Effects of Street Patterns on Injury Risks in Two-Vehicle Crashes

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Road crashes not only claim lives and inflict injuries but also create an economic burden on society because of lost productivity. Many studies have identified factors affecting the frequency and severity of crashes. However, few, if any, studies have explored the effect of street pattern on injury risks in urban crashes. In this study, street pattern or urban form is classified into four categories: gridiron, warped parallel, loops and lollipops, and mixed patterns. Their effects on injury risk are examined together with other factors including road features, drivers' characteristics, crash characteristics, environmental conditions, and vehicle attributes. Calgary, Alberta, Canada, is chosen as the case study, and the logistic regression model is applied with reported crash data from 2003 to 2005 to investigate various factors. The results suggest that current popular patterns, including the loops and lollipops design, are safer than the conventional gridiron pattern from an injury risk perspective in the event of a crash.

Around the world, an estimated 1.2 million people are killed in road crashes each year and as many as 50 million are injured (*1*). Moreover, motor vehicle collision injuries will move from ninth place in 1990 to third place by 2020 as the leading cause of disease or injury (*1*). Injuries and deaths from road crashes are a problem not only for developing countries but for many developed countries as well. For example, recent Canadian data showed that 2,899 deaths and 199,337 motor vehicle collision injuries occurred in 2006 (*2*).

One way of improving road safety is to reduce crash occurrences by implementing crash reduction countermeasures. Another way is to reduce severity of crashes. However, these two methods can only be successfully applied if relevant factors that contribute to the occurrence or increase the severity of crashes are known. The injury risks of individuals in traffic crashes are influenced by a multitude of factors, including vehicle characteristics, roadway design characteristics, driver behaviors, types of collisions, and environmental conditions. Moreover, it is essential to quantify the relative magnitude of the impact of these factors on collision severity so that measures to prevent collisions or reduce collision severity can be identified, prioritized, and implemented.

Many research studies have identified risk factors that can significantly influence the injury outcomes of traffic collisions. The studies mostly examine the effects of different types of collision (*3–5*); vehicle mass (*6–8*) and vehicle type (*9–11*); and the effects of drivers' age, gender, and impairment (*12–17*). In addition, numerous studies have focused on the effects of restraint devices, such as seat belts or helmets, on injury severity levels (*13, 18*). These studies help researchers understand factors affecting crash severity and provide suggestions with regard to safety countermeasures to be adopted to reduce the severity of collisions.

Although the effects of numerous factors have been explored in past studies, little research has been done on the effect of street pattern on crash severity. Among the commonly observed street patterns, gridiron is the more traditional urban form and is made up of intersecting streets that are mostly straight thoroughfares. On the other end is the loops and lollipops design, which comprises roads that are usually curvilinear as well as loop streets and cul-de-sacs. A cul-de-sac is defined as the bottom of the sack, commonly referred to as a dead-end street. It has no outlet except by the entrance.

The Garden City movement at the end of the 19th century instigated a trend away from the traditional grid design toward a new pattern and scale of streets that would improve safety and increase light, air, and the sense of nature in suburban communities (*19*). Raymond Unwin and Barry Parker were considered two of the pioneers and advocates of cul-de-sac and loop street design when they were commissioned to design the suburban community of Hampstead Garden Suburb near London in 1904 (*20*). For the first time, the cul-de-sac was systematically used throughout a development. Moreover, the roadways in Hampstead ignored right angles and avoided regularity in every way. They meandered about aimlessly, comfortably, following the natural contour and advantages of the land. Residential streets were narrow and did not have equal width. In short, they were designed to discourage traffic and keep it on the main thoroughfares.

Over the past 50 years, the loops and lollipops design has become the basic building block of many suburban road networks in most North American cities. Although the design was developed to improve the social living environment, this combination of cul-de-sac and loop streets has the support of many traffic engineers because of its traffic calming effects. Perhaps because of its intuitive appeal, few studies were conducted to examine the effect of the design on road crashes. In the only publicly available study, Marks (*21*) found that 50% of all intersections in Los Angeles, California, with the traditional grid pattern had at least one collision, whereas only 8.8% of the intersections in the limited-access pattern had collisions between 1951 and 1956. However, the results of this study must be interpreted with caution in today's context because the study examines only right-angled crashes at intersections and ignores all nonintersection crashes. In addition, it does not control for many important influences such as land use and neighborhood density as well as economic, social, and demographic composition.

Moreover, the loops and lollipops design has several limitations that may affect the injury risks of crashes. For example, the loops and

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Transportation Research Record: Journal of the Transportation Research Board, No. 2102, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 61–67.
DOI: 10.3141/2102-08

lollipops design has horizontal alignment issues and restricted sight because of parked vehicles, trees, and other roadside furniture. These restrictions may increase the severity of a crash because of a shorter distance for stopping and thus higher impact speed. These limited-access streets may encourage more vulnerable modes of local travel and leisure activities, such as walking and cycling, which may also have an impact on injury risks associated with a crash. Therefore, the effect of street pattern on injury risks in a crash is not as certain as popularly believed.

Accordingly, the main objective of this study is to understand how different street patterns affect injury risks in collisions. Other factors related to road features, drivers' characteristics, crash characteristics, environmental condition, and vehicle attributes are also explored. Calgary, Alberta, Canada, is chosen as a case study because of its rapid growth, which is 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 neighborhood designs and street patterns on traffic safety is needed to help policy makers, developers, and residents make informed choices.

METHODOLOGY

Classification of Street Patterns

The street pattern in each community is classified by using a scheme that is adapted from a similar scheme developed by Southworth and Ben-Joseph (*22*). The authors classify street patterns into five categories: gridiron, fragmented parallel, warped parallel, loops and lollipops, and lollipops on a stick. Their classification is shown in Figure 1.

Since most of the social, economic, and demographic data were collected from the Canadian population census, the community areas defined by the census were used as the basic unit of analysis for street patterns. The street maps of different community areas defined by the census were extracted from the street directory for the city of Calgary. On the basis of the street maps, the research team first classified the street pattern of each unit by using the classification scheme shown in Figure 1. There were few units with the fragmented parallel pattern, and this category was merged with the gridiron pattern since it contained mainly straight roadways. In addition, the two street patterns with the lollipops designs were merged into one to simplify the classification scheme. Finally, a separate category, mixed pattern, was created to allow for community areas with mixed designs. An example of a community in each of the four categories is shown in Figure 2.

Of the 227 community areas, 46 are classified as gridiron, 55 are warped parallel, 87 are loops and lollipops, and the remaining 39 are mixed pattern (see Figure 3). To check that the units were classified correctly, the procedure was repeated by using a sample of 23 transportation engineering students at the university. The classification produced by the sample matched those produced by the research team. If a crash occurs in a given community, the street pattern of the community is then used to capture its effect on crash severity.

Logistic Regression Model

For the purpose of this study, the response variable is a binary or dichotomous variable indicating whether a given crash results in an injury to at least one of the road users involved or no injury is sustained by any persons involved. 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 (*12, 23–27*). 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 by

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

where $\boldsymbol{\beta}$ is a vector of parameters to be estimated and $\boldsymbol{X}$ 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). OR 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

To develop a logistic regression model that identifies the factors affecting injury crashes, a crash data set is needed that includes environmental factors, vehicle attributes, crash characteristics, roadway features, and drivers' particulars expected to be correlated with the injury risks. Crash data for this study are obtained from Alberta Transportation, which is responsible for maintaining the database on police-reported crashes for the Province of Alberta. Crash data for the city of Calgary were extracted from the whole Alberta database for 2003–2005. For the purpose of this study, only crashes involving two vehicles were considered. During the period, 35,993 crashes involving two vehicles were reported in Calgary communities. Crashes on roadways that formed the boundaries between communities were not considered because of the boundary problem. Furthermore, data

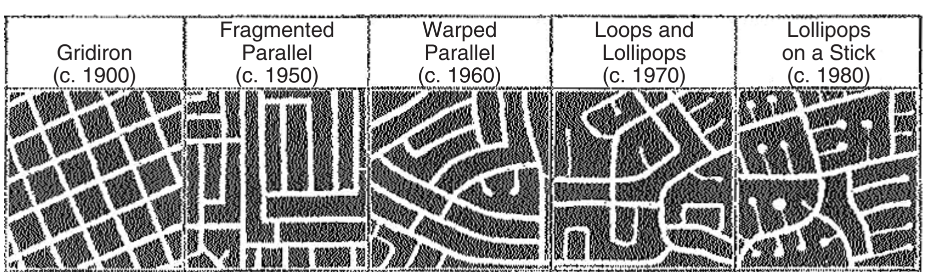

FIGURE 1 Classification of street patterns (*22*, p. 115).

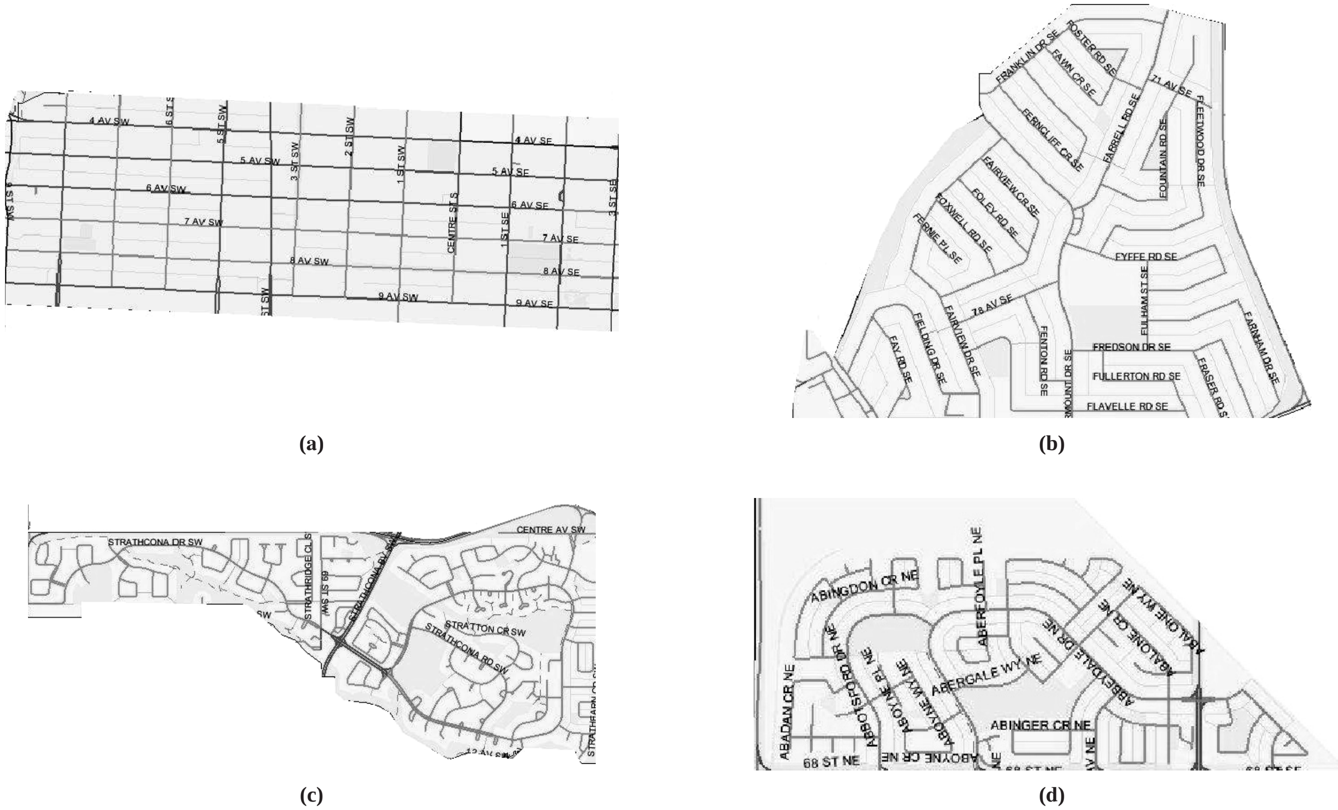

FIGURE 2 Examples of each class of road pattern found in Calgary: (*a*) gridiron pattern, downtown commercial; (*b*) warped parallel pattern, Fairview; (*c*) loops and lollipops pattern, Strathcona Park; and (*d*) mixed pattern, Abbeydale.

on one or more of the variables used in the final model were missing for some crashes. Therefore, only 22,704 crashes (45,804 observations) were used to fit the final model. About 7.44% of the crashes were classified as injury crashes, and the rest were classified as noninjury crashes. A crash is considered an injury crash if at least one person is injured, hospitalized, or dead within 30 days of the collision. A noninjury crash is defined as a crash associated with no injury but only damage to the vehicles or properties, with damage costs exceeding $1,000.

An important task in developing the model was the selection of appropriate factors from driver, vehicle, crash, road, and environmental characteristics that could reasonably be expected to influence injury crashes. Two approaches were used to select the factors. The first was to review similar research where they had been examined. The second was to focus on local context to determine other variables that might have some influence on injury crashes. Some factors were tested and excluded in the final model reported because they were found to be statistically insignificant. After preliminary analyses, 16 factors were retained in the final model; the descriptive statistics of these factors are shown in Table 1.

Since most of the factors were recorded in categories, several dichotomous variables were formed from each factor to facilitate the estimation and interpretation of the ORs. The estimates of the variables should be interpreted as relative to the omitted variable (or variables) of the factor to which they belonged. For example, in considering the effect of street pattern, the reference case used in estimation was gridiron. The estimated effects of warped parallel, loops and lollipops, and mixed pattern were then computed relative to gridiron.

Some important factors, such as speed limit, road width, median width, shoulder width, and annual average daily traffic (AADT), which were identified as having a significant effect on crash severity in previous studies, were not explored here because of lack of information. Although AADT data were available for major roadways in the city, they were not available for local roads within the community. However, an exposure variable such as AADT, which measures traffic volume, is not expected to have a significant effect in the model developed here because the dependent variable is the probability of an injury given that a crash has already occurred (*28*). Whereas exposure is often significant in determining the frequency or likelihood of a crash, its impact on crash severity is minimal, especially under free-flow conditions (*28*).

Although the speed limit of the road is expected to be correlated with the operating speed, its effect on the impact speed of the vehicle involved in a crash, and hence crash severity, is only indirect. More important, the posted speed limit is highly correlated with the type or functional class of the road, which is included in the study. Quddus et al. (*10*) found that type of road and speed limit were strongly correlated and that type of road was a better indicator in predicting injury severity than speed limit. From their findings, it is clear that either road type or speed limit is sufficient to reflect the effect of speed on crash injury. In addition to road type, the study examined whether the involved vehicles were reported to be driven at a safe or unsafe speed.

RESULTS

The estimation results of the logistic regression model are presented in Table 2. In general, the model fits the data well, with a large chi-square statistic and a small *p*-value for goodness of fit. The 90% confidence level has been chosen for deciding the statistical significance

FIGURE 3 Distribution of street patterns in Calgary.

of the variables. The model results are presented into two categories: street pattern, which is the main interest; and control variables, which are formed from road characteristics, environmental conditions, vehicle features, crash characteristics, and driver attributes.

Street Patterns

The main objective of the study is to identify the effect of different street patterns on injury risks in two-vehicle crashes. In comparison with the gridiron pattern, all the other types of street patterns decrease the risk of injury, but most of the results are not statistically significant. Only the loops and lollipops design is marginally significant (OR = 0.927, $p = .06$). This result indicates that roads with less connectivity and frequent curves are marginally safer than traditional gridiron roads. Perhaps the presence of frequent curves and dead ends induces drivers to be more cautious and to reduce their speed. These behavior adaptations are consistent with the risk compensation theory in economics (*29–33*) and the risk homeostasis theory in psychology

TABLE 1 Profile of Crashes

Variable	Noninjury Crashes	Injury Crashes	Total Crashes
1. Street pattern			
Gridiron	89.75	10.25	33.08
Warped parallel	90.34	9.66	13.69
Loops and lollipops	89.65	10.35	30.68
Mixed	89.92	10.08	22.55
2. Road class			
Undivided one-way	88.62	11.38	8.71
Undivided two-way	89.55	10.45	43.26
Divided with barrier	84.42	15.58	12.34
Divided, no barrier	85.30	14.70	3.79
Others	93.20	6.80	31.90
3. Road surface condition			
Dry	88.63	11.37	57.73
Wet	87.73	12.27	7.84
Snow or ice	91.20	8.80	22.24
Loose surface material	89.29	10.71	0.43
Others	94.60	5.40	11.76
4. Location of crash			
Nonintersection	91.17	8.83	34.08
Intersection	86.02	13.98	40.93
At or near railroad crossing	81.63	18.37	0.21
Others	94.39	5.61	24.78
5. Special road location			
No special location	89.83	10.17	97.99
Private driveway	95.97	4.03	0.54
Interchange ramp	85.86	14.14	0.66
Bridge	87.13	12.87	0.37
Others	92.46	7.54	0.44
6. Traffic control device			
None	91.49	8.51	52.82
Traffic signal	86.47	13.53	26.34
Stop sign	87.51	12.49	8.27
Yield sign	85.16	14.84	2.83
Pedestrian crosswalk	84.12	15.88	1.81
Other traffic control device	95.43	4.57	7.93
7. Collision type			
Head-on	86.88	13.12	34.45
Rear-end	89.91	10.09	22.95
Sideswipe	92.28	7.72	41.75
Others	87.95	12.05	0.85
8. Lighting condition			
Daylight	89.79	10.21	73.35
Sun glare	85.62	14.38	0.65
Darkness	88.43	11.57	19.69
Others	95.37	4.63	6.31
9. Seasonal condition			
Fall	90.03	9.97	34.85
Winter	89.97	10.03	35.60
Spring	89.76	10.24	14.90
Summer	89.12	10.88	14.65
10. Type of vehicle			
Passenger car	89.07	10.93	56.79
Pickup/van/minivan	90.80	9.20	37.51
Truck	90.98	9.02	4.19
Bus	91.96	8.04	0.87
Emergency vehicle	90.75	9.25	0.64
11. Land use			
Industrial	88.32	11.68	17.29
Residential	90.15	9.85	82.71
12. Driver sex			
Male	90.48	9.52	63.10
Female	88.73	11.27	36.90

(continued)

TABLE 1 *(continued)* **Profile of Crashes**

Variable	Noninjury Crashes	Injury Crashes	Total Crashes
13. Driver's condition			
Normal	89.18	10.82	72.75
Impaired by alcohol	80.43	19.57	1.73
Others	92.35	7.65	25.52
14. Driver age (years)			
0–24	89.62	10.38	21.03
25–44	89.62	10.38	47.22
45–69	90.36	9.64	28.38
70 and above	89.77	10.23	3.37
15. Driver action			
Driving properly	88.84	11.16	41.13
Backed unsafely	98.75	1.25	5.61
Left turn across path	83.73	16.27	4.36
Improper lane change	96.05	3.95	3.26
Improper turn	92.78	7.22	2.36
Stop sign violation	81.20	18.80	2.76
Other driver action	87.14	12.86	40.52
16. Unsafe speed			
Yes	87.56	12.44	4.39
No	89.94	10.06	95.61

NOTE: Numbers in second and third columns are row percentages, while those in the last column are column percentages ($N = 45{,}804$).

TABLE 2 Parameter Estimates of the Model

Variable	Coefficient	Standard Error	p-Value	Odds Ratio
Street Pattern (reference: gridiron)				
Warped parallel	–0.061	0.0516	0.239	0.940
Loops and lollipops	–0.075	0.0408	0.067	0.927
Mixed	–0.059	0.0430	0.173	0.942
Control Variables				
Divided with barrier	0.552	0.0421	< 0.001	1.737
Divided, no barrier	0.465	0.0712	< 0.001	1.592
Wet	0.114	0.0550	0.038	1.120
Snow or ice	–0.154	0.0405	< 0.001	0.857
Nonintersection	–0.160	0.0346	< 0.001	0.852
At or near railroad crossing	0.580	0.2657	0.029	1.785
Private driveway	–0.708	0.3244	0.029	0.492
Yield sign	0.373	0.0815	< 0.001	1.452
Pedestrian crosswalk	0.451	0.0982	< 0.001	1.569
Rear-end	–0.206	0.0412	< 0.001	0.814
Sideswipe	–0.562	0.0366	< 0.001	0.569
Darkness	0.163	0.0397	< 0.001	1.176
Fall	–0.074	0.0333	0.026	0.928
Pickup/van/minivan	–0.179	0.0337	< 0.001	0.836
Truck/truck tractor	–0.149	0.0845	0.078	0.861
Industrial communities	0.161	0.0420	< 0.001	1.174
Driver age 25–44	0.069	0.0314	0.026	1.072
Male driver	–0.189	0.0326	< 0.001	0.827
Impaired by alcohol	0.683	0.0960	< 0.001	1.979
Left turn across path	0.615	0.0654	< 0.001	1.849
Stop sign violation	0.794	0.0760	< 0.001	2.211
Unsafe speed	0.001	0.0003	0.012	1.001
Constant	–1.927	0.0502	< 0.001	—

(*34*). In addition, the loops and lollipops street pattern may have a traffic calming effect on drivers and increase the perception of drivers that the neighborhood is residential, with an increased likelihood of children at play, pedestrians, and cyclists on the roads (*28*).

Control Variables

The effects of different roadway classes were investigated by using five categories: undivided one-way, undivided two-way, divided with barrier, divided with no barrier, and others. The severity of accidents was found to be significantly higher on higher categories of roads such as divided with no barrier (OR = 1.592, $p < .001$) and divided with barrier (OR = 1.737, $p < .001$). The increased traffic at higher speed allowed on the divided highway may be a factor in increasing injury severity.

To examine the effect of road surface on severity of collisions, five surface conditions were considered: dry, wet, snow or ice, loose material, and other surface condition. Compared with a dry surface, the injury risk is significantly higher on wet surfaces (OR = 1.12, $p = .038$). Drivers in Calgary generally do not slow down on rainy days, which are not common, and the increased risk of skidding and losing control of the vehicle on wet surfaces may increase the impact speed. A negative correlation is observed between injury crashes and snow or ice (OR = 0.857, $p < .001$). This result is not surprising since the road surface in Calgary is often covered by snow or ice, and drivers are well aware of the slippery conditions and reduce their operating speed accordingly.

Four locations of crashes were examined to identify their influences on injury severity: nonintersection, intersection, at or near railway crossing, and others. Relative to other locations, nonintersection crashes are safer from an injury perspective (OR = 0.852, $p < .001$). The result is expected since there are fewer conflict points and less chance of unexpected behavior from drivers, allowing drivers to reduce vehicle speed even if a crash occurs. More important, there is a lower chance of side-impact crashes in midblocks or links.

Another interesting finding is that crashes at or near railroad crossings are more likely to increase injury severity (OR = 1.785, $p = .029$). This may be due to the tendency of drivers to take risks near railroad crossings or to hurry when they find the rail gate is to be lowered soon. Lack of patience may be a key reason for crashes near such crossings and for the speed of the involved vehicles being higher. Thus, the presence of a crossing may not directly increase injury severity but may create a complex traffic atmosphere that increases drivers' workloads and their response time. As a consequence, the impact speed and force are higher in a crash.

The severity of crashes on any kind of special road locations was also examined. Crashes on private driveways (OR = 0.492, $p = .029$) are associated with lower severity. This result is expected since vehicles on private driveways are usually driven at lower speed, which results in lower injury severity in a crash.

The effects of different types of traffic control devices were also explored. The results show that crashes near yield signs (OR = 1.452, $p < .001$) and pedestrian crosswalks (OR = 1.569, $p < .001$) increase the likelihood of injury. Unexpected movements of other vehicles or pedestrians are often seen at these two locations. Moreover, crashes at these locations often involve side impacts (turning vehicles stopping for pedestrians), which tend to be more serious.

With regard to the effect of the type of crash on injury risk, the analyses show that rear-end crashes (OR = 0.814, $p < .001$) and sideswipes (OR = 0.569, $p < .001$) are less likely to result in severe injuries than head-on collisions. This result is consistent with the findings of previous studies (*35, 36*). Relative to head-on collisions, rear-end and sideswipe collisions are less likely to result in injuries; the lower differential speed results in lower kinetic energy.

The study shows that when a community is developed for industrial purposes, it has an increase in injury risk (OR = 1.174, $p < .001$). One possible reason for the higher injury risk is the higher speed associated with traffic in industrial areas than in residential areas. Crash severity is also higher in industrial communities, probably because of the presence of more heavy vehicles. Collisions involving heavy vehicles tend to be more severe because of their larger mass and size.

Daylight, sun glare, darkness, and other conditions were examined to capture the effect of visibility. Darkness is found to be positively correlated with crash injury (OR = 1.176, $p < .001$). The vision of drivers may be restricted because of darkness, which hampers the detection of other vehicles, thereby reducing the time available to reduce vehicle speed.

The effect of seasonal variation on injury crashes is also significant in this study. As expected, crashes during the fall season (OR = 0.928, $p = .026$) are less serious. The reduction in injury crashes during fall may be due to favorable driving conditions. The road surface is not covered by snow or ice during that season, which results in better control of the vehicle during a collision.

The study finds that medium-size vehicles (such as pickups, vans, and minivans) (OR = 0.836, $p < .001$) and heavy vehicles (OR = 0.861, $p = .078$) are involved in fewer injury crashes. This finding appears to contradict previous studies (*37–39*), since injury risk is expected to be higher in heavy-vehicle crashes because of greater vehicle masses and lower deceleration in an emergency, resulting in larger impact forces in a collision. However, the study focused on local roads instead of arterials or freeways. The speed of heavy and medium-size vehicles inside the community areas may be lower because the roads inside the communities are not as wide as arterials or freeways.

For purposes of comparison, drivers involved in collisions were divided into four age groups (<25, 25 to 44, 45 to 69, >69) on the basis of similarities of lifestyle and travel behavior (*40*). Surprisingly, injury severity was found to be higher for the age group 25 to 44 years old (OR = 1.072, $p = .026$). Perhaps people in this age group are overconfident after driving for several years and hence take more risks, such as speeding and paying less attention. It was observed that males (OR = 0.827, $p < .001$) experience lower risk of injury than females.

The study shows that drivers impaired by alcohol are associated with an increased chance of injury (OR = 1.979, $p < .001$), a result that is consistent with previous studies (*41–43*). Alcohol-impaired drivers have reduced physical or mental alertness, which results in slower information processing and decision making, slower reaction time, poorer judgment, reduced performance on attention-based tasks, and reduced capacity to process and integrate information. All these deficiencies may result in failure to reduce vehicle speed during a collision with another vehicle.

The results indicate that left turn across path and stop sign violation are two risky actions from a crash severity perspective. They increase injury risk by 85% and 121%, respectively. Both of these actions usually result in side-impact crashes, which tend to be more serious.

Finally, the study finds that if at least one of the vehicles is driven at an unsafe speed during the crash, the likelihood of injury increases (OR = 1.001, $p = .012$). The higher injury risk is due to higher vehicle speed, which translates to larger impact forces in a collision.

CONCLUSION

There is a constant debate among transportation engineers and urban planners with regard to which type of street pattern should be recommended, particularly for new and developing communities. In the past, the main purpose of urban streets was to serve as thoroughfares for carrying people and goods from one place to another in a safe and reliable way with minimum delay. Since the gridiron street pattern or urban form satisfies these requirements well, it has been predominant in many urban areas for a long time. However, some transportation engineers and planners believe that urban streets should be places where people walk, shop, meet, and generally engage in the diverse array of social and recreational activities that make urban living enjoyable (*44*). Hence, limited-access street patterns, such as the loops and lollipops design, have become popular, especially for suburbs in North America.

While the social benefits and drawbacks of both types of designs have been discussed extensively in the literature, little attention has been devoted so far to the safety evaluation of these designs. In this study, the effects of different street patterns or urban forms on injury risk in a two-vehicle collision were analyzed by using data from the city of Calgary. The study finds that, in comparison with the gridiron design, the loops and lollipops design decreases the injury risk of crashes involving two vehicles. Although this design has frequent curves, which reduce sight distances compared with the traditional gridiron pattern, it has more dead-end roads and multistop controls, which reduce vehicle speed.

The results of this study will provide policy makers as well as transportation engineers and planners with important information for selecting the most appropriate street pattern or urban form for development of new communities. The information is particularly useful for rapidly expanding cities like Calgary, which has experienced great growth over the past decade because of the boom in the oil and gas industry. From a traffic safety perspective, limited-access street patterns may be preferred over the traditional gridiron pattern, although some planners have argued that the latter may be better for the environment because of its amenability to housing densification and public transportation.

ACKNOWLEDGMENTS

The authors thank the Natural Science and Engineering Research Council of Canada, the Centre for Transportation Engineering and Planning, and the Alberta Motor Association for their generous support. They also thank Alberta Transportation for providing the collision data.

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The Safety Data, Analysis, and Evaluation Committee sponsored publication of this paper.