## Modelling Injury Severity of Pedestrians in Collisions Involving Distracted Driving

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### Introduction

Distracted driving is increasingly becoming a road-safety concern; particularly, it's aggravated effect on injury severity level. For example, the National Highway Traffic Safety Administration (NHTSA) reported that 16% of the total fatalities in the USA in 2008 involved distracted drivers (National Highway Traffic Safety Administration, 2009). However, limited studies have examined the injury severity of collision involving distracted driving. In addition, it is imperative to explore how distracted driving affects active road-users (e.g. pedestrians), since they are more exposed and vulnerable to crash injury than vehicle occupants. Therefore, this study investigates the pedestrian injury severity of collisions involving distracted driving. The study utilizes data from the Nova Scotia Collision Record Database (NSCRD) for the years 2007-2011. A latent segmentation-based ordered logit (LSOL) model is developed to address the ordered nature of the reported injury severity levels. The LSOL model also disentangles whether there exists any heterogeneity across the involved parties and collisions attributes.

### Data Sources

This study utilizes Nova Scotia Collision Record Database (NSCRD) from 2007 to 2011. This database includes all police reported collisions in the Province of Nova Scotia, Canada. This study considers collisions that involves at least one distracted driver and at least one pedestrian, which yields a sample size of 360 pedestrians. Injury severity level is classified in the following five-point ordinal scales: 1) no injury, 2) minor injury, 3) moderate injury, 4) major injury, and 5) fatal injury. The statistical distribution of the injury severity levels is: 9.72% no injury, 26.67% minor injury, 55.28% moderate injury, 5.83% major injury, and 2.50% fatal injury. Additionally, land use, and location information of major activity points and transportation services are collected from the Desktop Mapping Technologies Inc. (DMTI). Neighborhood characteristics at the dissemination area (DA) are collected from the 2011 Canadian Census.

### Methodology

This study develops a latent segmentation-based ordered logit (LSOL) model to investigate the injury severity levels of pedestrians. The LSOL model accommodates ordinal nature of the injury severity level as well as captures latent heterogeneity. Assuming, *i* is in an ordinal scale and can take values of 0 (no injury), 1 (minor injury), 2 (moderate injury), 3 (major injury), and 4 (fatal injury). The actual injury severity level $Y_j$ can be expressed as:

$Y_j = i$ if $\mu_{i-1,s} < Y_j^* < \mu_{is}$ , where, latent propensity of injury severity, $Y_{js}^* = \beta_s Z_j + \varepsilon_{is}$

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Here, $j$ is individual, $s$ is latent segment, $i$ is injury severity level, $Z_j$ is the observed characteristics, $\beta_s$ is the coefficient parameter, $\varepsilon_{is}$ is random error term assumed to follow an identically and independently standard logit distribution, and $\mu$ is threshold parameter. Now, latent segment allocation component takes the following form:

$$P_{js} = \frac{e^{\gamma_s X_j}}{\sum_{s=1}^{S} e^{\gamma_s X_j}}$$

Here, $X_j$ is the observed attributes, and $\gamma_s$ is the coefficient parameter. The model is estimated by maximizing the likelihood function. The model estimates segment specific parameters $\beta_s$ for $s$ segments, and segment membership parameter $\gamma_s$ for *s-1* segments.

**Model Results**

*Goodness-of-fit Measures*

The number of segments of the LSOL model is determined based on BIC measures. The model results suggest a BIC value of 1022.78 and 1133.23 for two and three segments respectively. Therefore, the final LSOL model assumes two segments. For comparison purposes, a traditional ordered logit (OL) model is developed as well. The LSOL model outperforms the OL model with a higher adjusted pseudo r-squared value of 0.06 than that of the OL model (0.01). Hence, the LSOL model with two segments is considered as the final pedestrian injury severity level model for further discussion.

*Model Results of the Latent Segment Allocation Component*

The latent segment allocation model is estimated based on person profile and collision characteristics (Table 1). Person profile refers to the pedestrian and driver's age, and gender. The collision characteristics include vehicle type, and vehicle trajectory. The model assumes segment two as the reference segment. The model results suggest a negative relationship for female pedestrian in segment one. This implies that male pedestrians are more likely to belong to segment one. Male pedestrians intuitively are risk takers and might be involved in collisions yielding severe injury (Abay, 2013). The positive sign of the drivers' age reveal that older drivers are more likely to be assigned to segment one. Older drivers tend to have a slower reaction time in a crash situation (Yasmin et al., 2014), which coupled with distraction might yield severe injury for the pedestrian. The negative sign of the vehicle type representing passenger car suggests that collisions involving larger vehicles are more likely to be assigned to segment one, which increases the risk of severe injury for road users outside the vehicle such as pedestrians. The model suggests a positive sign for vehicle going straight, and vehicle turning to left or right. Vehicles going straight ahead are likely to be at a higher speed and might cause severe injury, which further ascertains the higher risk of injury in segment one. Therefore, segment one can be identified as a higher injury severity risk segment. On the other hand, segment two can be identified as a segment with lower injury severity risk.

*Discussion of Parameter Estimation Results*

The model estimation results for the pedestrian injury severity level is presented in Table 1. The model tests the effects of a wide array of variables, including environmental factors, roadway design and configuration, land use and environment, and distraction type, among others. The model results suggest that environmental factors significantly influence pedestrian injury severity. Clear and rainy weather results more severe injury for pedestrians in the high-risk segment two. The effect of rainy weather is found to be stronger than clear weather. This is a deviation from earlier findings by Mohamed et al. (2013), who argued that injury severity is lower in rainy weather as drivers are more cautious. However, this study focuses on the collisions involving distracted driving. Such distractions affect the alertness of the drivers and aggravate the influence of reduced visibility during rain, which might result in more severe collisions. The model results suggest that considerable heterogeneity exists across the two segments. For instance, while distraction type representing inattentiveness is interacted with clear weather, the relationship is found to be positive in low-risk segment two. This implies that inattentiveness of the driver might result in more severe injury in clear weather than other distraction types for pedestrians in segment two. In contrast, the same interaction variable shows a negative relationship in segment one. Darkness increases the likelihood for severe injury in both the segments, which is again a deviation from the findings in earlier studies by Yasmin et al. (2014). The effect of distraction along with reduced visibility during darkness might yield more severe injury.

In the case of built environment attributes, a curved road section is found to increase the likelihood of injury severity, which is aligned with the findings of Prato et al. (2017). Collisions occurring in the non-intersection portion of a roadway are associated with severe injury for pedestrians in the high-risk segment. Since vehicles are at a higher speed in the mid-block section of a street, this results in a higher probability for severe pedestrian injury. On the other hand, pedestrians in the low-risk segment reveal a lower likelihood of severe injury. Interestingly, the relationship for the low-risk segment is found to be positive when drivers' inattentiveness is interacted with collisions occurring at the intersection of a parking lot and roadway. Among the land use attributes, higher-mix land use areas are found to be associated with higher risk for severe pedestrian injury. Although this relationship initially seems counter-intuitive, it is expected in the case of collisions involving distracted driving. A higher mixed land use area includes a higher number of activity locations, which are accessible by walking. Higher pedestrian activities in such areas might trigger severe conflict between pedestrians and vehicles if the driver of the vehicle is distracted. Similarly, another variable indicating the collision occurring within 10km of the regional center shows a positive relationship. A variable representing length of sidewalk within 250m of the crash location reveals a lower likelihood for severe injury. Since sidewalks facilitate grade-separated safe walking opportunities for pedestrians, it reduces the severity of injury.

## Conclusions

This study presents the findings of pedestrian injury severity of collisions involving distracted driving. A latent segmentation-based ordered logit (LSOL) model is developed to address the ordinal nature of the injury severity as well as latent heterogeneity. The segment allocation model results suggest that individuals are allocated into two segments, which can be identified as high-risk and low-risk injury severity segments. The model estimation results reveal that higher mixed land use, collision in urban area, curved road, darkness, and rain increase the probability of severe injury. Longer length of side walk, and higher dwelling density are found to decrease the likelihood of injury severity. The model results reveal that significant heterogeneity exists between the latent segments. For instance, an inattentive driver in clear weather might yield higher injury severity in high-risk segment; whereas, it results in lower severity in the low-risk segment. The model confirms the interplay between built environment and distraction type. For example, inattentive driving is found to aggravate pedestrian injury at the intersections of parking lots. In summary, the findings of this study will assist in prioritizing road safety strategies and plans for the pedestrians.

## References


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**TABLE 1 Parameter Estimation Results of the LSOL Model for the Pedestrian Injury Severity Level**

| **Variables** | ***Segment 1*** | ***Segment 2*** |
|---|---|---|
| | ***co-efficient (t-stat)*** | ***co-efficient (t-stat)*** |
| **Latent Segment Allocation Component** | | |
| Constant | 3.596 (2.99) | - |
| ***Person Profile*** | | |
| Female | -1.649 (2.42) | - |
| Driver age (years) | 0.003 (2.68) | - |
| ***Collision Characteristics*** | | |
| Vehicle type - Car | -3.226 (2.60) | - |
| Vehicle going straight | 1.205 (1.60) | - |
| Vehicle turning to left or right | 3.343 (2.92) | - |
| **Injury Severity Component** | | |
| ***Environmental Factors*** | | |
| Weather - Clear | 0.906 (1.86) | - |
| Weather – Clear x Inattentive | -0.793 (1.61) | 5.871 (1.00) |
| Weather - Rain | - | 6.283 (1.85) |
| Light condition - Dark | 0.727 (3.12) | 2.232 (1.60) |
| Light condition - Street light off | 0.540 (3.12) | - |
| Time of Day - AM and PM peak | - | 2.611 (1.71) |
| Time of Day - Off-peak | 0.348 (1.93) | - |
| ***Built Environment*** | | |
| **Roadway Design and Configuration** | | |
| Road alignment curved | 0.706 (2.30) | - |
| Collision location - Non-intersection | 0.490 (2.67) | -2.863 (2.11) |
| Collision location - Intersection with parking lot * Inattentive | - | 4.284 (1.51) |
| **Land Use and Neighbourhood** | | |
| Land use mix index | 1.145 (1.71) | - |
| Collision <10km from regional center | - | 1.764 (1.83) |
| Length of sidewalk within 250m buffer (km) | - | -0.095 (1.43) |
| Dwelling density (dwelling/sqkm) | - | -0.484 (0.70) |
| ***Threshold Parameters*** | | |
| Threshold 1 | 0 (-) | 0 (-) |
| Threshold 2 | 0.806 (7.52) | 5.175 (1.67) |
| Threshold 3 | 2.668 (18.90) | 9.888 (2.16) |
| Threshold 4 | 3.368 (15.84) | 10.570 (2.27) |
| ***Goodness-of-fit Measures*** | | |
| Log-likelihood at convergence | -393.670 | |
| Log-likelihood at constant | -419.305 | |
| Number of observations | 360 | |
| Adjusted pseudo r-squared | 0.061 | |
| BIC | 1022.78 | |