# CONTRIBUTORY FACTORS TO INJURY SEVERITY OF WORK-ZONE RELATED CRASH IN NEW ZEALAND

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## ABSTRACT

Road works often take place on existing roads in New Zealand. The adverse effects of poor road condition and reduced road width, due to the presence of a work zone on the safety of road users and workers at the work zone have been a concern. Studies have been conducted to examine the risk factors contributing to the occurrence of road crashes in work zones in different countries. Slow and stopped vehicles near work zones were found the primary cause of crashes and casualties in work zones. Also, excessive speed of passing traffic has been recognized as a crucial factor contributing to work zone related crashes in New Zealand. In this study, we attempted to examine the effect of possible risk factors contributing to severe injury and fatality of work zone-related crashes in New Zealand. A multinomial logit regression model was established to measure the association between crash severity and factors including road environment, vehicle attributes, driver behavior and crash circumstance, based on the information on 453 road crashes during the period from 2008 to 2013. Results indicated that time period and vehicle involvement were deterministic to crash severity of crashes in road sections with temporary reduced speed limits. This should imply the improvements required in traditional temporary traffic management and work zone treatments and introduction of innovative technologies such as in-vehicle warning system for the enhancement of road safety in the long run.

**Keywords:** Road safety; Crash severity; Workzone; Multinomial logit regression; Traffic control

**Highlights:**

- Factors contributing to the crash severity at work zone in New Zealand are identified
- Crashes on weekday and during evening and night time have a lower likelihood of more severe injury
- Crashes involving motorcycle, bicycle and pedestrian have a higher likelihood of more severe injury
- No evidence is established for the association between driver attribute and crash severity at work zone

## 1. INTRODUCTION

Road work for maintenance and upgrades on an existing network, often operating and with heavy traffic flow, are common, but the risks of road crash and injury are high around the work zones due to the reduced road width, poor road condition, and inappropriate speed. Studies indicated that while maintaining existing and constructing new roads are necessary, the construction work could increase the perceived risk to a traveler on the same road (Hou et al., 2010). In the United States, work zone related crashes constitute up to 3% of overall road fatalities. Favorably, the proportion of work zone related road fatalities has been on a declining trend in the past decade, though the amount of road work has been increasing due to the high demand of road rehabilitations on US's road network (McAvoy et al., 2011).

The majority of New Zealand's road is undivided two lanes two-way carriageway. Road work for repairs and upgrades on New Zealand's roads are frequent and the safety of road users and workers around work zones has been of great concern. In particular, considerable vehicle speed differential and excessive speed were generally believed to contribute to the work zone related crashes *(1)*. To create a safe road system, and improve the operational performance, Austroads outlined three priority areas including credible limit compatible with road use expectations, consistent limits applied throughout the network, and clear and unambiguous limits, when selecting appropriate speed limits to frame a safe driving environment (Austroads, 2009).

The criteria of Austroads were set out based on driver's perception of speed environment with respect to their knowledge and experience on the existing road network. A similar approach is employed in the design of temporary speed limit at work zones in New Zealand. The Code of Practice for Temporary Traffic Management (COPTTM) of New Zealand outlines the types of signs, management plans, and other devices that required depending on the scale and location of work. It is to mitigate the risks attributed to road work on the New Zealand highway network, where detouring traffic is not always practicable. It is essential to identify possible risk factors including road environment, vehicle attributes, driver behavior, and work zone characteristics contributing to crash and injury around work zones.

In this study, a multinomial logit regression model is applied to examine the relationship between crash severity and factors including time period, vehicle types, driver behavior, and crash circumstances of work zone related crashes in New Zealand, based on the historical crash record extracted from the Crash Analysis System (CAS) during 2008-2013. In particular, the attributes including excessive speed, inattention and drink driving contributing to the risk of injury and fatality would be evaluated. The remainder of the paper is structured as follows. A literature review of work zone crash risk is presented in Section 2. Section 3 and Section 4 detail the method of data collection and analysis respectively. Results of the analysis and their implications to temporary traffic management at work zones are given in Section 5 and Section 6 respectively. Eventually, Section 7 concludes the study with suggestions for future research.

## 2. LITERATURE REVIEW

Diagnostic analysis was conducted for risk factors contributing to fatality at work zone using crash-severity-index model. In the exploratory analysis, factors including traffic control, driver errors and road conditions correlated to the fatal and severe injury crash at work zone were identified and validated (Li and Bai, 2008). Rear-end crashes have been the most common crash type at work zones. The increase in risk of road crashes at work zone could be attributed to the increase in the number of conflict points due to the lane closure(s) around a work zone (Weng and Meng, 2012). Also, study suggested that truck involvement contributed to higher risk of severe injury and fatality in work zone related crash. In particular, differences in speed changes between trucks and passenger cars were significant (Bai et al., 2015). Besides, using the data mining and visualization techniques, relationship between crash casualties at work zones and contributory factors was also examined, using 5-year data (2004-2008) in the United States. Results indicated that highways with more than 4 lanes, speed limit above 60km/h, and absence of traffic control device contribute to higher risk of injury in work zone related crash (Weng et al., 2016).

Speed compliance and speeding has been a concern of safety at work zones (Debnath et al., 2014). Excessive vehicle speed through work zones was found to be one of the leading causes of road crashes and fatalities around work zones (Wang et al., 1996; Raub et al., 2001; Mattox et al., 2007; Hou et al., 2010; McAvovy et al., 2011). Studies attempted to examine the factors contributing to non-compliance of speed at work zone. Results of Tobit model indicated that platoon position, gap size, time period, traffic volume, and compliance of other vehicles significantly correlated to the speeding behavior at work zones. It was indicative to the deployment of countermeasures to improve the speed compliance. A driving simulator study revealed that the presence of slow and stopped vehicles around the work zones significantly contributed to the increase in road crashes (McAvoy et al., 2011). Evidence established in Australia indicated that speed differential was correlated to higher crash risk at work zones (Austroads, 2009). This could be attributed to the phenomenon that a considerable proportion of drivers were choosing excessive speed, above the temporary speed limit, based on the perceived risk and road condition, regardless of the posted speed limit, while others might always comply with the temporary speed limit. Therefore, design and implementation of temporary speed limits at work zones must be carried out carefully, taking into account the drivers' perceived safety speed with respect to the speed environment and road condition (McAvoy et al., 2011).

Other research approached work zone safety issues from the perspective of driver response. Different work zone configurations could determine the crash risk at highway work zone. The driver speed, braking behavior and travel path were the proxies of driver response to different work zone configurations. Reduced taper length and the presence of a leading vehicle could increase the crash risk at work zone as revealed in a driving simulator study (Morgan et al., 2010). Results indicated that the risk of rear-end collision at work zone increased with the reduction in the distance approaching the start of a work zone. This suggested that merging activities should take place earlier in merging area before reaching the work zone, in order to improve the safety performance of work zone (Weng and Meng, 2012).

Studies on the injury and fatality risk at work zones indicated that traffic control devices and other safety features were correlated to the risk of work zone related road fatalities in the US (Weng et al., 2016). For example, the absence of symbolic sign and traffic cones could impact the safety at work zone, especially in adverse weather conditions like snow and fog (Weng and Meng, 2012). Attempts were made to investigate the effects of different treatments, for example deployments and locations of road cones and barriers, on the driver and pedestrian behavior, and thus the safety performance of work zone in New Zealand (Charlton, 2006; Allpress and Leland, 2009; Bai and Li, 2011). Possible factors including drivers' conspicuity, memorability, and comprehension can affect drivers' response to hazard warning signs. For example, a flashing variable message sign may increase the conspicuousness of the driver, through its effect on drivers' comprehensibility and memorability may not be significant (Charlton, 2006). Study also revealed that portable changeable message sign (PCMS), with messages e.g. 'Slow Down' and 'Drive Safely' displayed, significantly reduced the vehicular speed at the work zones. Application of speed-activated variable speed limit sign might have potential in reducing the conviction of excessive speed and 85th percentile speed at work zones, but its cost and practicability for implementation could be of great concern. Moreover, the novelty and long-term effects of innovative temporary traffic management devices, including speed-activated variable speed limit signage, would be worth exploring (Mattox et al., 2007; Allpress and Leland, 2009; Bai and Li, 2011; Whitmire et al., 2011). Results also indicated that a portable changeable message sign was effective in reducing the speed of truck at work zone, while the traditional temporary traffic sign was effective in reducing the speed of passenger cars (Bai et al., 2010).

As discussed above, efforts have been devoted to investigate the effectiveness of measures striking against speeding at work zones. It was argued that the effectiveness of a warning sign could only be revealed, with the support of legislation and enforcement (Hou et al., 2010). Also, it is worth exploring the intervention effects of possible factors on the relationship between speed reduction at work zones and relevant measures. In addition, effect of possible factors including road environment and condition, vehicle characteristics and driver behaviors on crash severity at work zones should be examined.

## 3. DATA

In this study, the crash severity of work zone related crashes, and effects of possible contributory factors are analyzed. In New Zealand, the population was about 4.4 million and the number of road fatalities was 328 respectively in 2016 (Ministry of Transport, 2017). The predominant speed limits in New Zealand are 50km/h for urban roads and 100km/h for rural roads and motorways respectively. The percentage of drivers above posted speed limit are 53-59% on 50 km/h limit urban roads, and 25-31% on open 100 km/h limit rural/open roads respectively, in 2010-2013 (Ministry of Transport, 2017). Travelling too fast for condition was found a contributory factor of 28-35% of road fatalities in New Zealand during the period 2010-2012 (Ministry of Transport, 2017). In New Zealand, road crashes are attended by police officers and are coded by New Zealand Transport Agency (NZTA). The crash records are maintained in the Crash Analysis System (CAS).

In this study, information on 453 work zone related crashes, during the 5-year period from 25 November 2008 to 25 November 2013, were extracted from CAS. CAS allows the users to select crashes for analysis using mapping functions and road maps, or by factor attributes. Specific work zone attributes are, however, not available for the search function in CAS. In this study, a selection criteria of crash that occurred in the areas where a reduced speed limit is in place.

The subject of this study is the severity of work zone related crashes. In CAS, crash severity is classified into four levels: (i) fatal crash, where person dies within 30 days of crash; (ii) serious crash, where person sustains fractures, concussion or injuries that require medical treatment or removal to and detention in hospital; (iii) minor crash, where person sustains injuries that are minor in nature such as sprains and bruises and which do not require medical attention; and (iv) non-injury crash. The severity level of a crash is determined by the person sustaining the highest severity level of injury.

With the use of CAS, attributes including road environment (i.e. whether a crash occurs in day or night condition, and under wet or dry road conditions), driver attributes (i.e. driving under the influence of alcohol and driver experience), crash circumstances (i.e. absence of/ insufficient/ ineffective road work sign, vehicle speed, failure to notice slow and stopped vehicle, and inattention), and vehicle types (i.e. passenger cars, heavy vehicles, or motorcycles) or road users (i.e. whether pedestrian and cyclist are involved) could be extracted. A summary of the 453 work zone related crashes which are used in the proposed crash severity prediction model is presented **Table 1**.

[Insert Table 1 here]

**Table 1** presents the summary of the sample extracted from CAS. Since the fatal crashes constitute a negligible proportion (0.9%) of the overall crashes only, the fatal and serious injury crashes are combined into one category (Killed and Severe Injury, KSI) in the subsequent analysis. Of the 453 crashes, 33 (7.3%) are KSI crash. Almost a quarter of crashes (102, 22.6%) occur during weekend and more than half of the crashes occurred during daytime (180, 61.8%) respectively. A majority of work zone related crashes involve one vehicle only (257, 56.7%) and can be attributed to excessive speed (184, 40.6%). In addition, a considerable proportion of crashes are attributed to inadequate road sign (94, 20.7%) and failure to notice slow or stopped vehicle (59, 13.0%).

## 4. METHOD

The objective of this study is to evaluate the relationship between crash severity at work zone and possible risk factors including road environment, time period, vehicle characteristics and crash circumstances. As the outcome has more than two categories (i.e. non-injury, minor injury, and fatal and serious injury), multinomial logit regression is applied (Washington et al., 2011). Let $g_{ij}$ be a link function that determines the crash outcome j for observation i such that,

$$g_{ij} = \beta_j X_{ij} + \varepsilon_{ij} \tag{1}$$

where $\beta_j$ is a vector of parameter estimates for crash outcome $j$, $X_{ij}$ is a vector explanatory variables that determine crash outcomes for observation $i$ and $\varepsilon_{ij}$ is the disturbance term.

Then, the probability of observation $i$ having crash outcome $j$ ($j \in J$) is given by,

$$P_i(j) = P(g_{ij} > g_{iJ}) \quad \forall J \neq j \tag{2}$$

The parameters could then be estimated using maximum likelihood approach, with the likelihood function given as follows,

$$L = \prod_i \prod_j P(j)^{\delta ij} \tag{3}$$

where $\delta$ equal to 1 if the observed crash outcome for observation $i$ is $j$ and zero otherwise.

One can simply entail the exponentiation of the parameter estimates $\beta$, and the impact of an individual attribute on the crash severity would then be interpreted by the corresponding odds ratio $e^{\beta}$. For the attribute $x$ with $\beta$ >0, the likelihood of having crash outcome $j$, relative to the base category ("Non-injury" in this study) is increasing as $x$ increase, and vice versa.

The goodness-of-fit of the predictive model should also be assessed. To evaluate the significance and predictive power of the logistic regression model, the change in deviance can be determined by comparing the log likelihood functions between the unrestricted model and the restricted model with the following expression.

$$G = -2(LL(c) - LL(\theta)) \tag{4}$$

where $LL(c)$ is the log likelihood function of the restricted model and $LL(\theta)$ is the log likelihood function of the unrestricted model.

Under the null hypothesis that the coefficients for the predictive model are equal to zero, $G$ is chi-square distributed with $f$ degree of freedom, where $f$ is the number of variables that are considered. If $G$ is significant at the 5% level, then the null hypothesis would be rejected, and one could conclude that the proposed model generally fit well with the observed outcome.

Prior to the development of consolidated regression model for the association measure between crash severity and possible risk factors, a preliminary analysis of potential candidate factors is conducted. In particular, threshold screening of candidate factor is at the 20% level of significance. Moreover, to identify possible collinearity among variables in the model fitted, Variance Inflation Factor (VIF) is estimated. Variables with a high value of VIF (greater than 5) will be removed (Sze and Wong, 2007; Sze et al., 2014).

## 5. RESULTS

We aim to identify the possible risk factors that determine the crash severity of work zones. It is essential to the design and implementation of effective temporary traffic management. The discrete outcome (KSI, minor injury and non-injury) facilitates the use of multinomial logit regression. With the use of historical crash data extracted from CAS, the possible factors are day of the week (weekday versus weekend, time of the day (morning, afternoon, evening, night time), number of vehicle involved (single vehicle versus multi-vehicle crash), vehicle/ road user involvement (truck, bus, motorcycle, bicycle and pedestrian), and driver or crash circumstances (e.g. excessive speed, inadequate sign, inattention etc.). A multiple regression that entails all possible factors is conducted to screen the candidate factors for subsequent analysis **(Table 2)**. For instance, a candidate factor that is influential to the probability of either minor injury or KSI crashes (non-injury crash to be base category), at the 20% level of significance, would be selected.

[Insert Table 2 here]

As shown in **Table 2**, factors including day of the week, time of the day, number of vehicle involved, involvements of motorcycle, bicycle and pedestrian, and crash attributed to driver inattention, driving under the influence of alcohol and driver with non-local driving license, are selected for subsequent analysis, at the 20% level of significance.

Results of the consolidated analysis of the association between the crash severity of work zone related crashes and influencing factors are presented in **Table 3**.

[Insert Table 3 here]

As shown in **Table 3**, for minor injury crashes, factors including day of the week, number of vehicle involved, and involvement of motorcycle, cyclist and pedestrian are significant at the 5% level. Besides, time of the day also marginally contributed to the likelihood of minor injury crash, at the 10% level. For example, crashes occurred during the weekday [Odds ratio = 0.60, 95% Confidence Intervals (CIs) = (0.40, 0.90)], in the evening time [Odds ratio = 0.63, CIs = (0.37, 1.06)], in the night time [Odds ratio = 0.46, 0.95CIs = (0.21, 1.01)] and involving more than one vehicle [Odds ratio = 0.60, 0.95CIs = (0.38, 0.94)] have a lower likelihood of incurring injury. On the other hand, crashes involving motorcycle [Odds ratio =1.71, CIs = (1.46, 21.13)], bicycle [Odds ratio = 6.72, CIs = (1.25, 36.22)] and pedestrian [Odds ratio = 11.84, CIs = (1.23, 113.53)] all have a remarkably higher likelihood of incurring injury for crashes at work zone.

For the KSI crashes, influences of factors including day of the week, time of the day, number of vehicle involved, and involvement of motorcycle, cyclist and pedestrian are all statistically significant at the 1% level. Again, crashes occurred during the weekday [Odds ratio = 0.26, CIs = (0.14, 0.49)], in the evening time [Odds ratio = 0.16, CIs = (0.06, 0.43)], in the night time [Odds ratio = 0.04, CIs = (0.005, 0.33)] and involving more than one vehicle [Odds ratio = 0.19, CIs = (0.07, 0.48)] all have a lower likelihood of incurring KSI. However, crashes involving motorcycle [Odds ratio =15.44, CIs = (3.53, 67.56)], bicycle [Odds ratio = 43.41, CIs = (5.56, 338.7)] and pedestrian [Odds ratio = 368.9, CIs = (30.24, 4501.1)] are all correlated to higher likelihood of killed and severe injury for crashes at work zone.

Yet, no statistical evidence could be established for the association between crash circumstances including driver inattention, driving under the influence of alcohol and driver with non-local driving license, and crash severity at work zone. The predicted model fit well with the observed data with chi-square test statistic being equal to 61.78, at the 1% level of significance. In addition, values of VIF of the variables included in the model are all below 2. No evidence could be established for the existence of collinearity among the variables.

## 6. DISCUSSION

Road works are frequent on New Zealand highway for upgrades, repairs and maintenance. Most of the New Zealand highways are undivided two-lane two-way carriageway, disruptions due to incident and road crashes at work zones are undesirable. Results of multinominal regression analysis in current study examined the factors including time period, road environment, vehicle attribute, driver behavior and crash circumstances that contributed to the likelihood of fatality and injury of crash on New Zealand road where temporary speed limits are posted. It could be indicative to the design and development of appropriate incident management strategies, and temporary traffic management measures that could improve the safety and operation performance of the transportation system.

For example, crashes that occurred in the evening time and night time are less likely to incur injury, regardless of slight injury, severe injury and mortality, compared to those occurred in the day time. It could be attributed to the absence of workers that are on duty during the concerned time periods. Crashes that are attributed to collision with workers and obstacles like a crane and other machinery are more likely to be serious (McAvoy et al., 2011). Also, it could be attributed to the higher level of alertness of the drivers during the night time, as most of the New Zealand roads are often unlit. The work zone may be easily recognized by the driver when his/her level of conspicuity is higher (Charlton, 2006). It is worth exploring the relationship between road environment, work zone configuration, driving behavior and safety level, when the comprehensive information on driver response and vehicular maneuver is available (Allpress and Leland, 2009; Bai and Li, 2011).

On the other hand, crashes involving vulnerable road users including motorcyclists, cyclists, and pedestrians, were found to be much more likely to incur injury, again regardless of severity level. It could be attributed to the lack of physical separation and protection compared to other motor vehicles. Driver perception and choice of action in terms of speed, acceleration and path in response to appropriate traffic control and management measures could affect the crash severity. For example, the use of appropriate guidance signs and markings that warn the motor vehicle drivers the presence of bicyclists and pedestrians could improve the drivers' alertness (Wong et al., 2006; Wong et al., 2012). It is worth exploring the effects of on-road and in-vehicle driver assistance system for advanced warning of the presence of workers, cyclists and pedestrians, especially during adverse weather conditions and a poor visibility environment (McAvoy et al., 2011; Weng et al., 2016).

No evidence was established in this study for the association between crash severity and crash circumstances including driver attention and distraction. However, it is worth exploring the effectiveness of flashing sign or variable message sign on enhancing driver attention, and reducing risk of speeding and collision (Charlton, 2006; Bai et al., 2010). For example, application of advanced vehicle-to-vehicle or vehicle-to-infrastructure technology, with the use of short-range communication techniques including radio-frequency identification (RFID), wifi or bluetooth, providing warning for the presence of queue and platoon of slow moving vehicles at the work zone ahead could have potential.

Current study is limited to the availability of information on road type (i.e. motorways, arterial roads, and local roads, etc.), road environment (rural and urban), and work zone characteristics (e.g. short-term or long-term, and configuration, etc.). It is worth exploring their effects on safety at work zone when comprehensive information on driver behavior and vehicular speed are available in naturistic or simulated driving experiments. For examples, the driver responses in terms of speed and lane change with respect to different work zone configuration could be investigated (Weng and Meng, 2012).

## 7. CONCLUSION

In this study, a multinomial logit regression model was established to measure the association between crash severity and possible risk factors, based on the information of 453 crashes at work zone in New Zealand during 2008 to 2013. Factors including day of the week, time of the day, involvements of motorcycle, bicycle and pedestrian, and crash circumstance are found affecting the likelihood of minor injury and KSI crashes. Also, no evidence is established for the association between crash severity and crash circumstance including driver attention and distraction. Such attributes could be correlated to likelihood of excessive speed. Results are indicative to appropriate temporary traffic management measures for work zones. In the future research, it is worth exploring the characteristics of problematic driver groups including young, novice and elderly driver and road environment (e.g. original speed limit, and road surface condition), attributed to higher crash and injury risk at work zone, with the use of driver behavior studies, such as perception survey and driving simulator study. For example, effect of the implementation of advanced in-vehicle and out-vehicle technology could be investigated.

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## Tables

### Table 1. Summary of Work Zone Related Crash Data Extracted from CAS

| Factor | Attribute | Count | (Proportion) |
|---|---|---|---|
| Crash severity | Fatal and Serious Injury | 33 | (7.3%) |
| | Minor Injury | 131 | (28.9%) |
| | Non-injury | 289 | (63.8%) |
| Day of the week | Weekday | 351 | (77.4%) |
| | Weekend | 102 | (22.6%) |
| Time period | Morning (6am- 12pm) | 124 | (27.4%) |
| | Afternoon (12- 6pm) | 156 | (34.4%) |
| | Evening (6pm- 12am) | 127 | (28.0%) |
| | Night time (12- 6am) | 46 | (10.2%) |
| Number of vehicle involved | Single vehicle | 257 | (56.7%) |
| | More than one vehicle | 196 | (43.3%) |
| Involvement other than passenger car | Truck | 47 | (10.4%) |
| | Bus | 7 | (1.5%) |
| | Motorcycle | 19 | (4.2%) |
| | Bicycle | 10 | (2.2%) |
| | Pedestrian | 10 | (2.2%) |
| Crash attribute | Excessive speed | 184 | (40.6%) |
| | Inadequate road sign | 94 | (20.8%) |
| | Failure to notice slow vehicle | 59 | (13.0%) |
| | Inattention | 46 | (10.2%) |
| | Alcohol related | 44 | (9.7%) |
| | Involving inexperience drivers | 32 | (7.1%) |
| | Involving drivers with non-local driving license | 12 | (2.6%) |
| Road condition | Dry | 370 | (81.7%) |
| | Wet | 83 | (18.3%) |

*Note: Number of observations = 453*

**Table 2. Preliminary Analysis of Candidate Factors Influencing Crash Severity**

| Factor: Attribute | Minor Injury VS Non-injury | | KSI VS Non-injury | |
|---|---|---|---|---|
| | Coefficient | (p-level) | Coefficient | (p-level) |
| Day of the week^ | | | | |
| Weekday | -0.46 | (0.04) | -1.08 | (0.005) |
| Weekend (base) | | | | |
| Time of the day^ | | | | |
| Morning (base) | | | | |
| Afternoon | 0.10 | (0.69) | -0.11 | (0.80) |
| Evening | -0.47 | (0.10) | -1.43 | (0.01) |
| Night time | -0.71 | (0.10) | -2.42 | (0.03) |
| Number of vehicle^ | | | | |
| Single vehicle (base) | | | | |
| More than one vehicle | -0.42 | (0.15) | -1.36 | (0.02) |
| Crash involving truck | -0.49 | (0.24) | 0.30 | (0.68) |
| Crash involving bus | -0.05 | (0.96) | -100.25 | (1.00) |
| Crash involving motorcycle^ | 1.72 | (0.01) | 2.92 | (<0.001) |
| Crash involving bicycle^ | 1.77 | (0.05) | 3.68 | (<0.002) |
| Crash involving pedestrian^ | 2.13 | (0.09) | 5.71 | (<0.001) |
| Crash attributed to excessive speed | 0.06 | (0.81) | -0.31 | (0.47) |
| Crash attributed to inadequate sign | -0.27 | (0.32) | -0.58 | (0.28) |
| Crash attributed to failure to notice | -0.26 | (0.50) | -1.43 | (0.22) |
| Crash attributed to inattention^ | 0.51 | (0.16) | -0.62 | (0.43) |
| Crash attributed to driving under the influence of alcohol^ | -0.79 | (0.08) | 0.48 | (0.48) |
| Crash attributed to inexperience of driver | -0.16 | (0.70) | -99.37 | (1.00) |
| Crash attributed to driver with non-local driving license^ | -1.06 | (0.19) | -99.63 | (1.00) |
| Road condition | | | | |
| Wet | -0.25 | (0.39) | -0.46 | (0.42) |
| Dry (base) | | | | |
| Presence of intersection | 0.28 | (0.32) | -0.79 | (0.20) |
| Presence of traffic signal | -0.06 | (0.91) | 0.43 | (0.73) |

^ *Selected at the 20% level of significance*

**Table 3. Main Analyses of Association Between Crash Severity and Possible Risk Factors**

| Factor: Attribute | Minor Injury | | | KSI | | |
|---|---|---|---|---|---|---|
| | **t-statistics** | **Odds Ratio** | **(95% CIs)** | **t-statistics** | **Odds Ratio** | **(95% CIs)** |
| Day of the week | | | | | | |
| Weekend (base) | | | | | | |
| Weekday | -0.51* | 0.60 | (0.40, 0.90) | -1.35** | 0.26 | (0.14, 0.49) |
| Time of the day | | | | | | |
| Morning (base) | | | | | | |
| Afternoon | -0.46 | 1.04 | (0.64, 1.68) | -0.50 | 0.60 | (0.29, 1.26) |
| Evening | -0.46^ | 0.63 | (0.37, 1.06) | -1.86** | 0.16 | (0.06, 0.43) |
| Night time | -0.77^ | 0.46 | (0.21, 1.01) | -3.22** | 0.04 | (0.005, 0.33) |
| Number of vehicle | | | | | | |
| Single vehicle (base) | | | | | | |
| More than one vehicle | -0.51* | 0.60 | (0.38, 0.94) | -1.68** | 0.19 | (0.07, 0.48) |
| Crash involving motorcycle | 1.71* | 5.55 | (1.46, 21.13) | 2.74** | 15.44 | (3.53, 67.56) |
| Crash involving bicycle | 1.90* | 6.72 | (1.25, 36.22) | 3.77** | 43.41 | (5.56, 338.7) |
| Crash involving pedestrian | 2.47* | 11.84 | (1.23, 113.53) | 5.91** | 368.9 | (30.24, 4501.1) |
| Crash attributed to inattention | 0.43 | 1.54 | (0.78, 3.04) | -0.69 | 0.50 | (0.11, 2.22) |
| Crash attributed to driving under the influence of alcohol | -0.64 | 0.53 | (0.23, 1.24) | 0.45 | 1.57 | (0.46, 5.41) |
| Crash attributed to driver with non-local driving license | -1.01 | 0.36 | (0.07, 1.78) | -99.43 | <0.001 | (<0.001, Undefined) |
| Number of observations | 453 | | | | | |
| Restricted log likelihood | -378.87 | | | | | |
| Unrestricted log likelihood | -347.98 | | | | | |
| Likelihood ratio test | 61.78 | | | | | |
| p-value | <0.001 | | | | | |

*Non-injury is the base category*
*^ Marginally significant at the 10% level*
** Significant at the 5% level*
*** Significant at the 1% level*