# A Logistic Model of Hit-and-Run Crashes in Calgary

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## Abstract

*A traffic collision in which at least one driver fled from the crash scene without reporting the crash would be classified as a hit-and-run collision. In the City of Calgary about 18 percent of total traffic collisions in 2005 were considered to be hit-and-run crashes. The objective of this study was to identify the environmental and road characteristics that contributed to the occurrence of hit-and-run in the event of a crash in the City of Calgary. A logistic regression model was developed to delineate the likelihood of hit-and-run crashes as opposed to non hit-and-run crashes. Our study showed that compared to weekday and daytime collisions, weekend and night time collisions had significantly higher likelihood of hit-and-run in the event of a crash. In terms of weather condition, snow and rain reduced the chance of hit-and-run compared to clear weather condition. Also, hit-and-run were more likely to occur on undivided roads and roads with artificial light. As for driver related factors, among the identified drivers, female drivers aged at 55 or above showed the greatest likelihood to run away after a crash compared to other gender and age groups.*

**Keywords**: Hit-and-Run, Logistic Model, Calgary

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## 1.0 Introduction

Road crashes not only contribute to the loss of life, disability and property damage, they also reduced the quality of life for many road users and their families. In Canada, about 3,000 road users are killed and an additional 200,000 injured in crashes each year, resulting in an estimated annual social cost of about $26 billion (Transport Canada, 2004). In Alberta alone, there were 142,592 motor vehicle collisions in 2006, resulting in 453 road users killed and 25,964 injured (Alberta Transportation, 2006).

Among the different types of crashes, hit-and-run crashes should be of special concern to road safety professionals and law enforcement officers. A hit-and-run crash would be one in which at least one of the drivers left the scene of accident without reporting the crash. Leaving the scene without reporting the crash might result in an increase in the severity of the crash since 85 percent of victims in fatal crash would die within one to two hours (Roess *et al*., 2005; Tay *et al.,* 2008, 2009). Hence, hit-and-run behavior is a punishable offence in many countries, including Canada. In addition, hit-and-run crashes also increase the investigation and prosecution costs.

The topic of hit-and-run in motor vehicle accidents had attracted a number of researchers from diverse disciplines including engineering, criminology, medical and social sciences. In the areas of engineering, criminology and medical sciences, the research thus far has focused mainly on examining the crash scene as well as the severity and type of injury to the victim to identify the type of vehicle involved and the collision characteristics such as collision time and vehicle speed (Karger *et al*., 2001; Teresinski and Madro, 2001; Cousins *et al*., 1989; Taylor *et al*., 1989; Locke *et al*., 1982, 1987, 1988).

In addition, Solnick and Hemenway (1995) examined the effects of victim characteristics, driver characteristics and circumstances on the hit-and-run decision in fatal pedestrian crashes. Their study showed that a driver would be less likely to run if the crash victim was a child or senior pedestrian, the crash occurred in daylight, and the driver was a senior citizen. In a previous study, the same authors also found that drunk driving was a significant determinant of hit-and-run behavior (Solnick and Hemenway, 1994).

In the area of transportation engineering and planning, a few studies had been conducted to identify the effects of roadway, environment, weather conditions and lighting in influencing the decision to run away from the crash scene. In one of the few studies, Tay *et al.* (2008) identified three general attributes that had significant effects on hit-and-run crashes in Singapore; namely, night time, lighting condition, and low density neighborhoods.

In another study, Kim *et al.* (2008) used rough set analysis tools combined with logistic regression to understand the key human factors as well as roadway features associated with hit-and-run collisions in Hawaii. The authors found factors such as being a male, tourist, intoxicated, and driving a stolen vehicle to be strong predictors of hit-and-run crashes.

Finally, Tay *et al.* (2009) showed that roadway functional class, route, traffic flow, type of roadway, speed limit, traffic control device, functioning of traffic control device, lighting condition, roadway alignment, roadway profile, weekend and night time are all important determinants of hit-and-run behavior in the event of a fatal crash in California.

A review of literature also found that the prevalence of hit-and-run behavior varied across jurisdictions depending on the social and road environment as well as law enforcement. For example, hit-and-run constituted only about 1.9% of the total reported crashes in Singapore (Tay *et al*., 2008) but 8.1% in California, which was the highest among all the states in America (Tay *et al*., 2009). By comparison, in the City of Calgary, hit-and-run crashes constituted 17.8% of the total number of crashes in 2005.

This very sizeable share of hit-and-run crashes made Calgary an interesting case study that might further advance our knowledge in this area. Moreover, the Alberta Motor Association revealed that hit-and run accident claims were extremely high in Alberta (Accidents Direct, 2010) and the Saskatchewan Government Insurance revealed that hit-and-run insurance claims have been doubled in eight years since 2000 (McKenna, 2009). Overall, hit-and-run behavior appeared to be a much more significant issue in Canada and understanding the factors contributing to this behavior would be provide useful insights for policy makers and insurance companies to assist them in reducing hit-and-run crashes.

Hence, the objective of this paper was to examine the impact of road features, environment and driver related factors on the likelihood of hit-and-run in motor vehicle accidents in the City of Calgary. Besides having a much higher share of hit-and-run accidents in Calgary compared to California, this study would also contribute to our understanding of the differences in the factors associated with hit-and-run behaviors in fatal crashes (Tay *et al*., 2009) versus all crashes (mostly non fatal crashes) in our study. Although Tay *et al.* (2008) also examined all crashes, their study was conducted using data from Singapore which is a small island state in Asia and would have significantly different social and legal factors.

## 2.0 Methodology

The binary logistic model is often used to predict a binary dependent variable as a function of several predictor variables. It is appropriate for this study because the response variable has two possible outcomes:

Y = 1 indicates a hit-and-run crash
Y = 0 indicates a non hit-and-run crash

In this study, the logit is defined as the natural logarithm of the odds or the likelihood ratio of the dependent variable being equal 1 (hit-and-run) as opposed to 0 (non hit-and-run). The probability P of a hit-and-run crash is given by:

$$Y = logit\,(P) = \ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p + \varepsilon_i \qquad (1)$$

where Y is a latent variable measuring injury severity
$x_1$, $x_2$,..., $x_n$ are explanatory variables
$\beta_1$, $\beta_2$,...,$\beta_n$ are unknown parameters
$\varepsilon_i$ is the error term with extreme value type I distribution

Holding all the other factors constant, the marginal effect arising from a unit change of an independent variable $x_i$ in the logit model is known as the odds ratio, which is quantified by the factor exp[$\beta_i$]. If $\beta_i > 0$, then OR > 1. It will indicate that the probability of occurrence of hit-and-run will increase due to a unit increase in $x_i$. In this study, the parameter vector β and the corresponding odds ratios are estimated by using the SPSS statistical software using maximum likelihood estimator (MLS) technique.

## 3.0 Data

Data on crashes occurring in the City of Calgary in 2005 were extracted from the official crash database maintained by Alberta Transportation. There were a total of 37,146 reported crashes and 6,636 of them were hit-and-run crashes, comprising about 17.8%. Note that only 36,936 observations were used to estimate the logistic regression model because some observations with missing key data were excluded. Of these 36,936 reported crashes, 6625 (17.9%) were hit-and-run crashes.

As shown in Table 1, the explanatory variables categories or contributing factors that were examined included day-of-week, time-of-day, driver gender and age, vehicle age, total number of vehicles involved, crash severity, weather condition, road class, lighting and road surface condition. Note that all of these factors were recorded using ordered or unordered categories and therefore several dichotomous variables were created in the model to capture each contributing factor.

**Table 1**
*Differences in Crash Profile (%)*

| Variables | Non Hit-and-Run | Hit-and - Run |
|---|---|---|
| Day of Week | | |
| Weekday | 69.7 | 66.3 |
| Weekend | 30.3 | 33.7 |
| Time of Day | | |
| Day | 88.4 | 84.5 |
| Night | 11.6 | 15.5 |
| Crash Severity | | |
| Injury/Fatality | 9.6 | 10.4 |
| Non-injury | 90.4 | 89.6 |
| Road Class | | |
| Undivided One-way | 4.1 | 4.8 |
| Undivided Two-way | 22.5 | 23.8 |
| Divided with Barrier | 16.1 | 16.4 |
| Divided No Barrier | 3.2 | 3.5 |
| Unknown | 54.1 | 48.5 |
| Environment Condition | | |
| Clear | 72.9 | 74.1 |
| Raining | 4.4 | 4.1 |
| Hail/Sleet/Snow | 4.3 | 3.7 |
| Others or Unknown | 18.4 | 18.2 |

| Variables | Non Hit-and-Run | Hit-and-Run |
|---|---|---|
| Surface Condition | | |
| Dry | 59.5 | 61.3 |
| Wet | 7.5 | 7.5 |
| Slush/Snow/Ice | | |
| Others or Unknown | 17.9 | 17.9 |
| Lighting Condition | | |
| No artificial Light | 53.4 | 49.0 |
| Artificial | 19.5 | 23.7 |
| Unknown | 25.4 | 25.2 |
| Vehicle Age | | |
| Age < 15 | 74.6 | 73.6 |
| Age ≥ 15 | 12.0 | 12.7 |
| Unknown | 13.4 | 13.7 |
| Number of Vehicles | | |
| One Vehicle | 15.1 | 16.0 |
| ≥ 2 Vehicles | 84.9 | 84.0 |
| Driver Age and Gender (M or F) | | |
| Unidentified | 15.4 | 16.4 |
| M Age ≤ 30 | 19.7 | 20.3 |
| M 30 < Age < 55 | 25.8 | 24.5 |
| M Age ≥ 55 | 8.3 | 8.5 |
| F Age ≤ 30 | 11.0 | 10.8 |
| F 30 < Age < 55 | 15.3 | 14.6 |
| F Age ≥ 55 | 4.5 | 4.9 |

Note: Of the 36,936 observations, 17.9% consisted of hit-and-run crashes.

Note that to avoid perfect multicollinearity, one category in each factor was arbitrarily chosen as the base or reference case and omitted in the estimation. The estimates obtained for the other categories would then be interpreted as the relative effect of the variable compared to the base case. Following Kockelman and Kweon (2002), Tay and Rifaat (2007) and Tay *et al.* (2008, 2009), some categorical variables that were statistically insignificant were retained in the model as long as one of the categories for the same factor was statistically significant.

## 4.0 Discussion of Results

The estimation results are reported in Table 2. In general, the model fitted the data quite well, with a large chi-square statistic and very small p-value for the goodness-of-fit. It is important to note that our model compares the likelihoods of hit-and-run and non hit-and-run crashes, which imply that they are conditional probabilities of "running away" or reporting the incident after a crash has occurred and not the unconditional probability of having a hit-and-run crash or not having a hit-and-run crash.

**Table 2**
*Estimation of Results*

Number of Observations: 36,936; Chi-square statistic: 181.62; p-value: <0.0001

| **Variables** | **Odds Ratio** | **p-value** |
|---|---|---|
| Day of Week (Ref. Weekday) | | |
| Weekend | 1.148 | <0.001 |
| Time of Day (Ref. Daytime) | | |
| Night | 1.233 | <0.001 |
| Crash Severity (Ref. Non-injury) | | |
| Injury/Fatality | 1.086 | 0.070 |
| Road Class (Ref. Divided with Barrier) | | |
| Undivided One-way | 1.187 | 0.009 |
| Undivided Two-way | 1.072 | 0.035 |
| Divided No Barrier | 1.096 | 0.227 |
| Environment Condition (Ref. Clear) | | |
| Raining | 0.842 | 0.080 |
| Hail/Sleet/Snow | 0.869 | 0.078 |
| Unknown | 0.967 | 0.404 |
| Surface Condition (Ref. Dry) | | |
| Wet | 1.048 | 0.532 |
| Slush/Snow/Ice | 0.858 | 0.001 |

| **Variables** | **Odds Ratio** | **p-value** |
|---|---|---|
| Lighting Condition (Ref. No artificial Light) | | |
| Artificial | 1.227 | <0.001 |
| Unknown | 0.825 | 0.005 |
| Vehicle Age (Ref. Age < 15) | | |
| Age ≥ 15 | 1.058 | 0.179 |
| Unknown | 0.825 | 0.005 |
| Number of Vehicles (Ref. ≥ 2 Vehicles) | | |
| One Vehicle | 1.021 | 0.580 |
| Age of Male Driver (Ref. 30 < Age < 55) | | |
| Age ≤ 30 | 1.032 | 0.402 |
| Age ≥ 55 | 1.081 | 0.131 |
| Age of Female Driver (Ref. 30 < Age < 55) | | |
| Age ≤ 30 | 1.007 | 0.873 |
| Age ≥ 55 | 1.162 | <0.001 |
| Unidentified Drivers | 1.305 | <0.001 |
| Constant | 0.163 | <0.001 |

### 4.1 Occurrence Time and Day

As shown in Table 2, crashes occurring at night were more likely to be associated with hit-and-run. The odds ratio for night time was 1.23 which implied that likelihood of hit-and-run crashes at night was 23% greater than that in daytime. This result was expected since drivers might think that they would be less likely to be caught because of the relatively low traffic volume and poor visibility at night. Our result was consistent with those obtained in other studies on total crashes (Tay *et al*., 2008, 2009; Kim *et al*., 2008) but contrast with those obtained by Tay *et al.* (2009) who examined only fatal crashes.

Our model also suggested that weekend was associated with a 15% higher likelihood of hit-and-run crashes than weekdays. This result could be explained by the lower traffic volumes on weekends as compared to weekdays and hence the lower perceived likelihood of detection. Our result was consistent with those obtained by Tay *et al.* (2009) for fatal crashes in California.

### 4.2 Lighting conditions

Our study also found that lighting condition was a crucial factor for hit-and-run crashes in the City of Calgary. Our model indicated that the likelihood of occurrence of hit-and-run crashes at locations with artificial light were 23% greater than those at locations with no artificial light. Even though contrary to expectation, this finding was consistent with Tay *et al*. (2009) who found that likelihood of hit-and-run was higher at night on lighted roads compared to unlit roads although the difference in their finding was not statistically significant.

### 4.3 Accident Severity

Compared to property damage only crashes, injury accidents had an odd ratio of 1.09 although it was only marginally significant level with a p-value of 0.07. This result revealed that drivers exhibited a higher chance of running away when at least one victim sustained an injury in the crash. This finding was consistent with the results obtained by Tay *et al*. (2008) who attributed their results to higher expected implications of reporting the accident.

### 4.4 Driver's Gender and Age

Driver gender and age was investigated in this study using middle-aged drivers as the reference category for both gender. Consistent with previous studies (Solnick and Hemenway, 1995; Tay *et al*., 2008), drivers aged 30 or below and 55 or above both showed higher chances of running after the crash than their middle age counterparts although our results were statistically significant for older female drivers only. Younger drivers would be relatively more risk taking and might perceive a lower risk associated with running. Senior drivers, on the other hand, be concerned that they would incur a higher increase in insurance premium if they reported the crash, especially since most of the crashes were property damage only crashes. In addition, some senior drivers fear that their driving license might be suspended if they reported the accident. However, the over representation of senior female drivers in hit-and run might be attributed to the fact that they usually avoid driving in complex and demanding traffic conditions such as peak hours and high speed limit road (Tay, 2006, 2008). The lower traffic and speed on the road might reduce the likelihood of detection and increase the likelihood of running. Not surprisingly, unidentified drivers were also more likely to be involved in hit-and-run crashes.

### 4.5 Road Class

Divided road with barrier was selected as the reference variable under this category. Our model revealed that all other types of roads had higher odd ratios than divided roads with barriers. In particular, one-way roads and undivided two-way roads were associated with a significant increase in the probability of running after the crash. These results were consistent with those obtained by Tay *et al*. (2009). In general, divided roads would carry more traffic and thus drivers might be less inclined to run because of higher probability of detection.

### 4.6 Environmental and Road Surface Conditions

Compared to clear weather, the likelihoods of hit-and-run in snowy and rainy weather conditions were lower although these variables were only marginally significant. Also, the likelihood of hit-and-run was lower when the road surface was slushy, snowy or icy as compared to a dry road and this difference was highly significant ($p$-value $< 0.001$). These results were consistent with previous studies (Tay *et al*., 2008, 2009) although the results obtained by Tay *et al*. (2009) were not statistically significant. As suggested by Tay *et al*. (2008), drivers might perceive the likelihood of blame, and thus the expected implications of reporting the crash, to be lower under poor weather and road conditions, and hence more likely to report them.

### 4.7 Number and Age of Vehicle

Our study found that single vehicle crashes had a higher likelihood of hit-and-run than crashes involving two or more vehicles. However, this difference was not statistically significant but was qualitatively different from the results obtained by Tay *et al*. (2009) who found that relative to single vehicle crashes, crashes involving two or more vehicles were more likely to be hit-and-run crashes. Since the majority (over 90%) of the crashes in our sample consisted of property damage only crashes, the likelihood of not reporting the crashes if they did not involved in third party (single vehicle crash) would be higher.

The effect of vehicle age on hit-and-run had not been explored in earlier studies and this study found no significant difference in hit-and-run likelihood between vehicles that were less than 15 years old and those that were older. If vehicle age could be used as an indicator of economic and social status, then hit-and-run did not appear to be more prevalent in higher or lower social economic groups.

## 5.0 Conclusion and Recommendation

In this study, a logistic regression model was applied to identify the factors that contributed to the occurrence of hit-and-run crashes relative to non-hit-and-run crashes in the City of Calgary. It should be noted that the conclusions from this study were related to the situation in the City of Calgary although the most of the outcomes from this study were consistent with the other hit-and-run studies conducted in Singapore, Hawaii and California.

Consistent with Tay *et al*. (2009), we found that crashes occurring during weekends, during clear weather, on dry roads, undivided roads or on artificially lit roads were more likely to involved hit-and-run behaviors. However, in contrast to Tay *et al*. (2009), we also found that crashes occurring during the night or involved only a single vehicle to be more likely to involved hit-and-run behaviors although the latter effect was not statistically significant. The differences in the findings might be attributed to the different local conditions as well as the differences in the types of crashes analyzed. This study examined all hit-and-run crashes whereas Tay *et al*. (2009) examined only fatal crashes.

In terms of traffic enforcement, more effort should be targeted at night, on weekends and along undivided roadways that are artificially lit to increase both the general and specific deterrence. Note that simply the presence of more police patrols during these times and at these locations would have an effect in reducing the likelihood of hit-and-run. These enforcement efforts could be incorporated into speeding and drink-driving enforcement, which also tend to occur more frequently under the same conditions (Slonick and Hemenway, 1994; Tay, 2010, 2005a, 2003). Moreover, automatic enforcement should also be considered to reduce enforcement cost, increasing the enforcement efficacy, and increase the likelihood of targeting females and older drivers (Tay, 2009, 2005b,c,d).

These enforcement efforts could also be accompanied by more public education to raise awareness of the issue as well as change driver behavior (Lewis *et al*., 2007a, b, c; Tay *et al*., 2002a, b; Tay, 2001,1999). Currently, most of the road safety campaigns in Alberta and across

Canada tend to focus mainly on drunk-driving, speeding and seatbelt use, with little attention to hit-and-run behavior (McKenna, 2009). In addition to targeting hit-and-run by drivers, the campaigns should also aim to increase public awareness and support for tougher measures and sanctions. Public support is also needed to increase co-operation with police investigation and increase the likelihood of detection (Hutton, 2010)

In terms of highway design and engineering, simple barriers and medians should be installed in more hazardous locations to not only prevent crashes but also reduce the likelihood of running from the scene of the crash without reporting it (Tay *et al*., 2009; Tay and Churchill, 2007). Appropriate barriers will also reduce the severity of crashes (Barua and Tay, 2010) which, according to the results obtained in this study, will reduce the likelihood of hit-and-run as well. Hence, many traffic calming measures that reduce the severity of crashes could also be used to reduce the likelihood of hit-and-run.

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