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# Analyzing road surface conditions, collision time, and road structural factors associated with bicycle collisions from 2000 to 2010 in Saskatoon, Saskatchewan

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ABSTRACT

*Objective:* The purpose of this study was to analyze the relationship between the likelihood of bicycle collisions and time of day, traffic volume, road surface conditions, legal speed limit, and weather.
*Method:* Data from the Saskatchewan Traffic Accident Information System (TAIS) was used. Descriptive statistics, mapping and logistic regression analysis were conducted to examine factors associated with bicycle collisions.
*Results:* Legal speed limits greater than 70 km/h were shown to be more dangerous when compared to legal speed limits less than 50 km/h, which showed an 84% reduced probability of collisions (OR=0.26, CI: 0.11 to 0.54). Compared to morning cycling, night time cycling was associated with 2.13 times the risk of collision (95% CI: 1.28 to 3.82). Hazardous road surface conditions, such as snow and ice, increased the likelihood of a collision by 12.13 times (95% CI: 8.13 to 19.98). Contrary to previous research, our analysis showed that collisions do not occur more frequently at intersections.
*Conclusion:* The results from this study demonstrated that road conditions and time of day play an important role in cycling collisions. Transportation and public health policies such as regular maintenance of roadways for cyclists and more bicycle scale street lights could address these factors at relatively low cost.



## 1. Introduction

Promoting cycling as a mode of transportation can increase population health and potentially benefit the environment (Harris et al., 2009). Cycling rates in Canada are low (~2%) in comparison to European countries with well-developed cycling infrastructure, such as the Netherlands (~28%) (Pucher, 2003). The gap in utilitarian cycling rates can be partially explained by a lack of safe cycling environment in North America. Harris et al. (2009) showed that American cyclists are 8 to 30 times more likely to be involved in a collision than their European counterparts. Cycling injuries represent 3.4% of all recorded injuries in Canada (Public Health Agency of Canada, 2008). Including both recreational and utilitarian cycling, 81.0% of injuries result from cyclists falling off their bicycle and 14.3% involved a collision with a motor vehicle. The majority of cycling injuries occurred in children less than 10 years old, and among males. To successfully promote cycling in Canada, factors associated with bicycle collisions need to be investigated in order to implement public policies that create a safe environment for cycling. The purpose of this study was to examine the association between environmental factors, such as road surface conditions, and bicycle–motor vehicle collisions.

Research on factors associated with bicycle collisions shows that certain environmental elements, including legal speed limits, road structure and traffic volumes, are consistently correlated with cyclist-motor vehicle collisions(Harris et al., 2009). Harris et al. (2009) showed that different road features are associated with collision rates. For example, intersections at the bottom of a downhill road are associated with 2.22 times greater collision risk compared to a straight road with no intersection. In separate studies, the risk of a bicycle–vehicle collision increases at intersections where tall buildings impair the view of the drivers and lead to cyclists failing to slow down (Works, & Department, E. S, 2003; Transport Canada, 2007; Schepers et al., 2011). For collisions at non-intersection roads, streetcar tracks increase the frequency of collisions, whereas local streets with diverters reduce collision risk (Harris et al., 2009; Yan et al., 2011). Other features on the road can also increase the likelihood of collisions, such as open car doors, the leading cause of cyclist collisions in downtown Toronto

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(Works, & Department, E. S, 2003). Finally, higher legal speed limits are associated with higher risk of bicycle–vehicle collisions due to reduced driver reaction time and higher speed differential between motor vehicle and bicycle (Wang and Nihan, 2004; Johnston, 2004).

Beyond road features and speed limits, time of day is associated with bicycle–motor vehicle collisions. Although most bicycle collisions tend to occur in the day when cyclists are most likely to ride their bicycles, the risk of collisions at night is significantly greater (Rowe et al., 1995). Klop and Khattak (1999) showed that night time cycling increases the risk of a collision due to poor vision from both drivers and cyclists.

To date, the majority of studies assume a consistent road surface when examining bicycle–motor vehicle collision rates on different road features. Limited research has focused on the association between specific road surface conditions (e.g., snow or gravel) and road features on the likelihood of bicycle collisions. The purpose of this study was to examine factors associated with bicycle collisions, specifically road surface conditions, time of the day and road structures.

## 2. Method

The data for this analysis included collision records from 2000 to 2010 in Saskatoon, Saskatchewan. The data was obtained from the Saskatchewan Traffic Accident Information System (TAIS), which included collision locations by vehicle type, external factors and collision time. The TAIS is the collision dataset used by the provincial government to report annual collision rates and trends. Weather data from 2000 to 2010 from Environment Canada was merged with the collision data from TAIS to examine weather factors associated with bicycle collisions.

The climate in Saskatoon is generally colder with more snowfall compared to other Canadian cities. The average temperature in Saskatoon between 1971 and 2010 was 2.2 °C, with monthly averages ranging from −17.0 to 17.3 °C in January and August, respectively. Average snowfall in the same period was 97 cm per year with 18.5 cm on average falling in December (Government of Canada, 2013). Saskatoon has no mountain or significant hills the landscape is quite flat.

### 2.1. Measure

The explanatory factors included in this study were collision time, road surface conditions, road features, traffic volume, legal speed limits, major contributory factors (MCFs) and snow precipitation. Collision time was categorized as Morning (6:01 am to 12:00 am), Afternoon (12:01 am to 6:00 pm), Evening (6:01 pm to 12:00 am) and Night (12:01 am to 6:00 am). Road surface conditions were categorized as dry, wet, snow or construction surfaces(Insurance, 2011). Road structures were categorized as intersection, non-intersection, cross passing (e.g., bridge or overpass), and other road conditions (e.g., entrance ramps or exits). Traffic volume was categorized as low (from 220 to 23,924) versus high (from 23,925 to 45,684, which was the highest value in the data set). Legal speed limit on the road was categorized as $<50$ km/h, 50–60 km/h, and $>70$ km/h. Major contributing factors (MCF) assigned by the traffic information systems were categorized into traffic violations (e.g., alcohol consumption or failing to stop at red light), human conditions (e.g., defective eyesight and hearing, driver confusion and careless driving), environmental conditions (e.g., construction zones, snow drift and too much gravel on the ground), and vehicle malfunction. Snow precipitation was included as a binary variable indicating snowfall on the day of the collision.

### 2.2. Mapping

ArcGIS 10.1 was used to map bicycle collisions including the road network and neighborhoods in Saskatoon. The road network and neighborhoods layer files were obtained from the city of Saskatoon, and overlaid with the collisions from the TAIS dataset. We also highlighted the Central Business District because it is the neighborhood with the highest number of collisions.

### 2.3. Analysis

Descriptive statistics, bivariate and multivariable analysis were conducted. Specifically, bivariate and multivariable logistic regression

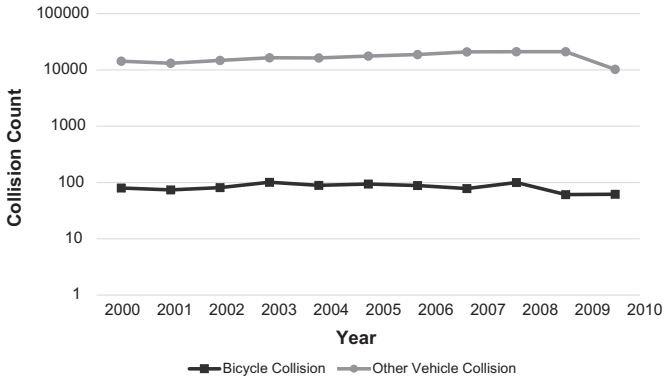


**Fig. 1.** Collision trend from 2000–2010 between bicycle and other vehicle types. Descriptive graph illustrating the collision trend between bicycle collisions and other vehicle collisions from 2000 to 2010.

**Table 1**
Descriptive statistics of explanatory variables associated with bicycle collision.

| Explanatory variables | Bicycle collision count % (*n*) | All other collisions count % (*n*) |
|---|---|---|
| Legal speed limit | | |
| $<50$ km/h | 4.3% (39) | 4.6% (8437) |
| 50–60 km/h | 97.3% (857) | 89.8% (165,589) |
| $>70$ km/h | 1.4% (12) | 5.6% (10,394) |
| Traffic volume | | |
| Low | 83.1% (492) | 82.0% (96,127) |
| High | 16.9% (100) | 18.0% (21,054) |
| Collision time | | |
| Morning | 20.3% (181) | 25.2% (45,558) |
| Afternoon | 51.2% (457) | 48.8% (88,396) |
| Evening | 25.7% (229) | 19.1% (34,627) |
| Night | 2.8% (25) | 6.9% (12,489) |
| Road structure | | |
| Intersections | 83.6% (751) | 67.0% (120,451) |
| Non-intersections | 14.1% (127) | 29.7% (53,585) |
| Other roads | 2.1% (18) | 1.3% (2330) |
| Cross passing | 0.2(2) | 2.0% (3594) |
| MCFs | | |
| Traffic violations | 29.9% (130) | 27.0% (19,656) |
| Human conditions | 66.7% (290) | 47.9% (34,806) |
| Environmental conditions | 2.5% (11) | 24.5% (17,789) |
| Vehicle malfunction | 0.9% (4) | 0.6% (423) |
| Road surface conditions | | |
| Wet surfaces | 8.4% (66) | 8.2% (12,495) |
| Snow surfaces | 3.5% (27) | 39.6% (60,945) |
| Dry surfaces | 87.7% (684) | 51.2% (78,305) |
| Construction surfaces | 0.4% (3) | 1.0% (1092) |
| Snow Precipitation | | |
| Yes | 3.5% (32) | 17.7% (32,608) |
| No | 96.5% (876) | 82.3% (151,812) |