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Etiology of Motor Vehicle Collision Fatalities in Urban and Rural Canada

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ABSTRACT

While it has been consistently demonstrated that fatal motor vehicle collision (MVC) rates are higher for rural than urban roadways, it remains to be elucidated which collision factors account for this difference. Fatal MVC rates have been demonstrated to be higher in rural locations even when controlling for age, restraint use, and vehicle speed. This study aims to assess which collision factors are most prevalent for fatal rural motor vehicle collisions, and to address how those factors differ in significance between rural and urban regions. Our study indicates that a combination of human, environmental, and vehicular factors may account for the fact that the majority of Canadian fatal MVCs occur on rural roadways.

KEYWORDS

motor vehicle collision, traumatic injury, forensic biomechanics, road safety, collision analysis, collision prevention

TABLE OF CONTENTS

INTRODUCTION

Human, vehicular and environmental factors have been cited in the causation of fatal motor vehicle collisions (MVCs).

1.1 - Human factors associated with fatal motor vehicle collisions

Gender and Age

Differences in motor vehicle collision-related injury and fatality rates based on gender and age have been described.

Males have a higher risk than females to be in a fatal MVC[1]. Males exceed females in rates of loss of control collisions, and this finding was more prominent in young and old male drivers (aged 15-24 and 85-89, respectively)[2]. Another study showed young males were not only more likely than their same-age opposite gender counterparts to be responsible for the initiation of fatal MVCs, and older females showed a similar trend compared to same-age males[3]. One study classified collision types as single-vehicle or multiple-vehicle and observed that the male motor vehicle collision fatality rate was more than 5 times higher compared to females in single-vehicle collisions[4]. This same study found that the non-fatal injury rate was higher for male drivers in both the single-vehicle and multiple-vehicle collision categories[4].

Young and older drivers are the most likely to be in MVCs[1,2,3,5]. Young drivers were found to be more likely to cause the death of other vehicle occupants, while older drivers were found to be more likely to die in MVCs[3]. Risk factors have been identified to

explain these trends. Young drivers are known to engage in excessive risk taking driving behavior compared to older drivers, including: alcohol and drug use; speeding; non-compliance with restraint use, and driving while fatigued[5]. Novice drivers are also at risk[6]. In contrast, the increased risk of MVCs for older drivers has been associated with medical and physical conditions, inattention and right-of-way infractions[5,7]. Vigilant monitoring of the fitness of older drivers by medical assessment increases in importance as the population demographics shifts to a more aged population. An Ontario study found that for older drivers (defined as age 60 or older), right-of-way infractions, non-compliance with restraint use, ejection from vehicle, higher posted speed limit at collision site, and frontal impact type were most significantly related to the increased risk of death[8].

Collision over-involvement (number of collisions per vehicle distance travelled) is a significant contributing factor to MVC fatalities for young drivers[7]. An inverse association was found for drivers aged 30 or older who showed less involvement in at-fault fatal motor vehicle collisions[9]. Another study confirmed the finding that older drivers had a higher fatal motor vehicle collision involvement than younger drivers, while younger drivers had a higher rate of involvement in all police-reported collisions[1].

Body Habitus

Increased body mass index (BMI) (>35 kg/m^2) has been shown to significantly increase the risk of death for male drivers involved in MVCs[10]. Males with low BMIs (<22 kg/m^2) were also shown to possess a significantly higher risk of death in MVCs than average mass males[10]. The association between BMI and male fatality increased significantly with an increase in vehicle speed[10]. A two-fold increased risk of diaphragmatic injury in side-impact collisions was observed for individuals with a body mass index greater than 25 while no association was found for large individuals involved in MVCs of other impact types[11]. Another study observed that obese males (>30 kg/m^2) compared to normal weight males had a higher risk of serious injury to the head, face, thorax, and spine but not to the abdomen and extremities[12]. The increased risk for obese males was suggested to be due to differences in body shape, center of gravity, and fat distribution[12].

Alcohol and Drugs

A 2015 Ontario study found that 56% of fatal MVCs involved drivers who were found to have alcohol or other drugs in their blood at the time of death, with alcohol being the most common followed by cannabis, benzodiazepines, and antidepressants[13]. The risk of a MVC is compounded when alcohol is ingested by the driver in combination with other drugs[14]. Another study observed that drivers with positive blood alcohol concentrations were significantly more likely to be: male; involved in a single-vehicle collision (non-collision); unrestrained; ejected from the vehicle, and travelling at higher

speeds than drivers with negative blood alcohol concentrations[15]. Specific physiological effects of alcohol account for the increased risk of a MVC, including: reduced peripheral vision; poorer recovery from glare; poor performance in complex visual tracking, and reduced divided attention performance[16]. In fact, alcohol has been observed to surpass restraint use non-compliance as the strongest indicator of fatal collision incidence by a driver[17].

Initiatives deployed by law enforcement that stop motorists in order to detect alcohol use have been used to decrease the incidence of driving while intoxicated. Random breath testing and sobriety checkpoints have resulted in the decrease of alcohol-related fatalities between 8% and 71% in different locales that deployed a random screening program[18].

Law Enforcement and the Driver

An Ontario study found that while the risk of a fatal collision was lowered by 35% in the month following a driving-related conviction, this decrease was not sustained for two months after the conviction[19]. The same study found that the decreased risk of a fatal collision following a driving-related conviction was greater for drivers who had speeding convictions with penalty (demerit) points compared to drivers with speeding convictions without demerit points[19]. However, the decrease in risk of fatal motor vehicle collision was not seen in drivers who had their licences suspended compared to those who had been convicted without an associated suspension[19]. Previous motor vehicle convictions were observed to be associated with a reduced risk of motor vehicle collision injury for older but not younger drivers[20]. Drivers who had past driving-while-intoxicated (DWI)

convictions were more likely to be involved in alcohol-related fatal motor vehicle collisions, i.e., the drivers were more likely to have a positive blood alcohol concentration at the time of the collision[21].

A British Columbia study found that prior at-fault collision involvement provided a better predictive value for future at-fault collision involvement than prior convictions[22]. The same study found that past driver citations for right-of-way infractions resulting in MVCs (after the infraction) were less predictive than prior at-fault collision involvement, but more predictive than prior driver convictions[22].

A 2006 study assessed complete driver collision and conviction history in order to estimate the likelihood of a driver being involved in an at-fault collision, and found that the likelihood of a driver's involvement in an at-fault collision was significantly increased when the driver had previous at-fault crash involvements; license suspensions; traffic school referrals, and/or speeding convictions[23].

Driving without a licence was a risk factor for older, but not younger drivers[24]. Drivers who drove without a valid driver's license and drivers who had a collision within the previous 1-year period were observed to be more likely to initiate a fatal motor vehicle collision[23].

Driver Distraction

The presence of passengers in the collision vehicle has been associated with increased rates of at-fault fatal MVCs for young drivers[9]. A 2007 study assessed the impact of distractions to teenage drivers on the likelihood of certain collision types, and found that those who were distracted either at an intersection or by passengers were more likely to be involved in a rear-end impact or side-impact collision[25]. The same study found that in-vehicle distractions which included cell phone and passenger distractions contributed to an increased likelihood of a fixed-object collision[25].

1-2. *Vehicular factors associated with fatal motor vehicle collisions*

Impact Type and Injury Patterns

MVCs can be classified by impact type. Some collisions (frontal collisions, ran-off-road collisions, fixed-object collisions) involve the departure from the driving lane when a driver exits his/her lane and collides with another vehicle or nearby object. Collision types common to intersections and junctions include rear-end collisions and side-impact collisions. Rollover type collisions are single-vehicle collisions that occur with loss of driver control and involve one or more 90 degree rotations around the vehicle's horizontal axis.

While different injury patterns and injury severities have been observed for individual collision types, there is a lack of research that compares injury patterns in fatal motor vehicle collisions based on collision type. For example, the pattern of thoracic injury

sustained by a motor vehicle collision victim has been shown to be dependent on the direction of the impact, and that the injury severity was dependent on the velocity change as a result of the impact[26]. Some studies demonstrated that frontal and side-impact collisions were associated with an increased risk of blunt thoracic aorta injury. Specifically, collisions involving vehicle crush of greater than 40cm or intrusion greater than 15cm were found to increase the risk of the highly lethal blunt thoracic aorta injury[27].

While frontal impact motor vehicle collisions (head-on collisions) are the most common, side-impact collisions are associated with a higher risk of fatality and injury[28]. In side-impact collisions, occupants of the impacted vehicle often contact interior vehicle structures (door, doorframe, window) and exterior structures (impacting vehicle, foreign object), and these contacts are more likely to result in injuries because of greater energy loading of the occupant compared to a frontal impact collision in which the vehicle bumper, fender, and crushing of the front compartment act to dissipate the collision energy[28]. Intrusion of other vehicles or other outside objects into the passenger compartment occurs mostly in side-impact and rollover collisions, and this intrusion is positively associated with increased injury severity for the occupants involved[29].

Seatbelts prevent ejection of motor vehicle occupants in rollovers. A 2010 study found that victims of rollover motor vehicle collisions who were ejected were at a greater risk for serious injury even if they were restrained by a seatbelt prior to collision compared to unrestrained ejected occupants[30]. However, the same study found that the relative risk

for occupant ejection in event of a motor vehicle collision for all impact types (not exclusive to rollover collisions) was 193-fold greater for unrestrained compared to restrained occupants[30].

Vehicle Type

Vehicle type is a factor in motor vehicle collision fatalities. Typically, vehicles are classified according to three categories: passenger cars; light-truck vehicles (LTVs, including pick-up trucks, sports utility vehicles, and minivans), and heavy commercial vehicles (transport style rigs).

Side-impact collisions which involved a light truck vehicle striking a passenger car accounted for a higher risk of fatality for the occupants of the lighter passenger car[31,32]. Another study confirmed that light-truck vehicles when colliding with passenger cars were more likely to cause serious injuries in the occupants of the latter, but added that other characteristics related to light trucks (stiffness of vehicle exterior and height of vehicle) also influenced the risks of fatality and injury in event of a MVC[33]. A 2003 study found that older drivers are more likely to travel in passenger cars, and young drivers are more likely to travel in light-truck vehicles[34]. The same study also found that older drivers are more likely to be struck in side-impact collisions than younger drivers.

Restraint Systems

Airbag deployment and restraint (seatbelt) use have been demonstrated to reduce motor vehicle collision fatality rates by 63% and 72% respectively when the variables of

age, sex, and vehicle type are controlled[35]. Combined airbag and restraint use have been observed to reduce motor vehicle collision fatality rates by more than 80%[35]. Another study evaluated the effectiveness of airbags and seatbelts in the context of fatal MVCs and found that prevention of ejection accounted for almost 50% of seatbelt effectiveness in the prevention of fatalities, and that airbag deployment reduced fatalities to drivers and right front passengers by 20% and 15%, respectively[36]. There was a 41% increase in motor vehicle collision fatality risk when drivers switched from seatbelt and airbag protection to solely airbag protection[36]. Although vehicle safety and protection measures traditionally favour drivers and front-seat passengers, several remedies have been suggested for rear-seated passengers which include: load-limiting seatbelts with cinching and good restraint geometry; reduced contact velocity with the seatback and interior vehicle side interior; improved containment via inflatable side curtains and laminated side glass, and inflatable seatbelts[37].

1-3 Environmental factors associated with fatal motor vehicle collisions

While novel vehicular safety features can detect slippery roads, adverse road surface conditions continue to contribute to fatal MVCs. An Ontario study showed that snow-covered roads were associated with an increased risk of a fatal MVC for elderly drivers[8]. The influence of adverse road surface conditions on older drivers is particularly challenging for these drivers when considered with their reduced ability to react because of cognitive and physical decline that can occur with increased age. A 2011 study also assessed the influence of road surface conditions on MVC driver injury severity, and found that for all females and older males, the risk of severe injuries

increased when MVCs occurred on non-dry road surfaces[38]. Interestingly, the same study found that for male drivers younger than 45 years of age, the risk of serious injury decreased on non-dry road surfaces compared to dry road surfaces, which highlighted the observation that perception and reaction to road surface conditions are different between age and gender subpopulations[38].

2. Differences between rural and urban motor vehicle collisions.

Rationale for the Present Study

Differences in fatal and non-fatal injury rates have long been described between various subpopulations. Subpopulations can be based on age or geographic locale. MVCs are the primary contributor to accidental injury and fatality rates. The majority of Canadian fatal MVCs occur on rural roadways[39]. To address the higher susceptibility of certain subpopulations to injury and death in MVCs, vehicle manufacturers have worked to adapt modern vehicular safety factors (e.g. airbag systems) that account and adjust for the specific profile of the driver or passenger. However, past literature has demonstrated that pre-collision variables other than age, weight, and height increase the risk of injury in MVCs. This highlights the need for the identification of other specific risk factors unique to certain subpopulations in order to assess which individuals are at the greatest risk of injury or death from MVCs in order to develop specific prevention and protection measures that protect the greatest percentage of motorists.

MVC-related deaths have been implicated in accounting for the discrepancy in injury death rates between urban and rural regions[40]. Motor vehicle-related death rates were 93% higher for rural collisions than urban collisions in an American study[40]. A later study found that fatal MVCs were more than twice as likely to occur on rural roadways than urban roadways[41]**.** Fatal MVC rates have been demonstrated to be higher in rural locations even when controlling for age, restraint use, and vehicle speed[41]. One study divided fatal collision incidence density into three variables: the injury fatality rate; the collision injury rate, and the collision incidence density[41]. The injury fatality rate (the ratio of deaths from injuries in a region to the population of that region) was almost three times higher for rural areas than urban areas. This factor accounted for the much of the difference between the rural and urban motor vehicle fatal collision incidence[41]. However, which collision causation factors account for the increased incidence of fatal motor vehicle collisions in rural regions needs to be defined.

Although past literature has consistently demonstrated the contrast between rural and urban motor vehicle collision fatality rates, few studies have described specific collision factors that are responsible. A 1996 American study found that collision factors related to higher rates of fatality in rural regions were the following: the involvement of light and heavy truck type vehicles; more frequent alcohol use and higher levels of intoxication; more frequent occupant ejection, and more frequent non-collisions (collisions involving only one vehicle)[42]*.* Because the contribution of various collision factors is different between geographical regions, this underscores the need for analyses of fatal collision data from different locales[43].

Access to Emergency Medical Care

Fatality rates have been shown to be proportional to the proximity of a MVC to the nearest medical care facility[44]. Various authors have suggested that relative access to emergency medical care may contribute to the regional differences between rural and urban fatal motor vehicle collision rates[43]. This observation has been supported by some studies, but not by others. A 1995 study found that rural fatal motor vehicle collisions caused more severe injuries[45]. In urban fatal motor vehicle collisions, there was a higher preventable death rate; victims who succumbed to collision-related head injuries ranked with a score less than five on the Abbreviated Injury Scale (AIS) were included in the preventable death classification which suggested that a difference in preventable injury rate and not in the quality of medical care was a significant factor in the regional variation in motor vehicle collision fatality rates[45]. A more recent study found that after controlling for the effect of injury severity, the risk of death in a motor vehicle collision is nearly twice as high on rural roadways[43]. Emergency medical service response times, transport times, and overall pre-hospital times have been demonstrated to be higher in rural areas for both fatal and non-fatal collisions[46].

Socioeconomic Factors

A recent study showed that, over a six year period, rural populations in British Columbia experienced a three-fold increase in relative risk of death from motor vehicle collisions and a 50 percent increase in relative risk of hospitalization due to non-fatal injuries[47]. This study also showed that the risk of motor vehicle collision fatality in rural areas is inversely proportional to socioeconomic status, with poorer areas at a higher risk for

death. Another paper also stated that an increased dependence on private transport and lower socioeconomic status, correlated with older and less safe vehicles, may also be factors accounting for increased fatalities on rural roadways[44]. When rural regions have been subdivided based on population density, the fatality rate was found to be inversely proportional to the density[48]. The same trend was not seen for motor vehicle collision fatality rates in urban regions[48]. Regardless of the type of roadway where the motor vehicle collision occurred, the fatality rate was inversely proportional to the population density of the driver's home county in a study done in Nebraska[43].

Age

A 2006 study from Alberta showed that children and youths (0–19 years of age) were at a five-fold higher risk of a MVC fatality in rural regions compared to urban regions, and hospitalization and fatality rates were higher for rural collisions even when gender and time of collision were controlled[49]**.** Another study assessed the subpopulation of older drivers (defined as drivers 68 years of age and older) in a rural community and found that older drivers with recent episodes of back pain, prescriptions for non-steroidal anti-inflammatory drugs, and poor performance on free-recall memory tests were at increased risk of death in the event of a motor vehicle collision[50]. The vulnerability of geriatric motorists was likely compounded by less accessible medical care in the rural regions.

HYPOTHESIS

Further understanding of human, vehicular, and environmental factors that predispose to fatal MVCs in urban and rural locations will lead to improved prevention and protection measures that can be applied by automotive researchers, trauma specialists, and government and law enforcement agencies in order to protect Canadian motorists.

I hypothesize that there are significant differences in human, environmental, and vehicular variables observed in fatal MVCs occurring in urban or rural locations.

This study aims to assess which collision factors are most prevalent for fatal urban and rural MVCs, and to address how those factors could be significant in influencing fatality prevention in rural and urban regions.

METHODOLOGY

Transport Canada, under the federal Motor Vehicle Safety Act, has the mandate to set motor vehicle safety standards to protect the public. To fulfill this mandate, Transport Canada relies on real world data from certain types of collisions to correlate with its crash safety research. These data are collected through a network of investigative teams across Canada which have contractual relationships with Transport Canada. The Motor Vehicle Safety (MOVES) Research Team, based at Western University, is one of six teams in Canada. The MOVES database contains several sources of information for analysis. Overall case narratives are contained in the database for each collision case. These are documents compiled by the MOVES research team that have been submitted to Transport Canada and edited to remove any identifiable information that relates to the parties involved in the MVC.

MOVES has also had a long-standing relationship with, but not limited, to the following: various Ontario police agencies, the Ontario Fire Marshal, other motor vehicle and safety experts, insurance companies, provincial motor vehicle inspectors, car business owners, car salvage yards and motor vehicle repair centres. The MOVES team is contacted by one of the aforementioned agencies about a MVC of interest to Transport Canada. MOVES team investigators then work to: identify and document physical evidence at a MVC scene, reconstruct collision events, inspect, measure and document exterior damage to a motor vehicle, interior damage resulting in occupant contact and

witness marks due to collision loading of occupant restraint systems, photograph collision scene and involved vehicles, and quantitatively reconstruct the motor vehicle crash severity.

The present study focused on cases in the databases of the Transport Canada's Causes of Fatal Collisions studies (*CFC2* and *CFC3* – data elements for studies in Appendices A and B). This study included 243 fatal vehicle collision cases from 2007 to 2010. One hundred twelve cases were collected under the ***CFC3*** study (southern Ontario and Quebec regions), and an additional 131 cases were collected under the ***CFC2*** study (southern Ontario, Quebec, New Brunswick, Saskatchewan, and Ottawa regions). The MOVES database contained 83 fatal collision cases (REB approval #106293) and 160 were from the other research teams in Quebec, Saskatchewan, New Brunswick, and Ottawa.

There were no age or gender restrictions. Drivers and passengers involved in collisions were included in the study populations. If injuries or fatalities occur in both vehicles involved in a motor vehicle collision, both were considered case vehicles. Multiple vehicle and single-vehicle collisions and non-collisions were included in the study, and vehicle-pedestrian impacts were excluded. The study population included all fatally injured drivers and passengers with injuries of AIS-3 or greater.

Urban collisions were defined by Transport Canada as those that occurred on metropolitan roads and streets, or at a speed limit at the collision site of 60 km/h or less. Rural collisions were defined as those that occurred on primary or secondary highways; local roads in rural areas or at a speed limit at the collision site in excess of 60km/h.

Information in the MOVES database was obtained from the Transport Canada field forms and final reports submitted to Transport Canada. Information from the other research teams was collated by the Motor Vehicle Safety Directorate (Collision Investigations), Transport Canada.

The following information was analyzed:

- The gender, age, and weight of the motor vehicle collision victims

- Injuries and toxicology results (blood alcohol and marijuana) of drivers from autopsy reports obtained by data sharing agreements with the Office of the Chief Coroner for Ontario. Injuries were classified according to severity and anatomical position: craniocerebral, spinal, thoracic, abdominal, or extremities. The severity of the injuries in each anatomical position was described by the Abbreviated Injury Score (AIS)[51].

- Driver history was recorded from shared police reports This included the number of years since licensing, number of previous convictions, number of previous collisions, and number of past license suspensions.

- Interference or distractions to the driver of the case vehicle which included reduced visibility due to adverse environmental conditions.

- Damage to the interior and exterior of the vehicle. Interior vehicle damage included points of contact between the vehicle occupants and inside of the

vehicle. Metric length measurements for direct damage and maximum crush were recorded. Damage to the windshield from interior occupant contact was recorded. Other vehicular damage recorded included fuel integrity loss (associated with fuel leakage and risk of fire) and door latch/hinge failure (where the vehicle door is partially or completely removed from the vehicle due to collision impact and the occupants are exposed to the environment outside of the vehicle).

- Fractures, deformations, intrusions and extrusions to the case vehicle Interior and exterior photographs of the case vehicle were viewed. The state of the case vehicle prior to impact was recorded and included descriptions of the condition of the vehicle tires, brakes, and safety features prior to collision.

- Collision scene photos were useful for examining points of impact with stationary objects, tire skid marks, and collision debris. Drawn collision diagrams allowed for the determination of the dynamic movements in a specific MVC and the kinematics of its occupants.

- When available, event data recorder downloads were included in the database cases. The event data recorder provides textual and graphical data related to the vehicle speed, vehicle location, and usage of vehicle safety features in the event of a MVC and is useful in describing the events immediately preceding the collision. Collision damage analyses

and scene analyses allowed for the computation of vehicle impact speed when event data recorder records were unavailable, and served as verification when event data recorder downloads were available. Posted speed limits were also recorded.

- Vehicle Impact type (side, frontal, rear, rollover, off-road, fixed object) and the year, make, and model of the case vehicle.

- Safety belt use and airbag deployment status.

- The conditions of the lighting, weather, and roadway at the time of the collision.

- The type of roadway and geographic locale of the roadway (urban or rural)

Table I1 shows the variables included in the scope of this study classified by human, environmental, vehicular, and injury-based data elements. Parameters with quantitative descriptions are indicated.

Table I1. **Variables used in data collection classified by human, environmental, vehicular, and injury-based categorization.**

Classification	Data Element	Quantitative?
Human	***Sex***	N
	Age	Y
	Mass	Y
	Toxicology (Ethanol, THC)	Y
	Past Collisions	Y
	Past DWI Convictions	Y
	Past Speeding Convictions	Y
	Past Licence Suspensions	Y
	Years Licensed	Y
	Restraint Use	N
Environmental	***Lighting Conditions + Road Surface Conditions***	N
	Posted Speed Limit	Y
	Type of Roadway	N
	Location of Roadway	N
	Interference/Distractions to Driver	N
Vehicular	***Type of Vehicle (Make/Model)***	N
	Damage to Vehicle (Interior)	Y
	Damage to Vehicle (Exterior)	Y
	Type of Collision (Impact Type)	N
	Airbag Deployment	N
	Calculated Speed	Y
	Ejection	N
Injury	***Craniocerebral Injuries and Severity***	Y
	Thoracic Injuries and Severity	Y
	Spinal Injuries and Severity	Y
	Abdominal Injuries and Severity	Y
	Extremities and Severity	Y

After the collection of all available and relevant data from cases contained within the MOVES and the Transport Canada databases, hierarchal regression analyses was performed using IBM SPSS statistical analysis software[52] It determined which factors were the most predictive of a motor vehicle collision fatality independent of other factors such as gender and age. Human, environmental, and vehicular collision factors from the pre-collision, collision, and post-collision phases of the collision were analyzed in relation to their probability in causing a fatal collision in an urban or rural area. Analyses of the data and comparison between urban and rural populations of fatally injured motor vehicle collision victims elucidated the most pertinent factors that increased the likelihood of a fatality among the urban and rural Canadian motorists in the MOVES and Transport Canada database. Further logistic regression between urban and rural fatal motor vehicle collision subpopulations calculated odds ratios for each human, environmental, and vehicular variable. Odds ratios and their associated 95% confidence intervals were calculated according to equation 1 and 2 (below) and were validated with SPSS software[52].

$$(\mathrm{OR}) = \frac{a/b}{c/d} = \frac{a \times d}{b \times c}$$

Equation 1. Odds ratio calculation used for comparison of urban and rural motor vehicle fatality subpopulations. Variables: ***a*** = number in rural group with positive outcome; ***b*** = number in rural group with negative outcome; ***c*** = number in urban (control) group with positive outcome, and ***d*** = number in urban (control) group with negative outcome. For example, in the analysis of restraint use where the effect of an unrestrained occupant is evaluated, *a* = the number of fatal unrestrained rural

occupants; *b* = the number of fatal restrained rural occupants, *c* = the number of fatal unrestrained urban occupants, and *d* = the number of fatal restrained urban occupants. Where zeros caused problems with calculation of the odds ratio, 0.5 was added to variables a, b, c, and d[53].

$$95\%\ CI = \exp(\ \ln(OR) - 1.96\ \times \mathrm{SE}\{\ln(OR)\}\ )\quad \text{to}\quad \exp(\ \ln(OR) + 1.96\ \times \mathrm{SE}\{\ln(OR)\}$$

Equation 2. 95% confidence interval calculation used for comparison of urban and rural motor vehicle fatality subpopulations. Variables: ***OR*** = odds ratio (see equation 1); ***SE*** = Standard Error (see equation 3)[15]. Functions: ln = natural logarithm, and exp = exponential.

$$SE = \frac{\sigma}{\sqrt{n}}$$

Equation 3. Standard Error (SE) calculation used for comparison of urban and rural motor vehicle fatality subpopulations. Variables: *SE* = standard error;
σ = standard deviation, n = sample size.

In hierarchical multiple regression analysis, sets of variables are entered in blocks, with each independent (predictor) variable assessed in terms of the usefulness it adds in the prediction of the dependent (outcome) variable after certain independent variables are controlled. The prediction model generated describes how each independent variable contributes to the value of the dependent variable. In this analysis, age and gender were the independent variables that were controlled for. All collision cases involved fatalities, so the dependent variable used for the prediction model must be different than

fatal/non-fatal outcome. Injury severity (maximum AIS score), impact type and calculated speed were used as the dependent variables because both are outcomes of the collision and hence subject to dependent variable classification. Human, environmental, and vehicular factors were analyzed with age and gender controlled for in both rural and urban fatal collision subpopulations.

In order to evaluate the prediction model generated by hierarchical multiple regression analysis, several resultant values were assessed. *R-squared values* describe how much variation of dependent (outcome) variables is explained by independent variables even when the effects of gender and age have been statistically controlled. The *Significant F change* value was used to assess the significance of the R-squared values. A *Significant F change* value of less than 0.05 indicates that the addition of the independent (predictor) variables has a statistically significant contribution to the prediction of the outcome.

ANOVA (analysis of variance) significance values show how the model as a whole (including variables of age and gender) is able to predict the outcome. An ANOVA significance value of less than 0.05 indicates that the model is a statistically significant predictor of the outcome variables.

Beta standardized regression coefficients are used in order to assess how each independent variable individually contributes to predict the outcome. The beta coefficients represent the unique contribution of each independent variable when the

overlapping effects of all other independent variables have been statistically controlled . A larger magnitude coefficient indicates a larger contribution of the particular predictor variable to the outcome variable. Coefficient significance values assessed the significance of the Beta coefficient value. A coefficient significance value of less than 0.05 indicated that the independent variable described made a unique statistically significant contribution to the prediction model. Beta coefficients allow for the development of a hierarchy of independent variable contribution to the outcome even with coefficient significance values greater than 0.05.

RESULTS

Raw Data and Odds Ratios - Human factors

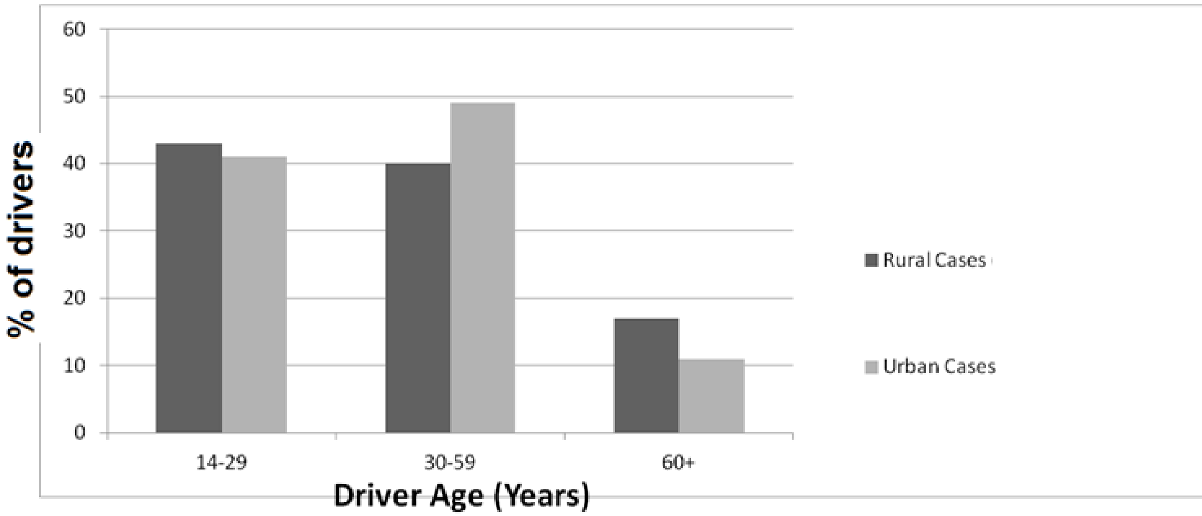

Figure 1. **Distribution of drivers by age in rural and urban fatal motor vehicle collisions.**

Table 1 - Driver's age in fatal motor vehicle collisions in rural and urban regions.

Driver Age (years old)	Total Cases (n=241)	Rural Cases (n=167)	Urban Cases (n=74)
14-29	103 (44%)	73 (43%)	30 (41%)
30-59	104 (43%)	68 (40%)	36 (49%)
60+	34 (14%)	26 (17%)	8 (11%)

Table 1 shows the distribution of ages for drivers involved in fatal motor vehicle collisions between rural and urban regions. Data were available for 241 cases. Young drivers (age 14-29) showed a slightly higher odds of involvement in a fatal rural collision (OR = 1.1390, 95%CI = 0.6534 to 1.9856, p=0.6462) whereas older drivers (age 60 or older) showed a slightly higher odds than younger drivers (OR = 1.5213, 95%CI = 0.6537 to 3.5402, p=0.3303) of being involved in a fatal rural motor vehicle collision. However, middle aged drivers (age 30-59) showed a higher odds of involvement in a fatal urban motor vehicle collision (OR = 1.3793, 95%CI = 0.7953 to 2.3919, p=0.2523).

Table 2 - Gender of drivers in fatal motor vehicle collisions in rural and urban regions.

Gender (Driver)	Total Cases (n=243)	Rural Cases (n=169)	Urban Cases (n=74)
F	54 (22%)	39 (23%)	15 (20%)
M	189 (78%)	130 (77%)	59 (80%)

Table 2 shows gender distribution for drivers involved in fatal motor vehicle regions between rural and urban regions. Data were available for 243 cases. Males showed a marginally higher odds of involvement in urban motor vehicle collisions (OR=1.1800; 95%CI = 0.6036 to 2.3066, p=0.6284).

Table 3 - Mass of drivers involved in fatal motor vehicle collisions in rural and urban regions.

Driver Mass (kg)	Total Cases (n=107)	Rural Cases (n=75)	Urban Cases (n=32)
<70	33 (31%)	23 (31%)	10 (31%)
70-79	55 (51%)	42 (56%)	13 (41%)
80+	19 (18%)	10 (13%)	9 (28%)

Table 3 shows the distribution of driver masses for drivers involved in fatal motor vehicle collisions amongst rural and urban regions. Data were available for 107 cases. Heavier drivers (80kg or heavier) showed a higher odds of involvement in a fatal urban collision (OR = 2.5435, 95%CI = 0.9186-7.0423, p=0.0724).

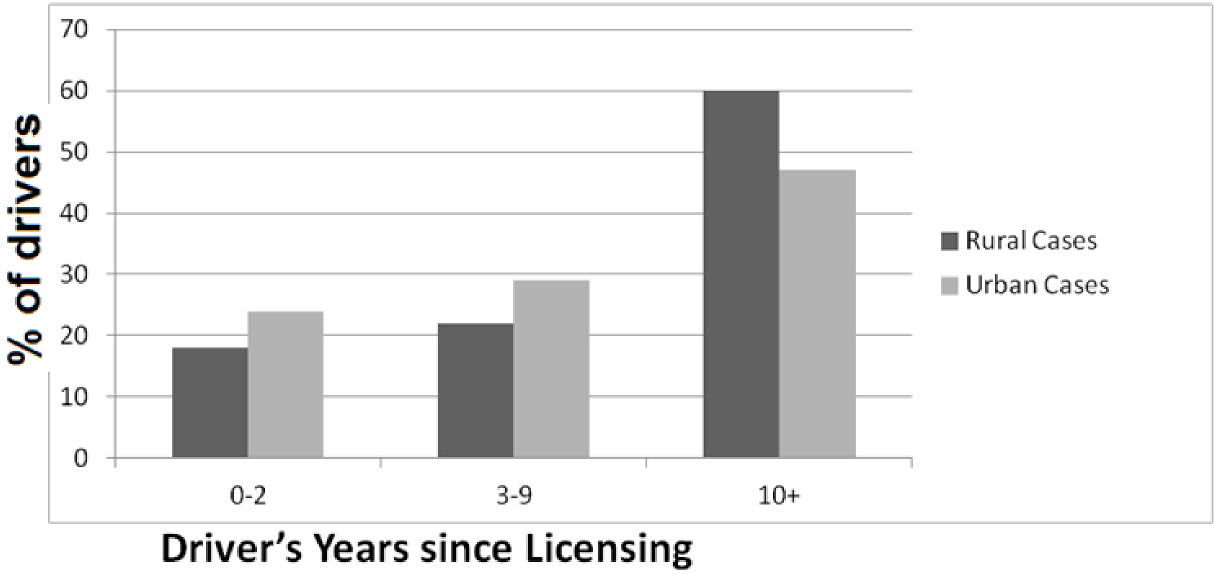

Figure 2. **Distribution of drivers by years since licensing in rural and urban fatal motor vehicle collisions.**

Table 4 - Years licensed for drivers involved in fatal motor vehicle collisions in rural and urban regions.

Years Licensed	Total Cases (n=190)	Rural Cases (n=128)	Urban Cases (n=62)
0-2	39 (21%)	24 (19%)	15 (24%)
3-9	46 (24%)	28 (22%)	18 (29%)
10+	105 (55%)	76 (59%)	29 (47%)

Table 4 shows the number of years since licensing for drivers involved in fatal motor vehicle regions between rural and urban regions. Data were available for 190 cases. While novice drivers (licensed for 0-2 years) showed a higher odds of involvement in an urban fatal collision (OR = 1.3830, 95%CI = 0.6656 to 2.8736, p=0.3849), experienced drivers (licensed for 10 years or more) showed an even higher odds of involvement in a rural fatal collision (OR = 1.6631, 95%CI = 0.9028 to 3.0639, p=0.1027).

Table 5 - Previous suspensions for drivers involved in fatal motor vehicle collisions in rural and urban regions.

Previous Suspensions	Total Cases (n=188)	Rural Cases (n=127)	Urban Cases (n=61)
Yes	54 (29%)	34 (27%)	20 (33%)
No	134 (71%)	93 (73%)	41 (67%)

Table 5 shows the distribution of drivers who incurred previous license suspensions in rural and urban regions. Data were available for 188 cases. Drivers with previous suspensions showed a higher odds of involvement in fatal urban collisions (OR = 1.3343, 95%CI = 0.6873 to 2.5903, p=0.3942) than rural regions.

Table 6 - Previous speeding convictions for drivers involved in fatal motor vehicle collisions in rural and urban regions.

Previous Speeding Convictions	Total Cases (n=181)	Rural Cases (n=123)	Urban Cases (n=58)
0	87 (48%)	57 (46%)	30 (52%)
1	28 (16%)	18 (15%)	10 (17%)
2+	66 (36%)	48 (39%)	18 (31%)

Table 6 shows the distribution of drivers who incurred previous speeding convictions in rural and urban regions. Data were available for 181 cases. Drivers with previous speeding convictions showed a higher odds of involvement in a fatal motor vehicle collision in rural regions (OR = 1.2406, 95%CI = 0.6639 to 2.3182, p=0.4991).

Table 7 - Previous driving-while-intoxicated (DWI) convictions for drivers involved in fatal motor vehicle collisions in rural and urban regions.

Previous DWI Convictions	Total Cases (n=182)	Rural Cases (n=123)	Urban Cases (n=59)
0	169 (93%)	112 (91%)	57 (97%)
1+	13 (7%)	11 (9%)	2 (3%)

Table 7 shows the distribution of drivers who incurred previous alcohol-related driving convictions in rural and urban regions. Data were available for 182 cases. Drivers with previous alcohol-related driving convictions showed a higher odds of involvement in rural collisions (OR = 2.7991, 95%CI = 0.6000 to 13.0573, p=0.1902).

Table 8 - Presence or absence of seatbelt use by drivers involved in fatal motor vehicle collisions in rural and urban regions.

Driver – Restraint Use	Total Cases (n=229)	Rural Cases (n=160)	Urban Cases (n=69)
Yes	167 (73%)	122 (76%)	45 (65%)
No	62 (27%)	38 (24%)	24 (35%)

Table 8 shows the presence or absence of restraint (seatbelt) use by fatally injured drivers involved in fatal motor vehicle collisions in rural and urban regions. Data were available for 229 cases. Unrestrained drivers showed a higher odds of being involved in a fatal urban collision (OR = 1.7123, 95%CI = 0.9259 to 3.1666, p=0.0864).

Table 9 - Presence or absence of seatbelt use by passengers involved in fatal motor vehicle collisions in rural and urban regions.

Passenger – Restraint Use	Total Cases(n=175)	Rural Cases (n=131)	Urban Cases (n=44)
Yes	92 (53%)	64 (49%)	28 (64%)
No	83 (47%)	67 (51%)	16 (36%)

Table 9 shows the presence or absence of restraint use by fatally and non-fatally injured passengers involved in fatal motor vehicle collisions in rural and urban regions. Data were available for 175 cases. Unlike unrestrained drivers, unrestrained passengers showed a higher odds of being involved in a fatal rural collision (OR = 1.8320, 95%CI = 0.9067 to 3.7015, p=0.0916).

Table 10 - Presence or absence of ejection at time of collision by drivers involved in fatal motor vehicle collisions in rural and urban regions.

Driver – Ejection	Total Cases (n=243)	Rural Cases (n=169)	Urban Cases (n=74)
Yes	61 (25%)	42 (25%)	19 (26%)
No	182 (75%)	127 (75%)	55 (74%)

Table 10 shows the presence or absence of ejection for fatally and non-fatally injured drivers in motor vehicle collisions in rural and urban regions. Data were available for all 243 cases. Drivers showed a marginally higher odds of ejection in fatal urban collisions (OR = 1.0446, 95%CI = 0.5577 to 1.9564, p=0.8916).

Table 11 - Presence or absence of ejection at time of collision by passengers involved in motor vehicle collisions in rural and urban regions.

Passenger - Ejection	Total Cases(n=172)	Rural Cases (n=128)	Urban Cases (n=44)
Yes	32 (19%)	27 (21%)	5 (11%)
No	140 (81%)	101 (79%)	39 (89%)

Table 11 shows the presence or absence of ejection for fatally and non-fatally injured passengers involved in motor vehicle collisions in rural and urban regions. Data were available for 172 cases. Like lack of restraint use, passengers showed a higher odds of ejection for fatal rural collisions (OR = 2.0851, 95%CI = 0.7494 to 5.8016, p=0.1593).

Raw Data and Odds Ratios - Vehicular factors

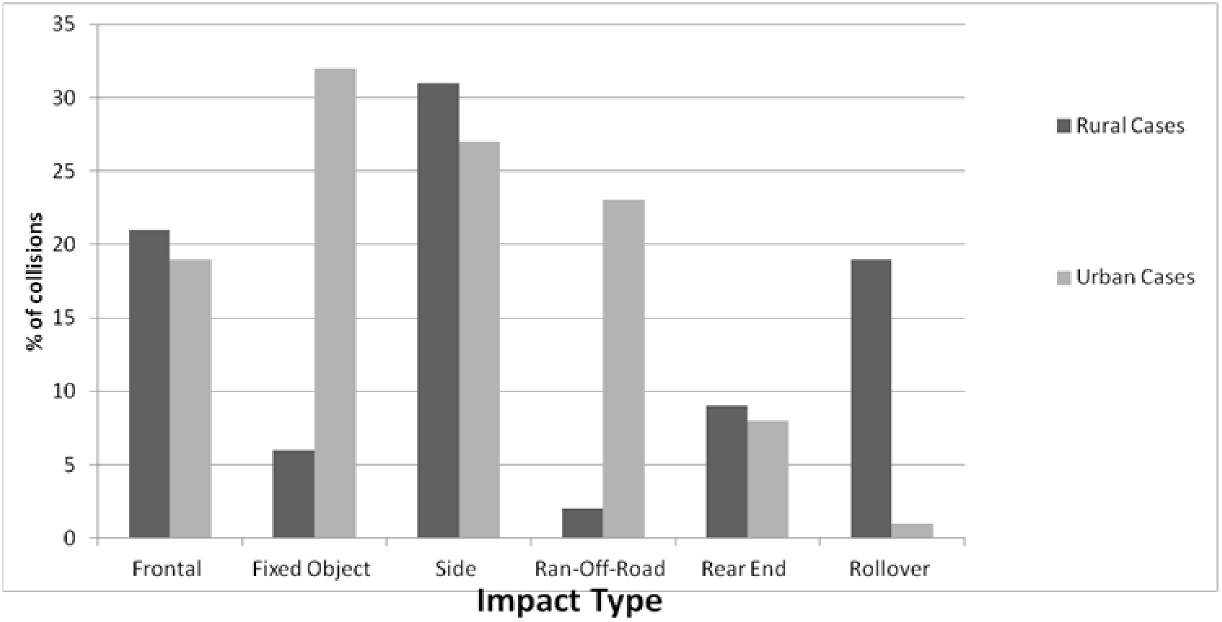

Figure 3. **Distribution of collisions by impact type in rural and urban fatal motor vehicle collisions.**

Table 12 - Fatal motor vehicle collision impact types in rural and urban regions.

Impact Type	**Total Cases (n=243)**	**Rural Cases (n=169)**	**Urban Cases (n=74)**
Frontal	51 (21%)	37 (22%)	14 (19%)
Fixed Object	24 (10%)	11 (6%)	13 (18%)
Side	71 (29%)	51 (30%)	20 (27%)
Ran-Off-Road	20 (8%)	3 (2%)	17 (23%)
Rear End	21 (9%)	15 (9%)	6 (8%)
Rollover	45 (19%)	44 (26%)	1 (1%)
Other	11 (5%)	8 (5%)	3 (4%)

Table 12 shows the distribution of impact types amongst urban and rural collisions. Data were available for 243 cases. Fatal frontal motor vehicle collisions occurred with a slightly higher odds for rural regions (OR = 1.2013, 95%CI = 0.6046 to 2.3868, p=0.6006). Fatal fixed object collisions occurred with a higher odds for urban regions (OR = 3.0611, 95%CI = 1.3011 to 7.2021, p=0.0104). Fatal side-impact collisions occurred with a slightly higher odds for rural regions (OR = 1.1669, 95%CI 0.6346 to 2.1459, p=0.6194). Fatal ran-off-road style collisions occurred with a much higher odds for urban regions (OR = 16.5029, 95%CI = 4.6636 to 58.3980, p<0.0001). Fatal rear-end collisions occurred with a slightly higher odds in rural regions (OR = 1.1039, 95%CI = 0.4107 to 2.9674, p=0.8447). Finally, rollover style collisions occurred with a much higher odds in rural regions (OR = 25.6960, 95%CI = 3.4669 to 190.4519, p=0.0015).

Table 13 - Calculated vehicle speed for fatal motor vehicle collisions in rural and urban regions.

Calculated Vehicle Speed (km/h)	Total Cases (n=96)	Rural Cases (n=70)	Urban Cases (n=26)
0-19	2 (2%)	2 (3%)	0 (0%)
20-39	6 (6%)	4 (6%)	2 (8%)
40-59	8 (8%)	4 (6%)	4 (15%)
60-79	20 (21%)	15 (21%)	5 (19%)
80-99	29 (30%)	24 (34%)	5 (19%)
100-119	23 (24%)	18 (26%)	5 (19%)
120-139	5 (5%)	3 (4%)	2 (8%)
140+	3 (3%)	0 (0%)	3 (12%)

Table 13 shows calculated vehicle speeds for vehicles involved in fatal motor vehicle collisions in rural and urban regions. Data were available for 96 cases. Pre-impact vehicle speeds of 100km/h or higher were found to be involved at a higher odds in urban collisions (OR = 1.4583, 95%CI = 0.5691 to 3.7373, p=0.4320).

Table 14 - Presence or absence of airbag deployment (driver or passenger) for fatal motor vehicle collisions in rural and urban regions.

Airbag Deployment	Total Cases (n=231)	Rural Cases (n=158)	Urban Cases (n=73)
Yes	97 (42%)	70 (44%)	27 (37%)
No	134 (58%)	88 (56%)	46 (63%)

Table 14 shows the presence or absence of airbag deployment for vehicles involved in fatal collisions in rural and urban regions. Data were available for 231 cases. Airbag deployment occurred with a higher odds for rural collisions (OR = 1.3552, 95%CI = 0.7668 to 2.3952, p=0.2955).

Table 15 - Presence or absence of interior windshield contact for fatal motor vehicle collisions in rural and urban regions.

Windshield Contact (Interior Damage from Driver/Passengers)	Total Cases (n=103)	Rural Cases (n=74)	Urban Cases (n=29)
Yes	58 (56%)	45 (61%)	13 (45%)
No	45 (44%)	29 (39%)	16 (55%)

Table 15 shows the presence or absence of windshield contact from drivers or passengers involved in fatal motor vehicle collisions in rural and urban regions. Data were available for 103 cases. Driver or passenger contact with the windshield was found to occur with a higher odds for rural collisions (OR = 1.9098, 95%CI = 0.8017-4.5495, p=0.1440).

Table 16 - Injury severities (Abbreviated Injury Scale, rated from 3 [serious] to 6 [maximum]) of drivers involved in fatal motor vehicle collisions in rural and urban regions.

Driver – Injury Severity	Total Cases(n=121)	Rural Cases (n=91)	Urban Cases (n=30)
AIS 3	21 (17%)	14 (15%)	7 (23%)
AIS 4-6	100 (83%)	77 (85%)	23 (77%)

Table 16 shows the distribution of injury severities for fatally injured drivers involved in motor vehicle collisions in rural and urban regions. Data were available for 121 cases. Less severe injuries (AIS scores of 3) occurred with a higher odds for drivers involved in fatal urban collisions (OR = 1.6739, 95%CI = 0.6037 to 4.6414, p=0.3221), whereas more severe injuries (AIS 6) occurred with a higher odds for drivers involved in fatal rural collisions (OR = 1.6739, 95%CI = 0.6037 to 4.6414, p=0.3221). Appendix B (Tables B1 and B2) lists the AIS 3 injuries recorded in the study.

Table 17 - Injury severities (Abbreviated Injury Scale, rated from 3 [serious] to 6 [maximum]) of passengers involved in fatal motor vehicle collisions in rural and urban regions.

Passenger – Injury Severity	Total Cases (n=29)	Rural Cases (n=20)	Urban Cases (n=9)
AIS 3	5 (16%)	4 (20%)	1 (11%)
AIS 4-6	24 (84%)	16 (80%)	8 (89%)

Table 17 shows the distribution of injury severities for fatally injured passengers involved in motor vehicle collisions in rural and urban regions. Data were available for 29 cases. Less severe injuries (AIS scores of 3) occurred with a higher odds for passengers involved in fatal rural collisions (OR = 2.0000, 95%CI = 0.1907 to 20.9702, p=0.5632). Inversely, more severe injuries (AIS 4-6) occurred with higher odds for passengers involved in fatal urban collisions (OR = 2.0000, 95%CI = 0.1907 to 20.9702, p=0.5632). Appendix B (Tables B1 and B2) lists the AIS 3 injuries recorded in the study.

Table 18 – Survival times in fatal motor vehicle collisions in rural and urban regions.

Survival Time	Total Cases (n=109)	Rural Cases (n=77)	Urban Cases (n=32)
Dead at Scene	61 (56%)	46 (60%)	15 (47%)
Died in Hospital	48 (44%)	31(40%)	17 (53%)

Table 18 shows the distribution of survival times for fatally injured occupants involved in fatal motor vehicle collisions between rural and urban regions. Data were available for 109 cases. Collisions where the victim was pronounced dead at the scene showed a higher odds of involvement in a fatal rural collision (OR = 1.6817, 95%CI = 0.7330-3.8582, p=0.2198). Collision victims in urban areas had a higher odds of being transported to the hospital prior to death (OR = 1.6817, 95%CI = 0.7330-3.8582, p=0.2198).

Table 19 – Type of vehicles involved in fatal motor vehicle collisions in rural and urban regions.

Vehicle Type	Total Cases (n=243)	Rural Cases (n=169)	Urban Cases (n=74)
Passenger Car (PC)	136 (56%)	97 (57%)	39 (53%)
Light Truck Vehicle (LTV)	65 (27%)	47 (28%)	18 (24%)
Heavy Commercial Vehicle (HCV)	19 (8%)	13 (8%)	6 (8%)
Motorcycle	17 (7%)	7 (4%)	10 (14%)
Other	6 (2%)	5 (3%)	1 (1%)

Table 19 shows the distribution of vehicle types involved in fatal motor vehicle collisions in rural and urban regions. Data were available for 243 cases. Passenger cars were involved with a higher odds for fatal rural collisions (OR = 1.2090, 95%CI = 0.6984 to 2.0931, p=0.4978). Light truck vehicles were involved with a higher odds for fatal rural collisions (OR = 1.1985, 95%CI = 0.6392 to 2.2474, p=0.5723). Heavy commercial vehicles were involved with a higher odds for fatal urban collisions (OR = 1.0588, 95%CI = 0.3863 to 2.9025, p=0.9115). Motorcycles were involved with a higher odds for fatal urban collisions (OR = 3.6161, 95%CI = 1.3193 to 9.9116, p=0.0125).

Table 20 - Manufacturing year of vehicles involved in fatal motor vehicle collisions in rural and urban regions

Vehicle Year	Total Cases (n=239)	Rural Cases (n=167)	Urban Cases (n=72)
<1998	67 (28%)	50 (30%)	17 (24%)
1998+	172 (72%)	117 (70%)	55 (76%)

Table 20 shows the distribution of vehicle types involved in fatal motor vehicle collision in rural and urban regions. Data were available for 239 cases. Older vehicles (manufactured prior to 1998) were involved with a higher odds for fatal rural collisions (OR = 1.3826, 95%CI = 0.7314 to 2.6137, p=0.3187).

Raw Data and Odds Ratios - Environmental factors

Table 21 - Road surface conditions for fatal motor vehicle collisions in rural and urban regions.

Road Surface Condition	Total Cases(n=243)	Rural Cases (n=169)	Urban Cases (n=74)
Dry	198 (81%)	133 (79%)	65 (88%)
Wet/Snow/Slush	45 (19%)	36 (21%)	9 (12%)

Table 21 shows the distribution of road surface conditions at the time of collision in urban and rural fatal collisions. Data for road surface condition were available for 243 cases. Wet road conditions (rain, slow, slush, or ice) were found to have a higher odds of involvement in rural collisions than urban collisions (OR = 1.9549, 95%CI = 0.8887 to 4.3004, p=0.0956).

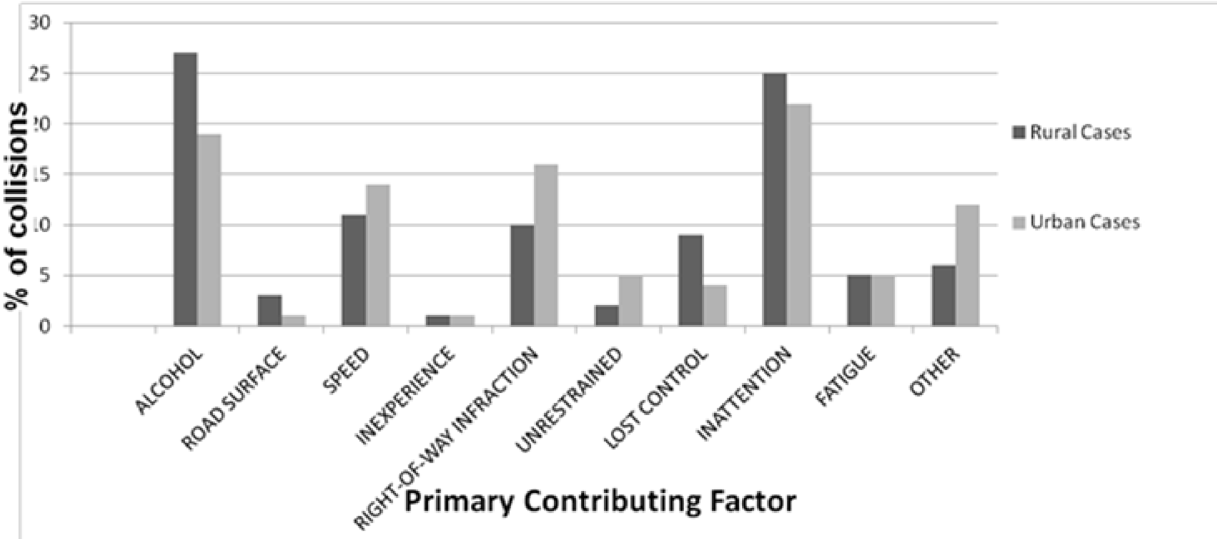

Figure 4. **Distribution of collisions by primary contributing factor in rural and urban fatal motor vehicle collisions.**

Table 22 - Primary contributing factors for fatal motor vehicle collisions in rural and urban regions.

Primary Contributing Factor	Total Cases (n=243)	Rural Cases (n=169)	Urban Cases (n=74)
ALCOHOL	57 (23%)	43 (25%)	14 (19%)
ROAD SURFACE	7 (3%)	6 (4%)	1 (1%)
SPEED	29 (12%)	19 (11%)	10 (14%)
INEXPERIENCE	3 (1%)	2 (1%)	1 (1%)
RIGHT-OF-WAY (ROW) INFRACTION	29 (12%)	17 (10%)	12 (16%)
UNRESTRAINED	7 (3%)	3 (2%)	4 (5%)
LOST CONTROL	19 (8%)	16 (9%)	3 (4%)
INATTENTION	59 (24%)	43 (25%)	16 (22%)
FATIGUE	13 (6%)	9 (6%)	4 (5%)
OTHER	20 (8%)	11 (7%)	9 (12%)

Table 22 shows the distribution of primary contributing factors for fatal motor vehicle collisions in rural and urban regions. Data were available for 243 cases. Alcohol use by drivers was found to be involved with a higher odds for fatal rural collisions (OR = 1.4626, 95%CI = 0.7432 to 2.8782, p=0.2710). Speed was found to be involved with a higher odds for fatal urban collisions (OR = 1.2335, 95%CI = 0.5434 to 2.8001, p=0.6158). Right-of-way (ROW) infractions were found to be involved with higher odds for fatal urban collisions (OR = 1.7306, 95%CI = 0.7808 to 3.8354, p=0.1768). Driver inattentiveness was found to be involved with a higher odds for fatal rural collisions (OR = 1.2371, 95%CI = 0.6440 to 2.3764, p=0.5229).

Single Equation Hierarchical Multiple Regression Analyses

Table 23 - Hierarchical Regression Analysis – Impact Type as Dependent Variable – Rural Fatal Collisions.

Block/ Model	Independent Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value change	*Significance of F change*	ANOVA significance value
1	Gender	0.385	0.040	0.023	0.523	0.523
	Age	0.269	0.194			
2	Light Condition	0.009	0.947	0.012	0.710	0.741
	Road Condition	0.207	0.171			
3	Region	0.317	**0.041**	0.072	0.265	0.536
	Posted Speed	0.113	0.464			
	Calculated Speed	0.053	0.790			
4	Vehicle Year	0.216	0.436	0.048	0.445	0.560
	Vehicle Airbag Generation	0.019	0.934			
	Vehicle Type	0.297	0.096			
5	Windshield Contact	0.079	0.615	0.069	0.275	0.470
	Fuel Integrity Loss	0.255	0.137			
	Door Latch/Hinge Failure	0.230	0.156			
6	Driver Mass	0.924	**0.000**	0.218	**0.008**	**0.046**
	Total Occupant Mass	3.072	**0.008**			
	Total Vehicle Mass	0.100	0.548			
	Number of Occupants	3.056	**0.011**			
7	Years Licensed	0.307	0.155	0.035	0.783	0.139
	Previous Collisions	0.005	0.978			
	Previous Speeding Convictions	0.089	0.608			
	Previous DWI Convictions	0.011	0.957			
	Previous Suspensions	0.105	0.578			
8	Ejection	0.144	0.429	0.095	0.081	0.063
	Restraint Use	0.290	0.079			
	Airbag Deployment	0.216	0.175			

Table 23 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables to the prediction of the dependent variable (impact type: frontal, rear, side, rollover, fixed object, or ran-off-road) when age and gender are controlled. Because some MVCs in the study did not have any passengers, driver mass and total occupant mass were equal for some cases.

While all independent variables assessed contributed to additional variance in impact type other than the variance contributed by gender and age, the variables driver mass (**β = 0.924**), total occupant mass (**β = 3.072**), and number of occupants (**β = 3.056**) had a significant contribution to the prediction of the outcome (impact type).Without the effects of gender and age, the independent variables in **Table 23** explain **54.9%** of additional variance in impact type. This percentage value is the summation of all r-squared value changes in the data blocks other than block 1 (gender and age).

See Table C15 (Appendix C) for a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 23.

Table 24 - Hierarchical Regression Analysis – <u>AIS</u> as Dependent Variable – <u>Rural</u> Fatal Collisions

Block/ Model	Independent Variable	Beta standardized regression coefficient (absolute magnitude)	Coefficient significance value	R-squared value change	*Significance of F change*	ANOVA significance value
1	Gender	0.179	0.412	0.012	0.713	0.713
	Age	0.052	0.833			
2	Light Condition	0.116	0.484	0.015	0.655	0.822
	Road Condition	0.133	0.459			
3	Region	0.045	0.801	0.015	0.851	0.941
	Posted Speed	0.126	0.494			
	Calculated Speed	0.053	0.823			
4	Vehicle Year	0.359	0.281	0.062	0.356	0.839
	Vehicle Airbag Generation	0.184	0.508			
	Vehicle Type	0.208	0.326			
5	Windshield Contact	0.047	0.804	0.065	0.334	0.751
	Fuel Integrity Loss	0.323	0.118			
	Door Latch/Hinge Failure	0.203	0.293			
6	Driver Mass	0.600	**0.035**	0.128	0.136	0.462
	Total Occupant Mass	2.933	**0.030**			
	Total Vehicle Mass	0.247	0.219			
	Number of Occupants	3.003	**0.033**			
7	Years Licensed	0.032	0.899	0.047	0.759	0.642
	Previous Collisions	0.088	0.681			
	Previous Speeding Convictions	0.089	0.670			
	Previous DWI Convictions	0.215	0.387			
	Previous Suspensions	0.234	0.302			
8	Ejection	0.026	0.904	0.041	0.544	0.688
	Restraint Use	0.207	0.288			
	Airbag Deployment	0.103	0.584			

Table 24 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables to the prediction of the dependent variable (AIS: maximum AIS of fatally injured occupant) when age and gender are controlled.

While all independent variables assessed contributed to additional variance in AIS other than the variance contributed by gender and age, the variables driver mass (**β = 0.600**), total occupant mass (**β = 2.933**), and number of occupants (**β = 3.003**) had a significant contribution to the prediction of the outcome (AIS).Without the effects of gender and age, the independent variables in **Table 24** explain **37.3%** of additional variance in AIS.

See Table C16 (Appendix C) for a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 24.

Table 25 - Hierarchical Regression Analysis – Calculated Speed as Dependent Variable – Rural Fatal Collisions

Block/ Model	Independent Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value change	*Significance of F change*	ANOVA significance value
1	Gender	0.194	0.215	0.054	0.212	0.212
	Age	0.346	0.046			
2	Light Condition	0.063	0.598	0.039	0.322	0.253
	Road Condition	0.302	**0.016**			
3	Region	0.198	0.123	0.125	**0.021**	**0.039**
	Posted Speed	0.319	**0.013**			
4	Vehicle Year	0.211	0.377	0.161	**0.010**	**0.003**
	Vehicle Airbag Generation	0.177	0.376			
	Vehicle Type	0.049	0.747			
5	Windshield Contact	0.187	0.165	0.074	0.116	**0.002**
	Fuel Integrity Loss	0.130	0.484			
	Door Latch/Hinge Failure	0.200	0.144			
6	Driver Mass	0.032	0.873	0.080	0.150	**0.002**
	Total Occupant Mass	0.888	0.347			
	Total Vehicle Mass	0.076	0.596			
	Number of Occupants	1.214	0.215			
7	Years Licensed	0.391	**0.029**	0.113	0.060	**0.001**
	Previous Collisions	0.041	0.790			
	Previous Speeding Convictions	0.274	0.063			
	Previous DWI Convictions	0.120	0.504			
	Previous Suspensions	0.280	0.081			
8	Ejection	0.066	0.674	0.020	0.581	**0.003**
	Restraint Use	0.127	0.362			
	Airbag Deployment	0.106	0.436			

Table 25 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables to the prediction of the dependent variable (calculated speed: speed of vehicle at time of impact) when age and gender are controlled.

While all independent variables assessed contributed to additional variance in speed other than the variance contributed by gender and age, the variables road condition (**β = 0.302**) posted speed (**β = 0.319**), and years licensed (**β = 0.391**) had a significant contribution to the prediction of the outcome (speed).Without the effects of gender and age, the independent variables in **Table 25** explain **61.2%** of additional variance in speed.

See Table C17 (Appendix C) for a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 25.

Table 26 - Hierarchical Regression Analysis – <u>Impact Type</u> as Dependent Variable – <u>Urban</u> Fatal Collisions

Block/ Model	Independent Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value change	*Significance of F change*	ANOVA significance value
1	Gender	0.868	0.010	0.087	0.402	0.402
	Age	0.030	0.884			
2	Light Condition	0.298	0.135	0.027	0.761	0.680
	Road Condition	0.779	**0.017**			
3	Region	1.460	**0.005**	0.039	0.876	0.896
	Posted Speed	0.370	0.125			
	Calculated Speed	0.901	**0.029**			
4	Vehicle Year	0.157	0.620	0.074	0.767	0.946
	Vehicle Airbag Generation	0.556	0.220			
	Vehicle Type	1.334	**0.009**			
5	Windshield Contact	0.717	**0.020**	0.177	0.484	0.896
	Fuel Integrity Loss	0.249	0.263			
	Door Latch/Hinge Failure	0.215	0.296			
6	Driver Mass	0.645	**0.026**	0.451	**0.007**	0.091
	Number of Occupants	1.750	**0.004**			

Table 26 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables to the prediction of the dependent variable (impact type: frontal, rear, side, rollover, fixed object, or ran-off-road) when age and gender are controlled.

While all independent variables assessed contributed to additional variance in impact type other than the variance contributed by gender and age, the variables road condition (**β = 0.779**), region (**β = 1.460**), calculated speed (**β = 0.901**), vehicle type (**β = 1.334**), windshield damage (**β = 0.717**), driver mass (**β = 0.645**), and number of occupants (**β = 1.750**) had a significant contribution to the prediction of the outcome (impact type).Without the effects of gender and age, the independent variables in **Table 26** explain **76.8%** of additional variance in impact type.

See Table C18 (Appendix C) for a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 26.

Table 27 - Hierarchical Regression Analysis – <u>AIS</u> as Dependent Variable – <u>Urban</u> Fatal Collisions

Block/ Model	Independent Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value change	*Significance of F change*	ANOVA significance value
1	Gender	0.212	0.802	0.012	0.907	0.907
	Age	0.032	0.961			
2	Light Condition	0.167	0.780	0.039	0.757	0.941
	Road Condition	0.261	0.757			
3	Region	0.031	0.980	0.164	0.537	0.865
	Posted Speed	0.025	0.972			
	Calculated Speed	0.180	0.871			
4	Vehicle Year	0.240	0.815	0.009	0.992	0.983
	Vehicle Airbag Generation	0.177	0.898			
	Vehicle Type	0.258	0.837			
5	Windshield Contact	0.379	0.643	0.100	0.860	0.993
	Fuel Integrity Loss	0.100	0.884			
	Door Latch/Hinge Failure	0.125	0.845			
6	Driver Mass	0.522	0.707	0.079	0.830	0.997
	Number of Occupants	0.251	0.745			

Table 27 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables to the prediction of the dependent variable (AIS: maximum AIS of fatally injured occupant) when age and gender are controlled.

While all independent variables assessed contributed to additional variance in AIS other than the variance contributed by gender and age, the variables driver mass (**β = 0.522**), windshield damage (**β = 0.379**), road condition (**β = 0.261**), vehicle type (**β = 0.258**), number of occupants (**β = 0.251**), and vehicle year (**β = 0.240**) had the largest contributions to the prediction of the outcome (AIS).Without the effects of gender and age, the independent variables in **Table 27** explain **39.1%** of additional variance in AIS.

See Table C19 (Appendix C) for a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 27.

Table 28 - Hierarchical Regression Analysis – Calculated Speed as Dependent Variable – Urban Fatal Collisions

Block/ Model	Independent Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value change	*Significance of F change*	ANOVA significance value
1	Gender	0.418	0.100	0.016	0.849	0.849
	Age	0.252	0.225			
2	Light Condition	0.093	0.630	0.076	0.485	0.766
	Road Condition	0.482	**0.047**			
3	Region	0.753	**0.030**	0.062	0.569	0.810
	Posted Speed	0.175	0.448			
4	Vehicle Year	0.106	0.752	0.108	0.604	0.840
	Vehicle Airbag Generation	0.767	0.060			
	Vehicle Type	0.781	**0.026**			
5	Windshield Contact	0.388	0.110	0.152	0.490	0.808
	Fuel Integrity Loss	0.086	0.703			
	Door Latch/Hinge Failure	0.197	0.336			
6	Driver Mass	0.919	**0.014**	0.394	**0.011**	0.106
	Number of Occupants	0.361	0.122			

Table 28 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables to the prediction of the dependent variable (calculated speed: speed of vehicle at time of impact) when age and gender are controlled.

While all independent variables assessed contributed to additional variance in speed other than the variance contributed by gender and age, the variables driver mass (**β = 0.919**), vehicle type (**β = 0.781**), region (**β = 0.753**), and road condition (**β = 0.482**) had significant contributions to the prediction of the outcome (speed).Without the effects of gender and age, the independent variables in **Table 28** explain **79.2%** of additional variance in speed.

See Table C20 (Appendix C) for a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 28.

DISCUSSION

Human factors associated with fatal motor vehicle collisions

Gender and Age

In the present study, young drivers (age 14-29, OR = 1.1390) and older drivers (age≥60, OR = 1.5213) were found to have higher odds than 30 to 59 year-old drivers of being involved in a fatal rural MVC (Table 1). While 17% of fatal rural MVCs involved an older driver (OR = 1.5213), only 11% of fatal urban MVCs involved this age group. A lower percentage difference was found for fatal rural and urban MVCs (43% and 41%, respectively) involving young drivers (OR = 1.1390). These observed trends support studies which have shown that young and older drivers are more involved in fatal MVCs, and the present study indicates they were more likely to be in rural collisions[1,2,3,5]. In the present study, young drivers represented 44% of total drivers involved in fatal MVCs even though the young drivers age group had a range of only 16 years, compared to the 30 year range of the middle age group (age 30-59) and 31 year range of the older age group (where the oldest driver was 90 years old). There were 103 drivers 14-29, 104 drivers 30-59, and 34 drivers age 60-90.

The present study found that 78% of drivers involved in fatal MVCs were male (Table 2). Males showed only a slightly higher involvement in urban compared to rural MVCs (OR=1.1800). Although no significant difference was found for fatally injured males between rural and urban MVCs, the higher incidence of male victims supports previous

studies which found that males had a higher risk than females of a fatal MVC[1]. Although female and male drivers each account for approximately 50% of the driving population, females have been found to drive less distance per year than males which may account for the difference between male and female deaths in the present study[54].

Body Habitus

Past studies have assessed the role of body mass index (BMI) in MVCs. In the present study, occupant weight (mass) was assessed. Weight has been found to be highly correlated with BMI in an analysis of twenty-five diverse population samples of men and women from the US, Europe, and Asia[10,55]. The present study found that heavier drivers (≥80kg) had higher odds of being in a fatal urban collision (OR = 2.5435) (Table 3). They accounted for 28% of fatal urban MVCs compared to 13% of rural MVCs. This finding contrasts with the literature that found an association between BMI and male fatality with increasing speed[10]. However, in the present study, speed was found to be involved with a higher odds as a primary contributing factor for fatal urban collisions (OR = 1.2335, Table 22). Furthermore, vehicle speeds of 100km/h or higher were found to be involved at a higher odds in urban collisions (OR = 1.4583) (Table 13). This suggests that despite lower posted speed limits for urban roadways, the fact that some motorists still travelled at high speeds contributed to a fatal MVC outcome. Therefore, further research is needed in order to explain the relationship between speed, body mass, and fatal injuries in the context of urban MVCs.

Heavier individuals have a higher risk of sudden death[56]. Although not researched in a context exclusive to MVCs, sudden death also occurs under circumstances during or immediately following physical and emotional stress[57]. The acutely stressful circumstances during an MVC could increase the odds of death in a MVC for a heavier individual. Furthermore, it has been suggested that comorbidities of obesity, and emergency and postoperative treatment problems in injured obese patients may account for the higher risk of death in MVCs[9]. Another study found that obesity is an independent risk factor of mortality in severely injured blunt trauma patients[58]. In the present study, 75% of heavy (80kg+) individuals died at the collision scene while only 53% of lighter (<80kg) individuals experienced the same fate. This suggests that increased body mass may decrease the survival interval after occurrence of MVCs, and that heavier individuals require more prompt medical attention than lighter individuals.

Regression analysis (Tables 23-24) revealed that for fatal rural MVCs, driver mass and total occupant mass (the mass of the driver and all passengers) were statistically significant predictors of impact type and AIS, respectively. As survival probability decreases with ascending Abbreviated Injury Scale scores (AIS 3 injuries are sometimes survivable while AIS 6 injuries are not survivable[59,60]), the finding that occupant mass significantly predicts AIS outcome suggests that mass may be a factor that contributes to a fatal outcome in MVCs. Research that compares occupant body mass in fatal and non-fatal MVCs would assist in explaining this suggestion.

For urban MVCs, driver mass was a statistically significant predictor of impact type and impact speed (Tables 26,28). This supports research that found higher MVC fatality rates for occupants with high BMIs[10]. Past studies have shown that high BMI males

have a higher risk of death in certain collision types (frontal and side-impact)[10]. The present study determined that fatal fixed object (OR = 3.0611) and ran-off-road (OR = 16.5029) MVCs occur with a higher odds in urban areas (Table 12).

The results from the current study have pointed to driver mass as being a significant predictor of impact type in urban and rural MVCs (Tables 23-28) which means that more research is needed to explain the relationship between specific impact types and body mass. It is possible that individuals who are heavier are in some way compromised in their ability to maneuver in order to avoid leaving their rightful lane of travel, running off the road and possibly hitting a fixed object.

Alcohol and Drugs

Alcohol use was one of the major contributing factors for fatal MVCs and was at a higher odds for fatal rural MVCs (OR = 1.4626) (Table 22). The current study supports previous findings which suggest more frequent alcohol use and higher levels of intoxication on rural roadways[42] .Twenty-five percent of fatal rural MVCs involved alcohol use as a contributing factor as opposed to 19% of urban fatal MVCs. Furthermore, drivers with prior DWI convictions had a higher odds of involvement in fatal rural MVCs (OR = 2.7991) (Table 7). The prevalence of alcohol use in motorists on rural roadways may be a result of the decreased law enforcement surveillance due to less human resources compared to urban areas. Inebriated motorists may feel more inconspicuous on less-travelled rural roadways leading to a higher chance of driving while intoxicated. Roadside screening tests for marijuana went into effect after the

culmination of the cases collected during the time period of the present study; therefore, marijuana use may have been grossly underreported. A 2012 Ontario study found marijuana to be the second most prevalent drug in toxicological analyses of fatally injured drivers over a one year period[13]. Further research using data acquired after implementation of broader roadside screening tests will assess the contribution of marijuana and drugs other than alcohol to fatal collision causation.

Regression analysis revealed that when the following were grouped: years licensed; previous collisions; previous speeding convictions, previous DWI convictions and previous suspensions, were a significant predictor of calculated impact speed for fatal rural collisions (Table 25). This shows that previous DWI convictions and other variables related to the driver's history with law enforcement influences driving speed. This supports findings that drivers had a temporary reduction in risk of fatal MVC that lasted for one month after a driving-related conviction, but this effect was not evident after two months[18].

Law Enforcement and the Driver

The current study found that drivers who had been licensed for ten years or longer had higher odds of a fatal rural MVC (OR = 1.6631), while novice drivers had higher odds of a fatal urban MVC (OR = 1.3830) (Table 4).Urban roadways demand consistent driver attentiveness due to increased vehicle density, stop-points, and pedestrian traffic which novice drivers may lack because of inexperience. Drivers on rural roadways travel at increased speeds and often travel further distances than urban drivers. If these rural

drivers are familiar with a frequently travelled route, they may be less vigilant about collision avoidance. Regression analysis found that years licensed was a statistically significant predictor of calculated impact speed in rural MVCs (Table 25). This result suggests that driving experience and the presumed consequent driving skills may affect the travel speed of rural motorists. Experienced road users may travel at higher speeds on rural roadways because they feel safer on these roads.

Drivers with previous suspensions had higher odds of involvement in a fatal urban MVC (OR = 1.3343) (Table 5). This particular finding may be related to the increased density of law enforcement surveillance in urban areas. Urban motorists have an increased chance of being caught for traffic infractions and violations leading to license suspensions compared to rural areas where drivers may be less likely to be apprehended because of the relative lack of police officers.

A history of previous collisions was not found to significantly predict impact type, AIS, or calculated impact speed (Tables 23-28). Motorists in the present study database did not have to initiate a collision in order to have a previous collision listed. “Previous at-fault collisions” may have provided a more significant result if the data were available.

Drivers with previous speeding convictions had higher odds of involvement in a fatal rural collision (OR = 1.2406) (Table 6). Although the risk of fatal collision has been shown to decrease following a speeding conviction, the decrease is not sustained[19]. Drivers who had speeding convictions may make a habit of driving above the speed

limit, and continue this behaviour even after being convicted for a speeding offence. This study supports previous findings which showed risk-taking driving behaviours, including speeding, were more prevalent on rural roadways than urban roadways[43]. Regression analysis revealed that besides years licensed, previous speeding convictions provided the strongest predictor of calculated impact speed (Table 25). This reinforces the idea that past driving-related charges can be indicative of future driving behaviour.

Driver Distraction

Driver inattention (OR = 1.2371) ranked with alcohol use (OR = 1.4626) as a major contributing factor and was at higher odds for fatal rural collisions (OR = 1.2371) (Table 22). Inattention could be more likely on rural roadways due to increased travel distances and travel times, decreased stop-points (intersections, traffic lights, and roundabouts), and less need by the driver to brake and turn compared to urban roadways. These factors increase the monotony of driving.

The number of occupants in the vehicle at time of impact was found by regression analysis to be a statistically significant contributor to the prediction of impact type and AIS in fatal rural collisions (Table 24), and a statistically significant contributor to the prediction of impact type in fatal urban MVCs (Table 26). This shows that the presence of occupants in the vehicle favors specific impact types, and supports research which found that young drivers carrying passengers were more likely to be involved in certain

types of MVCs[25]. Young drivers' tendency to engage in risky driving behaviour that includes speeding may combine with the distracting effect of passengers in the vehicle to further increase the odds of a fatal collision. The fact that number of occupants provides a statistically significant contribution to the prediction of AIS may be indicative of occupant-to-occupant contact at time of collision. Depending on the kinematics of the vehicle occupants at the time of collision, certain anatomical regions of the occupants may be cushioned from contacting the vehicle interior by another occupant, reducing the severity of the injury. Alternatively, occupant-to-occupant loading can exacerbate the injury severity of the involved occupants.

Vehicular factors associated with fatal motor vehicle collisions

Impact Type and Injury Patterns

Frontal (OR = 1.2013), side-impact (1.1669), rear (OR = 1.1039), and rollover (OR = 25.6960) MVCs occurred with higher odds in fatal rural MVCs, whereas fixed object (OR = 3.0611) and ran-off-road (OR = 16.5029) MVCs occurred with higher odds for fatal urban MVCs (Table 12). Rollover collisions occurred almost exclusively on rural roadways, most likely due to the high travelling speeds, loss of driver control leading to vehicle wheel contact with gravel shoulders and ditches on the side of rural roadways increasing the likelihood of a rollover trajectory. Fixed object collisions may be more frequent in urban areas due to the increased density of structures such as lampposts, traffic signs, traffic lights, and parked cars. Rear impacts may occur with higher odds for rural MVCs because vehicles are travelling at higher speeds (>60 km/h) and need more

time and distance to brake to avoid a collision with the rear of a vehicle or a road hazard. Rollover impacts and any other collisions involving a single vehicle can remain unnoticed in secluded rural settings leading to delayed recovery of victims. As rural collision victims were found to have higher odds of death at the scene of the collision than urban victims (OR = 1.6817) (Table 18), the inconspicuousness of rural rollover collisions and decreased proximity to medical facilities may both increase the odds of death in rural MVCs.

The present study found that less severe maximum AIS injuries (AIS-3) occurred with higher odds for fatally injured drivers in urban collisions (OR = 1.6739) (Table 16). The lower posted speed limits for urban roadways may account for the trend towards lesser injury severity; however, many of the cases with maximum AIS scores of 3 had injuries that affected multiple anatomical regions. More severe injuries (AIS 4-6) occurred with higher odds (OR = 1.6739) for drivers in fatal rural collisions (Table 16). This is likely attributed to the increased posted speed limits on rural roadways, as speed has been shown to be associated with AIS linearly[61]. Fatally injured passengers, who sustained less severe injuries (AIS 3), were more likely to be involved in fatal rural collisions (OR=2.000, Table 17). The opposite result was found for passengers who had more severe injuries (AIS 4-6) at higher odds (OR=2.000, Table 17) in urban MVCs. This is the inverse of the findings for drivers in this study and these conflicting results support previous studies that found injury severity does not account for the difference in mortality rates between fatal rural and urban collisions[43.] As increased injury severity was found not to be a trend for fatally injured passengers in rural MVCs, another factor must account for this. One possible explanation is that the decreased proximity to

medical facilities accounts for less severely passengers dying in rural MVCs, but this does not address the observation in the study that less severely injured drivers died in urban settings. Collisions where the victim was pronounced dead at the scene did show a higher odds of involvement in a fatal rural collision (OR = 1.6817) (Table 18). The fatally injured occupant was pronounced dead at the scene for 60% of rural MVCs; only 47% of urban MVCs shared the same outcome. More urban MVC victims were transported to hospital before death. Although this result does not allow for inference of the quality of medical care for MVC victims between urban and rural areas, temporal and geographical factors such as delays in emergency response times and increased proximity from medical centres may account for the higher odds of on-site deaths, at least for passengers, in rural MVCs.

Vehicle Type

The present study found that passenger cars (OR = 1.2090) and light-truck vehicles (OR = 1.1985) were involved at higher odds for fatal rural collisions, and that motorcycles (OR = 3.6161) and heavy commercial vehicles (OR=1.0588) were involved at higher odds for fatal urban collisions (Table 19). Past studies have shown that restrained occupants of a passenger car that experienced a frontal collision with a light-truck vehicle (LTV) had a higher fatality rate than belted occupants of an LTV[62]. While vehicle weight differential has been suggested to be a factor in the determination of the risk of fatality for occupants involved in a MVC, research has also found that in MVCs between passenger cars and LTVs where the former outweighed the latter, the

occupants of the passenger car still had a higher risk of fatality[62]. This suggested that additional factors including mismatches in vehicle design and structural load path (the direction and magnitude of energy transfer from exterior crash load) may be relevant[62]. For example, the bumper of a smaller passenger car may not be able to translate a satisfactory crash load because of its smaller cross section, and more energy is dissipated to the interior vehicle cabin[63]. Regression analysis revealed that vehicle type was a statistically significant predictor of impact type and calculated impact speed for fatal urban collisions (Tables 26, 28). This shows that in urban areas, specific vehicle types may favor particular impact types. Further research is needed in order to determine whether factors such as variation in stiffness of vehicle exterior, vehicle height, and vehicle mass are responsible.

Older model vehicles were involved at higher odds in fatal rural collisions (OR=1.3826; Table 20). Older model vehicles were those manufactured prior to 1998 before the introduction of second generation “less aggressive” airbags. These older vehicles also lacked many safety features available in newer models. A study found individuals of lower socioeconomic class were at a higher risk of fatal rural MVC because these motorists tended to drive older and less safe cars[64]. Poorer individuals tend to own cars that have lower crash-test ratings and lack sophisticated safety features such as side airbags, automatic warnings, and rear cameras[64]. Unlike vehicle type, vehicle manufacturing year was not able to significantly predict impact type, AIS of fatally injured occupants, or calculated speed in rural or urban MVCs (Tables 23-28). Although older vehicles may have less advanced safety features that may increase fatality risk,

the current study indicates that vehicle type is a better predictor of the collision parameter of impact type in urban collisions.

Restraint Systems

Interior windshield contact damage (OR = 1.9098) and airbag deployment (OR = 1.3552) were both shown to occur with higher odds in fatal rural collisions (Tables 14,15). A higher impact speed on a rural roadway is more likely to deploy an airbag and promote movement of unrestrained occupants and foreign objects inside the interior vehicle cabin.

Passengers in vehicles on rural roadways often travel for longer distances and times than urban passengers. Rural passengers can assume more comfortable seated positions which lead to increased bodily displacement following a collision and are less protected by vehicle safety features that are designed to protect an upright seated passenger.

Reduced enforcement surveillance because of limited police resources in rural regions could account for the reduction in seatbelt use observed for rural passengers involved in fatal collisions (Table 9: 49% of rural passengers vs. 64% in urban crashes) . This was not observed among drivers in the present study (Table 8: 76% of drivers in rural MVCs vs. 65% in urban MVCs were wearing seatbelts). These trends in the lack of seatbelt use is consistent with the higher odds of ejection of passengers in rural versus urban collisions (OR = 2.0851; Table 11), whereas drivers were found to have slightly higher odds for ejection in urban collisions (OR = 1.0446; Table 10). This further supports the

observation that passengers are at increased risk of fatality when travelling on rural roadways.

Environmental factors associated with fatal motor vehicle collisions

Adverse road surface conditions were more likely to contribute to fatal rural collisions (OR = 1.9549; Table 21). This is likely attributable to vehicles travelling at higher speeds on rural roadways, and driving skills such as steering and braking responses being negatively affected under adverse road surface conditions. Although past studies have showed that the perception and reaction to road surface conditions is different between age and gender subpopulations[39], the current study found that road condition was a significant predictor of calculated impact speed for fatal rural MVCs (Table 25). This shows that for the drivers included in this study, the presence of adverse road conditions affected their driving speed regardless of age or gender. Road surface condition was also found to be a significant predictor of impact type for fatal urban MVCs (Table 26). This suggests that adverse road conditions can lead to specific impact types over others on urban roadways. Lighting condition was not found to be a significant predictor of calculated speed or impact type.

Of the primary contributing factors to fatal impacts, alcohol use (OR = 1.4626) and inattention (OR = 1.2371) had higher odds of involvement in fatal rural collisions (Table 22). This supports previous studies which found an increased use of alcohol by drivers in rural regions compared to urban regions[41]. A possible reason for this could be

decreased law enforcement availability on rural roadways that may lead drivers to believe that their impaired driving behaviour is less likely to be noticed in rural areas. Right-of-way infractions were involved with a higher odds for fatal urban collisions (OR = 1.7306) (Table 22). Urban roadways have higher vehicle densities than rural roadways which provides the basis for more possible right-of-way infractions between vehicles.

Limitations

The sample size for this study (n=243) was relatively small and limited to fatal collisions investigated for Transport Canada's *Causes of Fatal Collisions* studies (CFC2/CFC3). Some odds ratios calculated were described by 95% confidence intervals that included the null value of 1.000 (example: Table 3, 95%CI = 0.9186-7.0423). An increased sample size may have found certain human, environmental, and vehicular factors to be significantly different between fatal rural and urban MVCs. Further research comparing fatal and non-fatal MVCs would determine which factors not only are prevalent in urban and rural MVCs but also predict the likelihood of fatality.

Injury scoring was done using the AIS coding. Interpretation about AIS severity for the CFC2 and CFC3 cases came from different individuals working in different regional teams. There was the possibility that similar injuries were reported with different AIS severities.

The human, environmental, and vehicular data between CFC2 and CFC3 fatal MVC cases were not uniform. Hierarchical regression analyses in this study only included

cases where all the variables (Table 23) were available. An increased sample size from a completely uniform database that includes the same data elements for every case would have enhanced the odds ratio calculations and regression analyses.

In Ontario, toxicological screening for drugs other than alcohol in MVC victims was implemented in 2012 after the time range of the CFC2 and CFC3 studies. Drugs other than alcohol were likely underreported in the present study particularly in the Ontario (MOVES) cases. Further research on fatal MVCs that occurred after 2012 would more completely assess the role of drugs in fatal rural and urban Canadian MVCs.

CONCLUSIONS

In the present study, differences in human, environmental, and vehicular variables were observed between fatal rural and urban MVCs. Odds ratios revealed significantly higher odds of impacts with fatal fixed objects or ran-off-road collisions on urban roadways, and rollover collisions on rural roadways. Hierarchical multivariate regression analysis revealed that for fatal rural MVCs, driver mass, total occupant mass, and numbers of occupants were significant predictors of impact type and AIS while years licensed was a significant predictor of calculated speed. For fatal urban MVCs, road surface condition, vehicle type, driver mass, and number of occupants were found to be significant predictors of impact type and calculated speed.

A common significant variable in the urban and rural collisions in this study was the body mass of the driver. Although other studies have assessed the role of BMI in MVCs,

our study found mass to be a novel and significantly relevant factor that accounts for variance in impact type, injury severity (AIS), and calculated speed between fatal MVCs. Further research is needed to compare the significance and usefulness of BMI and mass in the context of fatal MVCs.

The present study illustrates that passengers involved in fatal MVCs have higher odds of ejection and non-compliance with restraint use in a rural setting. This suggests that there is an increased need for passenger safety on rural roadways and further research should aim to elucidate other factors that promote passenger mortality in rural MVCs.

Our study indicates that a combination of human, environmental, and vehicular factors may account for the fact that the majority of Canadian fatal MVCs occur on rural roadways. Further research on these factors should assess their role in non-fatal and fatal MVCs in order to determine which intervention and prevention measures are best suited to protect Canadian rural motorists.

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APPENDIX A: CFC3 and CFC2 recorded Data Elements

Table A1. Human variables collected in study distributed between CFC3 and CFC2 cases.

Variable	Total Cases (n = 243)	CFC3 Cases (n=112)	CFC2 cases (n = 131)
Age	241	112	129
Gender	243	112	131
Mass	107	107	N/A*
Toxicology (Ethanol, THC)	243	112	131
Past Collisions	181	106	75
Past DWI Convictions	182	108	74
Past Speeding Convictions	181	106	75
Past Licence Suspensions	188	108	80
Years Licensed	190	107	83
Restraint Use	229	107	122

.* N/A indicates that the variable was not available in the cases.

Table A2. Environmental variables collected in study distributed between CFC3 and CFC2 cases.

Variable	Total Cases (n = 243)	CFC3 Cases (n=112)	CFC2 cases (n = 131)
Lighting Conditions + Road Surface Conditions	243	112	131
Posted Speed Limit	243	112	131
Type of Roadway	243	112	131
Location of Roadway	243	112	131
Interference/Distractions to Driver	243	112	131

Table A3. Vehicular variables collected in study distributed between CFC3 and CFC2 cases.

Variable	Total Cases (n = 243)	CFC3 Cases (n=112)	CFC2 cases (n = 131)
Type of Vehicle (Make/Model)	243	112	131
Damage to Vehicle (Interior)	103	103	N/A*
Damage to Vehicle (Exterior)	103	103	N/A*
Type of Collision (Impact Type)	243	112	131
Airbag Deployment	231	110	121
Calculated Speed	96	96	N/A
Ejection	243	112	131

*N/A indicates that the variable was not available in the cases.

Table A4. Injury variables collected in study distributed between CFC3 and CFC2 cases.

Variable	Total Cases (n = 243)	CFC3 Cases (n=112)	CFC2 cases (n = 131)
Survival Interval	109	109	N/A*
AIS	150	112	38

*N/A indicates that the variable was not available in the cases.

Tables A1-A4 show the human, environmental, and vehicular variables available for analyses in all CFC2 and CFC3 cases assessed in the present study.

APPENDIX B: AIS-3 Fatality Cases

Table B1 – CFC3 cases: fatality with AIS-3

Injury	Driver/Passenger	Location	Aspect	Source of data
Cerebrum edema	Driver	Urban	UNKNOWN / MULTIPLE REGIONS	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Lung NFS			BILATERAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
[redacted]				
Pelvis fracture	Driver	Urban	UNKNOWN / MULTIPLE REGIONS	LAY CORONER REPORT
Femur fracture			LEFT	LAY CORONER REPORT
[redacted]				
Basilar skull fracture	Driver	Urban	INFERIOR / LOWER	LAY CORONER REPORT
[redacted]				
Abdominal laceration (>20% blood loss by volume)	Driver	Urban	LEFT	EMERGENCY ROOM RECORDS ONLY (INCL X-RAY)
Humerus fracture			LEFT	EMERGENCY ROOM RECORDS ONLY (INCL X-RAY)
Femur fracture			RIGHT	EMERGENCY ROOM RECORDS ONLY (INCL X-RAY)
Femur fracture			LEFT	EMERGENCY ROOM RECORDS ONLY (INCL X-RAY)
Pelvis fracture			UNKNOWN / MULTIPLE REGIONS	LAY CORONER REPORT
[redacted]				
Rib cage fracture	Passenger	Urban	RIGHT	HOSPITAL / MEDICAL RECORDS OTHER THAN EMERGENCY ROOM
[redacted]				
Rib cage fracture	Driver	Rural	LEFT	HOSPITAL / MEDICAL RECORDS OTHER THAN EMERGENCY ROOM
[redacted]				
Basilar fracture	Driver	Rural	INFERIOR / LOWER	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Cerebrum contusion			UNKNOWN / MULTIPLE REGIONS	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Cerebellum NFS			POSTERIOR / BACK / DORSAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Rib cage fracture			BILATERAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Lung contusion			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Diaphragm laceration			INFERIOR / LOWER	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
[redacted]				
Spleen laceration	Passenger	Rural	LEFT	HOSPITAL / MEDICAL RECORDS OTHER THAN EMERGENCY ROOM
[redacted]				
Lung laceration	Driver	Rural	RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Rib cage fracture			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
[redacted]				
Leg amputation	Driver	Rural	RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Popliteal artery laceration			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Femur fracture			LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
[redacted]				
Femur fracture	Driver	Rural	LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Spleen laceration			LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Pelvis fracture			UNKNOWN / MULTIPLE REGIONS	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS

Scalp laceration			UNKNOWN / MULTIPLE REGIONS	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Forehead abrasion			UNKNOWN / MULTIPLE REGIONS	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Subtle sulcal subarachnoid hemorrhage	Driver	Rural	UNKNOWN / MULTIPLE REGIONS	HOSPITAL / MEDICAL RECORDS OTHER THAN EMERGENCY ROOM
Rib cage fracture	Passenger	Rural	RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Lacerations of pleural surfaces with hemothorax			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Lung laceration			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Retroperitoneum			INFERIOR / LOWER	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Symphysis pubis fracture			ANTERIOR / FRONT / VENTRAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Liver laceration			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Spleen laceration			LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Colon laceration			INFERIOR / LOWER	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Chest abrasions			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Chest contusion			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Rib cage fracture	Driver	Rural	LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Lacerations of pleural surfaces with hemothorax	Driver	Rural	UNKNOWN / MULTIPLE REGIONS	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Rib cage fracture			BILATERAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Sternum fracture			CENTRAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Rib cage fracture	Driver	Urban	BILATERAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Foot amputation			LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Femur fracture	Driver	Rural	LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Pelvis fracture	Driver	Rural	UNKNOWN / MULTIPLE REGIONS	HOSPITAL / MEDICAL RECORDS OTHER THAN EMERGENCY ROOM
Femur fracture			UNKNOWN / MULTIPLE REGIONS	HOSPITAL / MEDICAL RECORDS OTHER THAN EMERGENCY ROOM
Cerebrum contusion	Driver	Rural	BILATERAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Vault skull fracture			UNKNOWN / MULTIPLE REGIONS	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Sternum fracture			CENTRAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
C7 vertebral body fracture			POSTERIOR / BACK / DORSAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
C7 vertebral body fracture			POSTERIOR / BACK / DORSAL	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
eyebrow laceration			SUPERIOR / UPPER	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS

Table B1 shows the injury code, injury aspect, and source of injury data for the 19 CFC3 cases in which the fatally injured occupant received <AIS-4 injuries. Each individual fatally injured occupant is listed with their individual injuries between the black rows of the table.

Table B2 – CFC2 cases: fatality with AIS-3

Injury Code	Driver/Passenger	Location	Aspect	Source of data
Leg Amputation	Driver	Urban	RIGHT	HOSPITAL / MEDICAL RECORDS OTHER THAN EMERGENCY ROOM
Basilar skull fracture	Passenger	Rural	INFERIOR / LOWER	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Diaphragm laceration			INFERIOR / LOWER	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Lung contusion			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Rib Fracture			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Femur fracture			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Basilar skull fracture	Driver	Rural	INFERIOR / LOWER	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Basilar skull fracture			INFERIOR / LOWER	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Patella fracture			LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Patella fracture			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Contusion/subgaleal hematoma			UNKNOWN / MULTIPLE REGIONS	POLICE
Facial contusions			WHOLE REGION	POLICE
Forehead laceration	Driver	Rural	WHOLE REGION	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Fibula fracture			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Ankle fracture			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Tibia fracture			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Lower extremity laceration			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Lower extremity laceration			LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Ulna fracture			RIGHT	POLICE
Tibia fracture			RIGHT	POLICE
Tibia fracture			LEFT	POLICE
External jugular vein laceration	Passenger	Rural	UNKNOWN / MULTIPLE REGIONS	POLICE
Lung contusion	Driver	Urban	RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Abdominal laceration (>20% blood loss by volume)	Driver	Rural	RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Rib cage fracture			LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Rib cage fracture			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Humerus fracture			LEFT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS
Thoracic cavity injury with pneumothorax			RIGHT	AUTOPSY RECORDS WITH / WITHOUT HOSPITAL RECORDS

Table B2 shows the injury code, injury aspect, and source of injury data for the 7 CFC2 cases in which the fatally injured occupant received <AIS-4 injuries. Each individual fatally injured occupant is listed with their individual injuries between the black rows of the table.

APPENDIX C: Hierarchical Multiple Regression Analysis: Fatal Rural Collisions

Human Factors

Table C1. – Hierarchical multiple regression analysis of driver history while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value change	*Significance of F change*	ANOVA significance value
AIS	Previous DWI Convictions	0.063	0.661	0.026	0.860	0.900
	Previous Speeding Convictions	0.056	0.700			
	Previous Suspensions	0.171	0.228			
	Previous Collisions	0.025	0.861			
	Years Licensed	0.121	0.516			
Impact Type	Previous DWI Convictions	0.315	**0.023**	0.101	0.162	0.206
	Previous Speeding Convictions	0.049	0.725			
	Previous Suspensions	0.009	0.946			
	Previous Collisions	0.165	0.235			
	Years Licensed	0.199	0.263			
Calculated Speed	Previous DWI Convictions	0.004	0.979	0.064	0.575	0.433
	Previous Speeding Convictions	0.080	0.624			
	Previous Suspensions	0.190	0.229			
	Previous Collisions	0.054	0.738			
	Years Licensed	0.256	0.218			

Table C1 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables related to driver history to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C1** explain **2.6%** additional variance in AIS, **10.1%** additional variance in impact type, and **6.4%** additional variance in speed.

For AIS, previous license suspensions (**β = 0.171**) provided the greatest individual contribution to predict the outcome, followed by: years licensed (**β = 0.121**), previous DWI convictions (**β = 0.063)**; previous speeding convictions (**β = 0.056**); and previous collisions (**β = 0.025**).

For impact type, previous DWI convictions (**β = 0.315**) provided the greatest individual contribution to predict the outcome, followed by: years licensed (**β = 0.199**); previous collisions (**β = 0.165**); previous speeding convictions (**β = 0.049**), and previous suspensions (**β = 0.009**).

For speed, years licensed (**β = 0.256**) provided the greatest individual contribution to predict the outcome, followed by: previous suspensions (**β = 0.190**); previous speeding convictions (**β = 0.080**); previous collisions (**β = 0.054**), and previous DWI convictions (**β = 0.004**).

Table C2. - Hierarchical multiple regression analysis of mass while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Driver Mass	0.387	0.076	0.113	0.147	0.268
	Total Occupant Mass (Drivers + Passengers)	1.878	**0.032**			
	Total Mass (Vehicle + Occupants + Cargo)	0.123	0.346			
	Number of Occupants	1.823	**0.041**			
Impact Type	Driver Mass	0.582	**0.006**	0.190	**0.017**	**0.034**
	Total Occupant Mass (Drivers + Passengers)	1.410	0.086			
	Total Mass (Vehicle + Occupants + Cargo)	0.097	0.431			
	Number of Occupants	1.228	0.143			
Calculated Speed	Driver Mass	0.799	0.428	0.099	0.202	0.168
	Total Occupant Mass (Drivers + Passengers)	1.250	0.149			
	Total Mass (Vehicle + Occupants + Cargo)	0.183	0.164			
	Number of Occupants	1.474	0.097			

Table C2 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables related to mass to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C2** explain **11.3%** additional variance in AIS, **19.0%** additional variance in impact type, and **9.9%** additional variance in speed.

For AIS, total occupant mass (**β = 1.878**) provided the greatest individual contribution to predict the outcome, followed by: number of occupants (**β = 1.823**); driver mass (**β = 0.387**), and total vehicle/occupant mass (**β = 0.123)**.

For impact type, total occupant mass (**β = 1.410**) provided the greatest individual contribution to predict the outcome, followed by: number of occupants (**β = 1.228**); driver mass (**β = 0.582**); and total vehicle/occupant mass (**β = 0.097**).

For speed, number of occupants (**β = 1.474**) provided the greatest individual contribution to predict the outcome, followed by: total occupant mass (**β = 1.250**); driver mass (**β = 0.799**), and total vehicle/occupant mass (**β = 0.183**).

Vehicular Factors

Table C3 - Hierarchical multiple regression analysis of restraint use, airbag deployment, and ejection while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Restraint Use	0.102	0.353	0.103	**0.016**	**0.040**
	Airbag Deployment	0.295	**0.006**			
	Ejection	0.016	0.892			
Impact Type	Restraint Use	0.108	0.329	0.058	0.116	0.144
	Airbag Deployment	0.060	0.566			
	Ejection	0.199	0.091			
Calculated Speed	Restraint Use	0.315	**0.030**	0.094	0.126	0.113
	Airbag Deployment	0.157	0.249			
	Ejection	0.207	0.172			

Table C3 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables of restraint use, airbag deployment, and ejection (all pertinent to the driver) to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C3** explain **10.3%** additional variance in AIS, **5.8%** additional variance in impact type, and **9.4%** additional variance in speed.

For AIS, airbag deployment (**β = 0.295**) provided the greatest individual contribution to predict the outcome, followed by: restraint use (**β = 0.102**), and ejection (**β = 0.016**).

For impact type, ejection (**β = 0.199**) provided the greatest individual contribution to predict the outcome, followed by: restraint use (**β = 0.108**), and airbag deployment (**β = 0.060**).

For speed, restraint use (**β = 0.315**) provided the greatest individual contribution to predict the outcome, followed by: ejection (**β = 0.207**), and airbag deployment (**β = 0.157**).

Table C4 - Hierarchical multiple regression analysis of speed while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Posted Speed	0.095	0.503	0.021	0.749	0.858
	Calculated Speed	0.034	0.812			
	Region	0.090	0.502			
Impact Type	Posted Speed	0.129	0.251	0.061	0.304	0.412
	Calculated Speed	0.015	0.913			
	Region	0.204	0.122			
Calculated Speed	Posted Speed	0.331	**0.009**	0.111	**0.029**	**0.033**
	Region	0.090	0.466			

Table C4 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables of posted and calculated speed to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C4** explain **2.1%** additional variance in AIS, **6.1%** additional variance in impact type, and **11.1%** additional variance in calculated speed.

For AIS, posted speed (**β = 0.095**) provided the greatest individual contribution to predict the outcome, followed by: region (**β = 0.090**), and calculated speed (**β = 0.034**).

For impact type, region (**β = 0.204**) provided the greatest individual contribution to predict the outcome, followed by: posted speed (**β = 0.129**), and calculated speed (**β = 0.015**).

For calculated speed, posted speed (**β = 0.331**) provided the greatest individual contribution to predict the outcome, followed by region (**β = 0.090**).

Table C5 - Hierarchical multiple regression analysis of vehicle damage while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Windshield Damage	0.042	0.757	0.080	0.206	0.377
	Fuel Integrity Loss	0.155	0.243			
	Door Latch/Hinge Failure	0.228	0.103			
Impact Type	Windshield Damage	0.147	0.295	0.040	0.518	0.609
	Fuel Integrity Loss	0.055	0.679			
	Door Latch/Hinge Failure	0.158	0.263			
Calculated Speed	Windshield Damage	0.392	**0.004**	0.152	**0.025**	**0.028**
	Fuel Integrity Loss	0.046	0.711			
	Door Latch/Hinge Failure	0.013	0.923			

Table C5 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables related to vehicle function/damage to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C5** explain **8.0%** additional variance in AIS, **4.0%** additional variance in impact type, and **15.2%** additional variance in calculated speed.

For AIS, door latch/hinge failure as a result of the collision (**β = 0.228**) provided the greatest individual contribution to predict the outcome, followed by: fuel integrity loss (**β = 0.155**), and windshield damage (**β = 0.042**).

For impact type, door latch/hinge failure as a result of the collision (**β = 0.158**) provided the greatest individual contribution to predict the outcome, followed by: windshield damage (**β = 0.147**), and fuel integrity loss (**β = 0.055**).

For speed, windshield damage (**β = 0.392**) provided the greatest individual contribution to predict the outcome, followed by: fuel integrity loss (**β = 0.046**) and door latch/hinge failure (**β = 0.013**).

Table C6 - Hierarchical multiple regression analysis of vehicle parameters while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Vehicle Year	0.169	0.280	0.047	0.186	0.300
	Airbag Generation	0.022	0.882			
	Vehicle Type	0.073	0.478			
Impact Type	Vehicle Year	0.082	0.587	0.053	0.125	0.146
	Airbag Generation	0.082	0.577			
	Vehicle Type	0.217	**0.032**			
Calculated Speed	Vehicle Year	0.646	**0.001**	0.237	**0.001**	**0.001**
	Airbag Generation	0.213	0.224			
	Vehicle Type	0.036	0.759			

Table C6 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables related to vehicle year, airbag generation, and vehicle type to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C6** explain **4.7%** additional variance in AIS, **5.3%** additional variance in impact type, and **23.7%** additional variance in speed.

For AIS, vehicle manufacturing year (**β = 0.169**) provided the greatest individual contribution to predict the outcome, followed by: vehicle type (**β = 0.073**), and airbag generation (**β = 0.022**).

For impact type, vehicle type (**β = 0.217**) provided the greatest individual contribution to predict the outcome, followed by: airbag generation (**β = 0.082**), and vehicle manufacturing year (**β = 0.082**).

For speed, vehicle manufacturing year (**β = 0.646**) provided the greatest individual contribution to predict the outcome, followed by: airbag generation (**β = 0.213**), and vehicle type (**β = 0.036**).

Environmental Factors

Table C7 - Hierarchical multiple regression analysis of lighting and road surface condition while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Lighting Condition	0.086	0.400	0.015	0.460	0.596
	Road Surface Condition	0.094	0.356			
Impact Type	Lighting Condition	0.022	0.823	0.012	0.521	0.445
	Road Surface Condition	0.111	0.265			
Calculated Speed	Lighting Condition	0.015	0.909	0.039	0.303	0.227
	Road Surface Condition	0.200	0.125			

Table C7 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables of lighting and road surface conditions to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C7** explain **1.5%** additional variance in AIS, **1.2%** additional variance in impact type, and **3.9%** additional variance in speed.

For AIS, road surface condition (**β = 0.094**) provided the greatest individual contribution to predict the outcome, followed by lighting condition (**β = 0.086**).

For impact type, road surface condition (**β = 0.111**) provided the greatest individual contribution to predict the outcome, followed by lighting condition (**β = 0.022**).

For speed, road surface condition (**β = 0.200**) provided the greatest individual contribution to predict the outcome, followed by lighting condition (**β = 0.015**).

Appendix C - Hierarchical Multiple Regression Analysis: Fatal Urban Collisions

Human Factors

Table C8 - Hierarchical multiple regression analysis of driver history while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Previous DWI Convictions	0.140	0.533	0.115	0.755	0.882
	Previous Speeding Convictions	0.228	0.317			
	Previous Suspensions	0.098	0.684			
	Previous Collisions	0.135	0.581			
	Years Licensed	0.056	0.857			
Impact Type	Previous DWI Convictions	0.038	0.801	0.159	0.184	0.122
	Previous Speeding Convictions	0.355	**0.023**			
	Previous Suspensions	0.139	0.390			
	Previous Collisions	0.008	0.962			
	Years Licensed	0.092	0.859			
Calculated Speed	Previous DWI Convictions	0.076	0.772	0.097	0.887	0.954
	Previous Speeding Convictions	0.018	0.946			
	Previous Suspensions	0.031	0.913			
	Previous Collisions	0.198	0.491			
	Years Licensed	0.424	0.251			

Table C8 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables related to driver history to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C8** explain **11.5%** additional variance in AIS, **15.9%** additional variance in impact type, and **9.7%**additional variance in speed.

For AIS, previous speeding convictions (**β = 0.228)** provided the greatest individual contribution to predict the outcome, followed by: previous DWI convictions (**β = 0.140)**; previous collisions (**β = 0.135**); previous suspensions (**β = 0.098**), and years licensed (**β = 0.056**).

For impact type, previous speeding convictions (**β = 0.355)** provided the greatest individual contribution to predict the outcome, followed by: previous license suspensions (**β = 0.139**); years licensed (**β = 0.092**); previous DWI convictions (**β = 0.038**), and previous collisions (**β = 0.008**).

For speed, years licensed (**β = 0.424**) provided the greatest individual contribution to predict the outcome, followed by: previous collisions (**β = 0.198**); previous DWI convictions (**β = 0.076**); previous license suspensions (**β = 0.031**), and previous speeding convictions (**β = 0.018**).

Table C9 - Hierarchical multiple regression analysis of mass while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
Impact Type	Driver Mass	0.009	0.985	0.263	0.087	0.097
	Total Occupant Mass (Drivers + Passengers)	1.281	0.378			
	Total Mass (Vehicle + Occupants + Cargo)	0.106	0.633			
	Number of Occupants	0.794	0.530			

Table C9 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables related to mass to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C9** explain **26.3%** additional variance in impact type.

For impact type, total occupant mass (**β = 1.281**) provided the greatest individual contribution to predict the outcome, followed by: number of occupants (**β = 0.794**); total vehicle/occupant mass (**β = 0.106**); and driver mass (**β = 0.009**).

Table C10 - Hierarchical multiple regression analysis of restraint use, airbag deployment, and ejection while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Restraint Use	0.111	0.631	0.027	0.844	0.943
	Airbag Deployment	0.093	0.628			
	Ejection	0.169	0.447			
Impact Type	Restraint Use	0.053	0.748	0.021	0.747	0.295
	Airbag Deployment	0.120	0.385			
	Ejection	0.026	0.871			
Calculated Speed	Restraint Use	0.073	0.806	0.060	0.777	0.917
	Airbag Deployment	0.124	0.617			
	Ejection	0.153	0.592			

Table C10 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables of restraint use, airbag deployment, and ejection (all pertinent to the driver) to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C10** explain **2.7%** additional variance in AIS, **2.1%** additional variance in impact type, and **6.0%** additional variance in speed.

For AIS, ejection (**β = 0.169**) provided the greatest individual contribution to predict the outcome, followed by: restraint use (**β = 0.111**), and airbag deployment (**β = 0.093**).

For impact type, airbag deployment (**β = 0.120**) provided the greatest individual contribution to predict the outcome, followed by: restraint use (**β = 0.053**), and ejection (**β = 0.026**).

For speed, ejection (**β = 0.153**) provided the greatest individual contribution to predict the outcome, followed by: airbag deployment (**β = 0.124**), and restraint use (**β = 0.073**).

Table C11 - Hierarchical multiple regression analysis of speed while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Posted Speed	0.042	0.884	0.195	0.399	0.648
	Calculated Speed	0.431	0.118			
	Region	0.224	0.428			
Impact Type	Posted Speed	0.006	0.982	0.053	0.764	0.689
	Calculated Speed	0.198	0.384			
	Region	0.081	0.735			
Calculated Speed	Posted Speed	0.165	0.508	0.064	0.511	0.782
	Region	0.142	0.552			

Table C11 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables of posted and calculated speed to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C11** explain **19.5%** additional variance in AIS, **5.3%** additional variance in impact type and **6.4%** additional variance in speed.

For AIS, calculated speed (**β = 0.431**) provided the greatest individual contribution to predict the outcome, followed by: region (**β = 0.224**), and posted speed (**β = 0.042**).

For impact type, calculated speed (**β = 0.198**) provided the greatest individual contribution to predict the outcome, followed by: region (**β = 0.081**), and posted speed (**β = 0.006**).

For calculated speed, posted speed (**β = 0.165**) provided the greatest individual contribution to predict the outcome, followed by region (**β = 0.142**).

Table C12 - Hierarchical multiple regression analysis of vehicle damage while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Windshield Damage	0.313	0.258	0.102	0.641	0.851
	Fuel Integrity Loss	0.133	0.601			
	Door Latch/Hinge Failure	0.017	0.948			
Impact Type	Windshield Damage	0.299	0.157	0.150	0.257	0.274
	Fuel Integrity Loss	0.021	0.914			
	Door Latch/Hinge Failure	0.380	0.073			
Calculated Speed	Windshield Damage	0.065	0.790	0.173	0.337	0.570
	Fuel Integrity Loss	0.425	0.076			
	Door Latch/Hinge Failure	0.056	0.815			

Table C12 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables related to vehicle function/damage to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C12** explain **10.2%** additional variance in AIS , **15.0%** additional variance in impact type, and **17.3%** additional variance in speed.

For AIS, windshield damage (**β = 0.313**) provided the greatest individual contribution to predict the outcome, followed by: fuel integrity loss (**β = 0.133**), and door latch/hinge failure as a result of the collision (**β = 0.017**).

For impact type, door latch/hinge failure (**β = 0.380**) provided the greatest individual contribution to predict the outcome, followed by: windshield damage (**β = 0.299**), and fuel integrity loss (**β = 0.021**).

For speed, fuel integrity loss (**β = 0.425**) provided the greatest individual contribution to predict the outcome, followed by: windshield damage (**β = 0.065**), and door latch/hinge failure (**β = 0.056**).

Table C13 - Hierarchical multiple regression analysis of vehicle parameters while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Vehicle Year	0.092	0.782	0.021	0.882	0.957
	Airbag Generation	0.046	0.892			
	Vehicle Type	0.075	0.684			
Impact Type	Vehicle Year	0.062	0.783	0.049	0.350	0.115
	Airbag Generation	0.154	0.500			
	Vehicle Type	0.208	0.094			
Calculated Speed	Vehicle Year	0.209	0.605	0.098	0.562	0.779
	Airbag Generation	0.475	0.255			
	Vehicle Type	0.008	0.971			

Table C13 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables related to vehicle year, airbag generation, and vehicle type to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C13** explain **2.1%** additional variance in AIS, **4.9%** additional variance in impact type, and **9.8%** additional variance in speed.

For AIS, vehicle manufacturing year (**β = 0.092**) provided the greatest individual contribution to predict the outcome, followed by: vehicle type (**β = 0.075**), and airbag generation (**β = 0.046**).

For impact type, vehicle type (**β = 0.208**) provided the greatest individual contribution to predict the outcome, followed by: airbag generation (**β = 0.154**), and vehicle manufacturing year (**β = 0.062**).

For speed, airbag generation (**β = 0.475**) provided the greatest individual contribution to predict the outcome, followed by: vehicle manufacturing year (**β = 0.209**), and vehicle type (**β = 0.008**).

Table C14 - Hierarchical multiple regression analysis of lighting and road surface condition while controlling for age and gender.

Dependent (Outcome) Variable	Independent (Predictor) Variable	Beta standardized regression coefficients (absolute magnitude)	Coefficient significance value	R-squared value	*Significance of F change*	ANOVA significance value
AIS	Lighting Condition	0.037	0.848	0.039	0.539	0.797
	Road Surface Condition	0.187	0.311			
Impact Type	Lighting Condition	0.151	0.247	0.027	0.391	0.105
	Road Surface Condition	0.055	0.657			
Calculated Speed	Lighting Condition	0.109	0.642	0.076	0.448	0.730
	Road Surface Condition	0.235	0.300			

Table C14 shows the results of hierarchical multiple regression analysis to assess the contribution of the independent variables of lighting and road surface conditions to the prediction of the dependent variables (AIS, impact type, and calculated speed) when age and gender are controlled for. Without the effects of gender and age, the independent variables in **Table C14** explain **3.9%** additional variance in AIS, **2.7%** additional variance in impact type, and **7.6%** additional variance in speed.

For AIS, road surface condition (**β = 0.187**) provided the greatest individual contribution to predict the outcome, followed by lighting condition (**β = 0.037**).

For impact type, lighting condition (**β = 0.151**) provided the greatest individual contribution to predict the outcome, followed by road surface condition (**β = 0.055**).

For speed, road surface condition (**β = 0.235**) provided the greatest individual contribution to predict the outcome, followed by lighting condition (**β = 0.109**).

Table C15a – Ranked Beta coefficients - Hierarchical Regression Analysis – Impact Type as Dependent Variable – Rural Fatal Collisions

Independent Variable	Beta standardized regression coefficients (absolute magnitude)
Total Occupant Mass	3.072
Number of Occupants	3.056
Driver Mass	0.924
Gender	0.385
Region	0.317
Years Licensed	0.307
Vehicle Type	0.297
Restraint Use	0.29
Age	0.269
Fuel Integrity Loss	0.255
Door Latch/Hinge Failure	0.23
Vehicle Year	0.216
Airbag Deployment	0.216
Road Condition	0.207
Ejection	0.144
Posted Speed	0.113
Previous Suspensions	0.105
Total Vehicle Mass	0.1
Previous Speeding Convictions	0.089
Windshield Contact	0.079
Calculated Speed	0.053
Vehicle Airbag Generation	0.019
Previous DWI Convictions	0.011
Light Condition	0.009
Previous Collisions	0.005

Table C15b – Ranked r-squared Changes - Hierarchical Regression Analysis – <u>Impact Type</u> as Dependent Variable – <u>Rural</u> Fatal Collisions

Block	R-squared change
6	0.218
8	0.095
3	0.072
5	0.069
4	0.048
7	0.035
1	0.023
2	0.012

Block Variables:

1) Gender, Age (Controlled)
2) 1 + Light Condition, Road Condition
3) 2 + Region, Posted Speed, Calculated Speed
4) 3 + Vehicle Year, Vehicle Airbag Generation, Vehicle Type
5) 4 + Windshield Damage, Fuel Loss Damage, Door Latch/Hinge Failure Damage
6) 5 + Driver Mass, Total Occupant Mass, Total Mass, Number of Occupants
7) 6 + Years Licensed, Previous Collisions, Previous Speeding Convictions, Previous DWI Convictions, Previous Suspensions
8) 7 + Ejection, Restraint Use, Airbag Deployment

Table C15a and C15b show a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 23 (Results).

Table C16a - Ranked Beta coefficients - Hierarchical Regression Analysis – AIS as Dependent Variable – Rural Fatal Collisions

Independent Variable	Beta standardized regression coefficient (absolute magnitude)
Number of Occupants	3.003
Total Occupant Mass	2.933
Driver Mass	0.6
Vehicle Year	0.359
Fuel Integrity Loss	0.323
Total Vehicle Mass	0.247
Previous Suspensions	0.234
Previous DWI Convictions	0.215
Vehicle Type	0.208
Restraint Use	0.207
Door Latch/Hinge Failure	0.203
Vehicle Airbag Generation	0.184
Gender	0.179
Road Condition	0.133
Posted Speed	0.126
Light Condition	0.116
Airbag Deployment	0.103
Previous Speeding Convictions	0.089
Previous Collisions	0.088
Calculated Speed	0.053
Age	0.052
Windshield Contact	0.047
Region	0.045
Years Licensed	0.032
Ejection	0.026

Table C16b - Ranked r-squared Changes - Hierarchical Regression Analysis – <u>AIS</u> as Dependent Variable – <u>Rural</u> Fatal Collisions

block	r-squared change
6	0.128
5	0.065
4	0.062
7	0.047
8	0.041
2	0.015
3	0.015
1	0.012

Block Variables:

1) Gender, Age (Controlled)
2) 1 + Light Condition, Road Condition
3) 2 + Region, Posted Speed, Calculated Speed
4) 3 + Vehicle Year, Vehicle Airbag Generation, Vehicle Type
5) 4 + Windshield Damage, Fuel Loss Damage, Door Latch/Hinge Failure Damage
6) 5 + Driver Mass, Total Occupant Mass, Total Mass, Number of Occupants
7) 6 + Years Licensed, Previous Collisions, Previous Speeding Convictions, Previous DWI Convictions, Previous Suspensions
8) 7 + Ejection, Restraint Use, Airbag Deployment

Table C16a and C16b show a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 24 (Results).

Table C17a - Ranked Beta coefficients - Hierarchical Regression Analysis – Calculated Speed as Dependent Variable – Rural Fatal Collisions

Independent Variable	Beta standardized regression coefficients (absolute magnitude)
Number of Occupants	1.214
Total Occupant Mass	0.888
Years Licensed	0.391
Age	0.346
Posted Speed	0.319
Road Condition	0.302
Previous Suspensions	0.28
Previous Speeding Convictions	0.274
Vehicle Year	0.211
Door Latch/Hinge Failure	0.2
Region	0.198
Gender	0.194
Windshield Contact	0.187
Vehicle Airbag Generation	0.177
Fuel Integrity Loss	0.13
Restraint Use	0.127
Previous DWI Convictions	0.12
Airbag Deployment	0.106
Total Vehicle Mass	0.076
Ejection	0.066
Light Condition	0.063
Vehicle Type	0.049
Previous Collisions	0.041
Driver Mass	0.032

Table C17b - Ranked r-squared Changes - Hierarchical Regression Analysis – <u>Calculated Speed</u> as Dependent Variable – <u>Rural</u> Fatal Collisions

Block	r-squared change
4	0.161
3	0.125
7	0.113
6	0.08
5	0.074
1	0.054
2	0.039
8	0.02

Block Variables:

1) Gender, Age (Controlled)
2) 1 + Light Condition, Road Condition
3) 2 + Region, Posted Speed
4) 3 + Vehicle Year, Vehicle Airbag Generation, Vehicle Type
5) 4 + Windshield Damage, Fuel Loss Damage, Door Latch/Hinge Failure Damage
6) 5 + Driver Mass, Total Occupant Mass, Total Mass, Number of Occupants
7) 6 + Years Licensed, Previous Collisions, Previous Speeding Convictions, Previous DWI Convictions, Previous Suspensions
8) 7 + Ejection, Restraint Use, Airbag Deployment

Table C17a and C17b show a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 25 (Results).

Table C18a - Ranked Beta coefficients - Hierarchical Regression Analysis – Impact Type as Dependent Variable – Urban Fatal Collisions

Independent Variable	Beta standardized regression coefficients (absolute magnitude)
Number of Occupants	1.75
Region	1.46
Vehicle Type	1.334
Calculated Speed	0.901
Gender	0.868
Road Condition	0.779
Windshield Contact	0.717
Driver Mass	0.645
Vehicle Airbag Generation	0.556
Posted Speed	0.37
Light Condition	0.298
Fuel Integrity Loss	0.249
Door Latch/Hinge Failure	0.215
Vehicle Year	0.157
Age	0.03

Table C18b - Ranked r-squared Changes - Hierarchical Regression Analysis – Impact Type as Dependent Variable – Urban Fatal Collisions

block	r-squared change
6	0.451
5	0.177
1	0.087
4	0.074
3	0.039
2	0.027

Block Variables

1) Gender, Age (Controlled)
2) 1 + Light Condition, Road Condition
3) 2 + Region, Posted Speed, Calculated Speed
4) 3 + Vehicle Year, Vehicle Airbag Generation, Vehicle Type
5) 4 + Windshield Damage, Fuel Loss Damage, Door Latch/Hinge Failure Damage
6) 5 + Driver Mass, Number of Occupants

Table C18a and C18b show a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 26 (Results).

Table C19a - Ranked Beta coefficients - Hierarchical Regression Analysis – AIS as Dependent Variable – Urban Fatal Collisions

Independent Variable	Beta standardized regression coefficients (absolute magnitude)
Driver Mass	0.522
Windshield Contact	0.379
Road Condition	0.261
Vehicle Type	0.258
Number of Occupants	0.251
Vehicle Year	0.24
Gender	0.212
Calculated Speed	0.18
Vehicle Airbag Generation	0.177
Light Condition	0.167
Door Latch/Hinge Failure	0.125
Fuel Integrity Loss	0.1
Age	0.032
Region	0.031
Posted Speed	0.025

Table C19b - Ranked r-squared Changes - Hierarchical Regression Analysis – <u>AIS</u> as Dependent Variable – <u>Urban</u> Fatal Collisions

block	r squared change
6	0.79
3	0.164
5	0.1
2	0.039
1	0.012
4	0.009

Block Variables

1) Gender, Age (Controlled)
2) 1 + Light Condition, Road Condition
3) 2 + Region, Posted Speed
4) 3 + Vehicle Year, Vehicle Airbag Generation, Vehicle Type
5) 4 + Windshield Damage, Fuel Loss Damage, Door Latch/Hinge Failure Damage
6) 5 + Driver Mass, Number of Occupants

Table C19a and C19b show a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 27 (Results).

Table C20a - Ranked Beta coefficients - Hierarchical Regression Analysis – Calculated Speed as Dependent Variable – Urban Fatal Collisions

Independent Variable	Beta standardized regression coefficients (absolute magnitude)
Driver Mass	0.919
Vehicle Type	0.781
Vehicle Airbag Generation	0.767
Region	0.753
Road Condition	0.482
Gender	0.418
Windshield Contact	0.388
Number of Occupants	0.361
Age	0.252
Door Latch/Hinge Failure	0.197
Posted Speed	0.175
Vehicle Year	0.106
Light Condition	0.093
Fuel Integrity Loss	0.086

Table C20b - Ranked r-squared Changes - Hierarchical Regression Analysis – Calculated Speed as Dependent Variable – Urban Fatal Collisions

block	r-squared change
6	0.394
5	0.152
4	0.108
2	0.076
3	0.062
1	0.016

Block Variables

1) Gender, Age (Controlled)
2) 1 + Light Condition, Road Condition
3) 2 + Region, Posted Speed
4) 3 + Vehicle Year, Vehicle Airbag Generation, Vehicle Type
5) 4 + Windshield Damage, Fuel Loss Damage, Door Latch/Hinge Failure Damage
6) 5 + Driver Mass, Number of Occupants

Table C20a and C20b show a ranked list of Beta standardized regression coefficients and r-squared value changes from Table 28 (Results).

LIST OF TABLES

LIST OF FIGURES

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Transport Canada

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- Mr. Floyd Dempsey assisted with co-ordination of data collection for collision cases included in the study that occurred outside of southern Ontario.

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Publications and Presentations

Conference Publications

Roos J.
Rural and urban motor vehicle collisions: is there a fatal divide?
Canadian Association of Road Safety Professionals 26th Annual Conference, Halifax, Nova Scotia, Canada,
2016-06-04
Paper

Roos J, Shkrum M.
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