EFFECT OF STREET PATTERN ON SINGLE VEHICLE CRASH SEVERITY

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BACKGROUND

Road crashes not only claim lives but also impose economic burden on the society due to loss productivity. In Canada, for example, there were 7.6 road users killed and 609 injured in traffic collisions everyday in 2003, resulting in an estimated daily social cost of about $26 million (Transport Canada, 2006). In Alberta alone, there are over 120,000 reported crashes a year, resulting in about 400 road users killed. Among the different types of crashes, vehicle running off the right side of the road constitute about 40% of the total fatal crashes while vehicles running off the left side of the road comprise about 20% (Alberta Transportation, 2006). Since many of these crashes involve single vehicle, it is important to know the risk factors associated with this type of crash in order to develop proper countermeasures.

Therefore, the risk factors affecting severity of single vehicle crashes has been studied extensively in various studies (Savolainen and Mannering, 2007; Islam and Mannering, 2006; Albertson et al, 2006; Conroy et al, 2006; Yamamoto and Shankar, 2004; Holdridge et al. 2005; Dhungana and Qu, 2005; Parenteau et al, 2003; Dissanayake and Lu, 2002; Bernat et al, 2004; Lee and Mannering, 2002; Kockelman and Kweon, 2002; Sironi et al, 1999; Lang et al, 1996; Esterlitz, 1989; Huelke and Compton, 1983). These factors include: roadside objects such as beam-guardrail leading ends, bridge rail leading ends, concrete barrier or bridge, trees and tree stumps, light poles, utility poles, railway poles, traffic poles, overhead poles, sign boxes and appurtenances in ditch; roadway features such as intersection, gravel surface, grade and curve; driver attributes such as age, gender, race, speeding, drug and alcohol use, helmet and seatbelt use, driving while fatigued; vehicle features such as motorcycles, pickups and sport utility vehicles; crash characteristics such as point of impact, urban/rural locations, presence of passengers, and vehicle rollover; and environmental conditions such as poor visibility, night-time, ice and rain .

However, little attention has been devoted to examine the effect of street pattern on the severity of vehicle crashes in general and single vehicle in particular. Traditionally, most road networks are built using a gridiron design with mainly straight roads intersecting at right angles. After the Second World War, limited access design such as warped parallel and loops and lollipops designs had gained popularity because this design discourages through traffic and has a traffic calming effect. However, these types of designs are associated with frequent curves which may make it difficult for drivers to control their vehicles and result in more frequent and more severe single vehicle crashes.

OBJECTIVE OF THE STUDY

The main objective of the study is to understand how the different street patterns affect the severity of single vehicle collisions. Besides street pattern, other factors related to road features, drivers' characteristics, crash characteristics, environment condition and vehicle attributes are also explored.

Calgary is chosen as a case study because this city is growing rapidly due to the economic boom in the oil and gas sector. To accommodate the increased population, the city is expanding laterally and many new communities are being built. Therefore, evidence on the effects of different neighbourhood design and street pattern on traffic safety is needed to help policy makers, developers and residents to make informed choices

METHODOLOGY

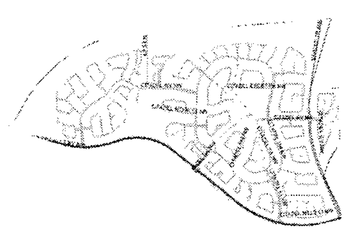
Classification of Street Pattern

The street pattern in each community area in Calgary defined by the Census is classified using a scheme adapted from Southworth and Ben-Joseph (2003). The authors classified street patterns into five categories: gridiron, fragmented parallel, warped parallel, loops and lollipops, and lollipops on a stick. However, the fragmented parallel pattern was found in very few communities in Calgary and this category was merged with grid iron pattern since it contains mainly straight roadways. Also, the two street patterns with the lollipop designs were merged into one to simplify the classification scheme. Finally, a separate category called mixed pattern was created to allow for community areas with mixed design. Figure 1 shows an example of a community in each of the four categories.

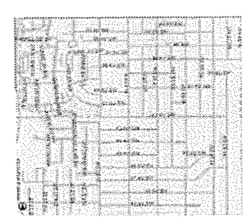
Figure1: Types of Street Pattern in Calgary Community Areas

Warped Parallel in Fairview

Gridiron in Forest Lawn



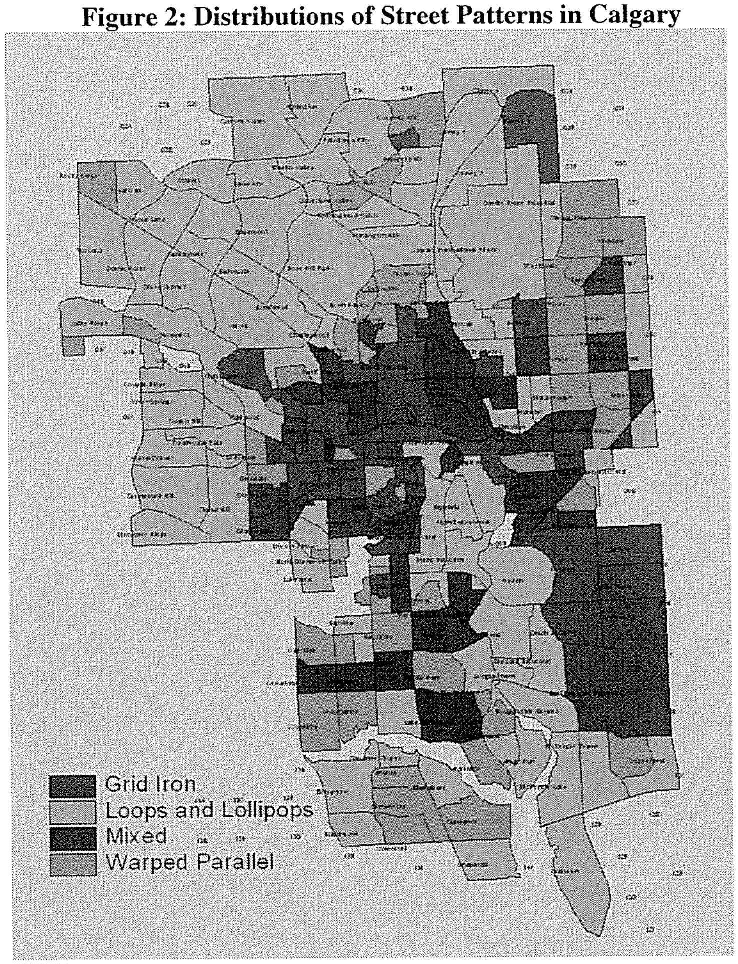
Loops and Lollipops in Citadel



Mixed Pattern in Altadore

Of the 227 community areas, 46 are classified as grid-iron, 55 are warped parallel, 87 are loops and lollipops, and the remaining 39 are mixed pattern (Figure 2). After classifying street pattern in each community, crashes are mapped with street addresses using Arc View 3.2 which enable to identify the patterns of streets where crashes occurred.

Figure 2: Distributions of Street Patterns in Calgary



Logistic Regression Model

The response variable in this study is a binary variable indicating whether a given crash resulted in an injury to at least one of the road users involved. Therefore, the logistic regression is a suitable technique to use because it is developed to predict a binary dependent variable as a function of predictor variables. The logistic regression model is widely used in road safety studies where the dependent variable is binary (Rifaat and Tay, 2009; Tay et al., 2008a,b, forthcoming; Zhang et al., 2000; Simoncic, 2002) In this model, the logit is the natural logarithm of the odds or the likelihood ratio that the dependent variable is 1 (injury in crash) as opposed to 0 (no injury in crash). The probability *P* of an injury in the crash is given

$$Y = logit\ (P) = \ln\left(\frac{P}{1-P}\right) = \beta X \qquad (1)$$

where β is a vector of parameters to be estimated and X is a vector of independent variables. When an independent variable x_i increases by one unit, with all other factors remaining constant, the odds increase by a factor $\exp(\beta_i)$ which is called the odds ratio (OR) and ranges from 0 to positive infinity. It indicates the relative amount by which the odds of the outcome (injury crash) increase (OR > 1) or decrease (OR < 1) when the value of the corresponding independent variable increases by one unit.

Data

Data on single vehicle crashes in the City of Calgary for the years 2003-2005 are extracted from the official crash database maintained by Alberta Transportation. Crashes on arterials are excluded to avoid boundary problems. Of the 340 single vehicle crashes, 24.12% were classified as injury crashes and remaining 75.88% were no injury or property-damage-only (PDO). In this study, a crash is considered to be an injury crash if at least one person is killed or injured. A PDO crash is defined as a crash associated with no injury but only damages to the vehicles or properties and the damage costs over $1000.

In theory, the severity of a crash is influenced by various factors related to the characteristics of road, environment, vehicle, driver and crash. Pre-selection of these factors are accomplished mainly by following previous research work where those factors have been explored. However, some local factors, thought to have influence on the severity of crashes, are also examined. It is noted that some important factors such as speed limit, traffic volume, etc, identified as having significant effect on crash severity in previous studies, were not explored here because these data were not available.

Following these considerations, 29 factors were considered in this study. Since most the factors were recorded in categories, several dichotomous variables were formed from each factor to facilitate estimation. From preliminary analyses, 20 factors were found to be insignificant and excluded from the final model which contained 9 factors. Some of the omitted factors are time trend, seasonal effects, day of week, collision location, environmental condition, surface condition, driver sex, lighting condition, drivers' action, type of traffic control device, vehicle age, driver license class, license province, and road condition. Table 1 shows the distribution (%) of the variables used in final model across the different severity levels.

Table1: Distribution of Variables

Variables	**No Injury (N=258)**	**Injury (N=82)**	**Total (N=340)**
Street Pattern			
Grid iron	71.05	28.95	22.35
Warped Parallel	78.95	21.05	11.18
Loops and lollipops	79.50	20.50	47.35
Mixed	70.77	29.23	19.12
Control Variables			
Road Class			
Undivided One-way	71.43	28.57	8.24
Undivided Two-way	77.42	22.58	36.47
Divided with Barrier	66.28	33.72	25.29
Divided No Barrier	66.67	33.33	7.06

Others	88.46	11.54	22.94
Road Alignment			
Level	74.78	25.22	67.65
Grade	69.57	30.43	13.53
Hillcrest	63.64	36.36	3.24
Sag	87.50	12.50	2.35
Others	88.89	11.11	13.24
Unsafe Speed			
Yes	71.43	28.57	39.12
No	78.74	21.26	60.88
Type of Vehicle			
Passenger Car	84.67	15.33	44.12
Pick-Up/Van	60.87	39.13	13.53
Minivan	83.02	16.98	15.59
Truck	79.17	20.83	7.06
Motorcycle	60.00	40.00	19.12
Others	50.00	50.00	0.59
Primary Event			
Struck object	90.48	9.52	30.88
Ron-Off-Road	70.18	29.82	33.53
Others	68.60	31.40	35.59
Point of Impact			
Side	79.20	20.80	36.76
Back	66.67	33.33	3.53
Front	85.25	14.75	17.94
Undercarriage	84.38	15.63	9.41
Rollover	61.33	38.67	22.06
Others	74.29	25.71	10.29
Time of day			
Morning peak	64.00	36.00	7.35
Evening	74.14	25.86	17.06
Midday	74.39	25.61	24.12
Night	79.10	20.90	39.41
Evening peak	78.05	21.95	12.06
Driver Condition			

Normal	75.42	24.58	69.41
Impaired by alcohol	68.29	31.71	12.06
Other driver condition	82.54	17.46	18.53
Driver Age (yrs)			
0-24	76.47	23.53	40.00
25-44	79.43	20.57	41.47
45-69	64.91	35.09	16.76
70 and above	83.33	16.67	1.76
Note: percentages shown in columns 2 & 3 sum to one for each row; percentages shown in last column sum to one for each factor			

As shown in Table 1, in terms of crash frequency, the loops and lollipops type design accounted for about half of the single vehicle crashes (47.35%), followed by grid iron (22.35%). However, there are 87 community areas that have this design compared to 46 with gridiron design. Also, the warped parallel and loops and lollipop designs have lower share of crashes resulting in injury than gridiron and mixed designs.

RESULTS AND DISCUSSION

The estimation results of the logistic regression model are presented in Table 2. In general, the model fitted the data well, with a large chi-square statistic and a very small p-value for goodness-of-fit.

TABLE 2 Parameter Estimates of the Model

Number of Observation	340		
Chi-square Statistic	70.90		
P-Value	< 0.0001		
Pseudo R-Square	0.1887		
Variables	**Coefficients**	**P-Value**	**Odd Ratio**
Street Pattern (Ref: Grid-iron)			
Warped Parallel	-0.386	0.480	0.680
Loops and lollipops	-0.438	0.235	0.645
Mixed	-0.106	0.805	0.899

Control Variables			
Constant	-2.247	0.00	-
Divided with Barrier	0.649	0.04	1.913
Hillcrest	1.452	0.05	4.272
Unsafe Speed	0.506	0.09	1.658
Pick-Up/Van	1.498	0.00	4.473
Motorcycle	1.503	0.00	4.494
Struck Object	-1.259	0.00	0.284
Rollover	0.846	0.01	2.330
Morning Peak	1.127	0.02	3.086
Impaired by alcohol	0.833	0.06	2.301
Age 45-69	0.921	0.01	2.511

Street Patterns

The main objective of our study is to identify the effect of different street patterns on the injury risks in single vehicle crashes. Compared with grid-iron pattern, all the other types of street patterns decrease the risk of injury but all of the results are statistically insignificant. Nonetheless, it is interesting to note that the odd ratios show an increasing order of severity from the more limited access designs to the more open access designs, indicating that the traffic calming effect may be more dominant than the potential issues related to sight distances and road curves in single vehicle crashes in urban areas.

The results are not surprising. Usually, majority of serious single vehicle crashes occurred on high speed roads like expressways or arterials. In those cases, speed plays a dominant role for failure to control the vehicle which often results in severe injury to the victims due to the high impact forces. However, in our study we considered only those crashes which occurred inside the community areas where the difference in the speed limits between gridiron and loops and lollipops type designs is quite small. Since posted speed limit, operating speed and impact speed are highly correlated, the small difference in the speed limit among the different types of community roads may reduce their effects on crash severity.

Control Variables

Consistent with Rifaat and Chin (2005), our study found severity to be significantly higher on divided roads with barrier because they are designed for higher speed. As expected, we found that crashes occurring on hillcrest had an increased probability of injury. Also consistent with previous findings (Kockelman and Kweon, 2002; Savolainen and Mannering, 2007; Quddus et al, 2002), out study found that pickup/van and motorcycles are associated with an increase in the propensity towards injury.

In terms of driver attributes, our study found that speeding and alcohol use increases the possibility of causing more severe injuries, a result that consistent with finding of other studies (Bedard et al, 2002; Zhang et al, 2000; Lee and Mannering, 2002; Holdridge et al, 2005; Yamamoto et al, 2004; Bernet et al, 2004; Lee and Mannering; 2002; Dissanayake and Lu, 2002; Ostrom and Anderseriksson, 1993). In contrast to previous studies, our study found that crashes involving drivers aged 45-69 tend to be more severe. This result is not surprising because most of the serious crashes involving young drivers occur on high speed roads instead of local roads.

Consistent with Lee and Mannering (2002), out study found that crashes during peak hours increase the likelihood of injury and fatality. Also, a positive association is also found between rollover and crash injury, a result that is consistent with previous findings (Esterlitz, 1989; Lane et al, 1995; Parenteaua et al, 2003). Finally, struck objects crashes are found to be more serious in our study because of the low speed environment and vehicle protection.

CONCLUSION

Although many studies have been conducted to examine the factors contributing to single vehicle crash frequency and severity, most of these studies were not restricted to local roads. Moreover, even though the effects of a wide range of factors associated with driver attributes, vehicle features, environmental condition, road design and crash characteristics have explored in these studies, the effect of different street pattern has not been explored before. Our study found that single vehicle crashes on urban roads tend to be less severe in neighborhoods with limited access roads than the traditional gridiron pattern but this effect is not statistically significant.

The results are expected since most of the roads within a community are local roads with uniformly low speed limits across the different street patterns. Since posted speed limit, operating speed and impact speed are highly correlated, the small difference in the speed limit among the different types of community roads may reduce their effects on single vehicle crash severity.

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