714  |                   **| .                  |
 10   -0.03984  |                   .*| .                  |
 11   -0.06811  |                   .*| .                  |
 12   -0.10845  |                   **| .                  |
 13   -0.06906  |                   .*| .                  |
 14   -0.05665  |                   .*| .                  |
 15   -0.06142  |                   .*| .                  |
 16    0.01805  |                   . | .                  |
 17    0.05656  |                   . |*.                  |
 18   -0.03020  |                   .*| .                  |
 19    0.04994  |                   . |*.                  |
 20    0.07841  |                   . |**                  |
 21    0.04185  |                   . |*.                  |
 22   -0.01458  |                   . | .                  |
 23    0.00670  |                   . | .                  |
 24    0.00030  |                   . | .                  |

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                       ARIMA Procedure

                   Partial Autocorrelations

Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
  1   -0.00153  |                   . | .                  |
  2    0.00459  |                   . | .                  |
  3   -0.00088  |                   . | .                  |
  4    0.06092  |                   . |*.                  |
  5    0.02790  |                   . |*.                  |
  6    0.00379  |                   . | .                  |
  7    0.02402  |                   . | .                  |
  8    0.00775  |                   . | .                  |
  9    0.09301  |                   . |**                  |
 10    0.02489  |                   . | .                  |
 11    0.05340  |                   . |*.                  |
 12    0.09107  |                   . |**                  |
 13    0.06239  |                   . |*.                  |
 14    0.05831  |                   . |*.                  |
 15    0.05845  |                   . |*.                  |
 16   -0.02528  |                   .*| .                  |
 17   -0.06052  |                   .*| .                  |
 18    0.04022  |                   . |*.                  |
 19   -0.04910  |                   .*| .                  |
 20   -0.08071  |                   **| .                  |
 21   -0.04496  |                   .*| .                  |
 22    0.01583  |                   . | .                  |
 23   -0.00707  |                   . | .                  |
 24   -0.00031  |                   . | .                  |

          Model for variable CON_DRIV

          Estimated Intercept = 0.32207032

          Autoregressive Factors

          Factor 1: 1 - 0.079637 B**(3)

          Moving Average Factors

          Factor 1: 1 + 0.070462 B**(2)

         Input Number 1 is RESTRICT.

          Overall Regression Factor  = -0.01862
```

Model 5: "At-fault" Crash Rate-Driving Restrictions

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ARIMA Procedure

Maximum Likelihood Estimation

Parameter	Estimate	Approx. Std Error	T Ratio	Lag	Variable	Shift
MU	0.0009823	0.0017840	0.55	0	CRASHL	0
MA1,1	0.91320	0.02265	40.31	1	CRASHL	0
NUM1	-0.44800	0.18375	-2.44	0	RESTRICT	0

Constant Estimate = 0.00098226

Variance Estimate = 0.15519921
Std Error Estimate = 0.39395331
AIC = 410.314279
SBC = 422.406335
Number of Residuals= 416

Correlations of the Estimates

Variable	Parameter	CRASHL MU	CRASHL MA1,1	RESTRICT NUM1
CRASHL	MU	1.000	0.136	-0.270
CRASHL	MA1,1	0.136	1.000	-0.441
RESTRICT	NUM1	-0.270	-0.441	1.000

Autocorrelation Check of Residuals

To Lag	Chi Square	DF	Prob	Autocorrelations					
6	3.21	5	0.668	0.057	-0.013	-0.002	-0.053	-0.025	0.028
12	16.17	11	0.135	0.080	0.067	0.081	-0.103	-0.048	0.002
18	25.62	17	0.082	-0.100	0.040	0.028	-0.059	-0.077	-0.005
24	27.66	23	0.229	-0.038	-0.044	-0.027	0.008	0.020	-0.008
30	31.19	29	0.357	0.050	-0.003	-0.051	-0.028	-0.005	0.043
36	35.36	35	0.451	-0.017	-0.011	0.049	-0.011	-0.048	-0.062
42	40.54	41	0.491	0.024	0.044	-0.040	-0.004	-0.016	-0.083
48	50.67	47	0.331	0.012	0.015	0.086	-0.066	0.050	-0.083

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ARIMA Procedure

Autocorrelation Plot of Residuals

```
            Lag Covariance Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
Std
              0   0.155199     1.00000  |                    |********************|
0
              1  0.0088071     0.05675  |                  . |*.                  |
0.049029
              2 -0.0020813    -0.01341  |                  . | .                  |
0.049187
```

```
                 3 -0.0003763   -0.00242  |                    . | .                    |
0.049195
                 4 -0.0082703   -0.05329  |                    .*| .                    |
0.049196
                 5 -0.0038140   -0.02457  |                    . | .                    |
0.049334
                 6  0.0042948    0.02767  |                    . |*.                    |
0.049364
                 7   0.012350    0.07957  |                    . |**                    |
0.049401
                 8   0.010366    0.06679  |                    . |*.                    |
0.049708
                 9   0.012613    0.08127  |                    . |**                    |
0.049923
                10   -0.016041  -0.10335  |                    **| .                    |
0.050240
                11 -0.0073810   -0.04756  |                    .*| .                    |
0.050749
                12 0.00026321    0.00170  |                    . | .                    |
0.050856
                13   -0.015591  -0.10046  |                    **| .                    |
0.050856
                14  0.0061433    0.03958  |                    . |*.                    |
0.051331
                15  0.0042788    0.02757  |                    . |*.                    |
0.051404
                16 -0.0091955   -0.05925  |                    .*| .                    |
0.051440
                17   -0.011887  -0.07659  |                    **| .                    |
0.051604
                18 -0.0007417   -0.00478  |                    . | .                    |
0.051876
                19 -0.0058699   -0.03782  |                    .*| .                    |
0.051877
                20 -0.0068344   -0.04404  |                    .*| .                    |
0.051943
                21 -0.0042409   -0.02733  |                    .*| .                    |
0.052033
                22  0.0012781    0.00824  |                    . | .                    |
0.052068
                23  0.0030706    0.01978  |                    . | .                    |
0.052071
                24 -0.0012930   -0.00833  |                    . | .                    |
0.052089
                                                   "." marks two standard errors


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                                                  ARIMA Procedure


                                              Inverse Autocorrelations

                       Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
                         1    -0.04589  |                    .*| .                    |
                         2     0.00617  |                    . | .                    |
                         3     0.00750  |                    . | .                    |
                         4     0.03419  |                    . |*.                    |
                         5     0.01103  |                    . | .                    |
                         6    -0.00438  |                    . | .                    |
                         7    -0.05853  |                    .*| .                    |
                         8    -0.05307  |                    .*| .                    |
                         9    -0.08943  |                    **| .                    |
                        10     0.09354  |                    . |**                    |
                        11     0.02834  |                    . |*.                    |
```

```
 12   -0.02857  |                   .*| .                  |
 13    0.09415  |                   . |**                  |
 14   -0.03715  |                   .*| .                  |
 15   -0.00169  |                   . | .                  |
 16    0.06668  |                   . |*.                  |
 17    0.07242  |                   . |*.                  |
 18   -0.01351  |                   . | .                  |
 19    0.00970  |                   . | .                  |
 20    0.03358  |                   . |*.                  |
 21    0.03741  |                   . |*.                  |
 22   -0.02062  |                   . | .                  |
 23   -0.00031  |                   . | .                  |
 24   -0.00285  |                   . | .                  |
```

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ARIMA Procedure

Partial Autocorrelations

```
Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
  1    0.05675  |                   . |*.                  |
  2   -0.01668  |                   . | .                  |
  3   -0.00071  |                   . | .                  |
  4   -0.05352  |                   .*| .                  |
  5   -0.01859  |                   . | .                  |
  6    0.02868  |                   . |*.                  |
  7    0.07625  |                   . |**                  |
  8    0.05689  |                   . |*.                  |
  9    0.07578  |                   . |**                  |
 10   -0.10969  |                   **| .                  |
 11   -0.02647  |                   .*| .                  |
 12    0.01041  |                   . | .                  |
 13   -0.09758  |                   **| .                  |
 14    0.03676  |                   . |*.                  |
 15    0.00037  |                   . | .                  |
 16   -0.07323  |                   .*| .                  |
 17   -0.07183  |                   .*| .                  |
 18    0.01238  |                   . | .                  |
 19   -0.01371  |                   . | .                  |
 20   -0.04021  |                   .*| .                  |
 21   -0.03737  |                   .*| .                  |
 22    0.02179  |                   . | .                  |
 23    0.00064  |                   . | .                  |
 24    0.00302  |                   . | .                  |
```

```
Model for variable CRASHL

Estimated Intercept = 0.00098226
Period(s) of Differencing = 1.

Moving Average Factors
Factor 1: 1 - 0.9132 B**(1)


Input Number 1 is RESTRICT.
Period(s) of Differencing = 1.
Overall Regression Factor  =   -0.448
```

Model 6: Conviction Rate-Licensing Restrictions

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ARIMA Procedure

Maximum Likelihood Estimation

Parameter	Estimate	Approx. Std Error	T Ratio	Lag	Variable	Shift
MU	1.88381	0.04141	45.50	0	CON_LIC	0
MA1,1	-0.13397	0.04845	-2.76	1	CON_LIC	0
MA1,2	-0.16331	0.04871	-3.35	2	CON_LIC	0
AR1,1	0.11145	0.04906	2.27	5	CON_LIC	0
NUM1	-0.20355	0.05832	-3.49	0	RESTRICT	0

Constant Estimate = 1.67386057

Variance Estimate = 0.16915579
Std Error Estimate = 0.41128554
AIC = 447.516033
SBC = 467.681464
Number of Residuals= 417

Correlations of the Estimates

Variable	Parameter	CON_LIC MU	CON_LIC MA1,1	CON_LIC MA1,2	CON_LIC AR1,1	RESTRICT NUM1
CON_LIC	MU	1.000	0.001	-0.001	-0.015	-0.706
CON_LIC	MA1,1	0.001	1.000	0.110	-0.001	-0.001
CON_LIC	MA1,2	-0.001	0.110	1.000	-0.010	0.001
CON_LIC	AR1,1	-0.015	-0.001	-0.010	1.000	0.024
RESTRICT	NUM1	-0.706	-0.001	0.001	0.024	1.000

Autocorrelation Check of Residuals

To Lag	Chi Square	DF	Prob	Autocorrelations					
6	1.57	3	0.665	-0.010	-0.012	-0.055	-0.017	-0.012	-0.004
12	9.55	9	0.388	0.002	0.010	-0.083	0.096	0.027	0.039
18	17.70	15	0.279	-0.027	-0.091	-0.009	0.042	-0.057	0.067
24	19.13	21	0.576	-0.029	0.001	-0.008	-0.012	0.047	-0.002
30	25.13	27	0.567	0.013	-0.030	-0.001	-0.068	-0.083	-0.027
36	29.80	33	0.627	-0.032	0.003	-0.048	-0.014	-0.004	-0.081
42	36.83	39	0.569	-0.041	0.077	-0.001	-0.058	0.065	-0.008
48	41.75	45	0.610	0.031	0.010	0.020	-0.027	-0.017	0.089

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ARIMA Procedure

Autocorrelation Plot of Residuals

```
                      Lag Covariance Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
Std
                        0   0.169156    1.00000   |                    |********************|
0
                        1 -0.0016966   -0.01003   |                  . | .                  |
0.048970
                        2 -0.0019505   -0.01153   |                  . | .                  |
0.048975
                        3 -0.0093342   -0.05518   |                  .*| .                  |
0.048982
                        4 -0.0029013   -0.01715   |                  . | .                  |
0.049130
                        5 -0.0020048   -0.01185   |                  . | .                  |
0.049145
                        6 -0.0006303   -0.00373   |                  . | .                  |
0.049152
                        7  0.0003889    0.00230   |                  . | .                  |
0.049152
                        8  0.0016243    0.00960   |                  . | .                  |
0.049153
                        9  -0.014122   -0.08349   |                  **| .                  |
0.049157
                       10   0.016265    0.09616   |                  . |**                  |
0.049496
                       11  0.0046053    0.02723   |                  . |*.                  |
0.049942
                       12  0.0066467    0.03929   |                  . |*.                  |
0.049978
                       13 -0.0045984   -0.02718   |                  .*| .                  |
0.050052
                       14  -0.015440   -0.09128   |                  **| .                  |
0.050087
                       15 -0.0015100   -0.00893   |                  . | .                  |
0.050484
                       16  0.0071727    0.04240   |                  . |*.                  |
0.050488
                       17 -0.0096269   -0.05691   |                  .*| .                  |
0.050573
                       18   0.011381    0.06728   |                  . |*.                  |
0.050727
                       19 -0.0049043   -0.02899   |                  .*| .                  |
0.050940
                       20 0.00011964    0.00071   |                  . | .                  |
0.050980
                       21 -0.0012866   -0.00761   |                  . | .                  |
0.050980
                       22 -0.0021008   -0.01242   |                  . | .                  |
0.050983
                       23  0.0079093    0.04676   |                  . |*.                  |
0.050990
                       24 -0.0003006   -0.00178   |                  . | .                  |
0.051093
                                              "." marks two standard errors


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                                            ARIMA Procedure

                                        Inverse Autocorrelations

                            Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
                              1    -0.00836  |                  . | .                  |
                              2     0.00736  |                  . | .                  |
                              3     0.05404  |                  . |*.                  |
```

```
  4   -0.00472 |                 . | .                  |
  5    0.02878 |                 . |*.                  |
  6    0.01683 |                 . | .                  |
  7   -0.02724 |                 .*| .                  |
  8    0.01527 |                 . | .                  |
  9    0.06345 |                 . |*.                  |
 10   -0.09524 |                 **| .                  |
 11   -0.01353 |                 . | .                  |
 12   -0.03188 |                 .*| .                  |
 13    0.02401 |                 . | .                  |
 14    0.08790 |                 . |**                  |
 15   -0.00311 |                 . | .                  |
 16   -0.03841 |                 .*| .                  |
 17    0.06512 |                 . |*.                  |
 18   -0.05591 |                 .*| .                  |
 19    0.01519 |                 . | .                  |
 20    0.00678 |                 . | .                  |
 21   -0.00308 |                 . | .                  |
 22    0.02402 |                 . | .                  |
 23   -0.03378 |                 .*| .                  |
 24   -0.01458 |                 . | .                  |

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                              ARIMA Procedure

                          Partial Autocorrelations

Lag Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
  1   -0.01003 |                 . | .                  |
  2   -0.01163 |                 . | .                  |
  3   -0.05543 |                 .*| .                  |
  4   -0.01850 |                 . | .                  |
  5   -0.01362 |                 . | .                  |
  6   -0.00755 |                 . | .                  |
  7   -0.00014 |                 . | .                  |
  8    0.00778 |                 . | .                  |
  9   -0.08466 |                 **| .                  |
 10    0.09521 |                 . |**                  |
 11    0.02788 |                 . |*.                  |
 12    0.03371 |                 . |*.                  |
 13   -0.01846 |                 . | .                  |
 14   -0.08804 |                 **| .                  |
 15   -0.00479 |                 . | .                  |
 16    0.04271 |                 . |*.                  |
 17   -0.06620 |                 .*| .                  |
 18    0.05680 |                 . |*.                  |
 19   -0.01426 |                 . | .                  |
 20   -0.01057 |                 . | .                  |
 21    0.00084 |                 . | .                  |
 22   -0.02537 |                 .*| .                  |
 23    0.03513 |                 . |*.                  |
 24    0.01517 |                 . | .                  |

     Model for variable CON_LIC

     Estimated Intercept = 1.88381269

     Autoregressive Factors
     Factor 1: 1 - 0.11145 B**(5)

     Moving Average Factors
     Factor 1: 1 + 0.13397 B**(1) + 0.16331 B**(2)

     Input Number 1 is RESTRICT.
     Overall Regression Factor  = -0.20355
```