Australasian Transport Research Forum 2017 Proceedings
27 – 29 November 2017, Auckland, New Zealand
Publication website: http://www.atrf.info

The Influence of Neighbourhood Socio-Demographic Characteristics on Injury Severity in Truck Crashes

Sivanandan Balakrishnan[1, 4], Sara Moridpour[2], Richard Tay[3]

[1,2]Civil and Infrastructure Engineering, School of Engineering, RMIT University, Melbourne, Australia

[3]School of Business IT and Logistics, RMIT University, Melbourne, Australia

[4]Civil Engineering Department, Politeknik Port Dickson, Port Dickson, Malaysia

Email for correspondence: sara.moridpour@rmit.edu.au

Abstract

Truck crashes are a major road safety concern due to the higher likelihood of a fatal or serious injury outcome. The primary objective of this research is to identify the neighbourhood socioeconomic characteristics affecting injury severity in truck collisions. Specifically, the influences of the socio-demographic characteristics of the neighbourhoods where the road user lives and where the crash occurs are explored using a multinomial logit model. Besides the neighboured socioeconomic variables (such as education, English language proficiency, occupation, income, birthplace), other variables affecting road user injury severity such as (environmental, temporal, road user, road, and vehicle characteristics) also was considered as a control variable. We find that road users residing in neighbourhoods with more people born in Australia have higher injury severity, while road users living in neighbourhoods with more people having university education and working in the sales profession have lower injury severity. Additionally, crashes occurring in neighbourhoods with more people working as professionals are more severe. We find mixed results for technical education, clerical jobs and people born overseas for neighbourhoods where the road users live, and people born in Australia, sales jobs and English language use for neighbourhoods where the crashes occur.

1. Introduction

1.1. Background

Road crashes are a major cause of deaths and serious injuries. About 1400 people are killed and 32000 people are severely injured each year in road crashes in Australia (ATC, 2011). With respect to vehicle types, truck are of special concern because the likelihood of a fatal or serious injury outcome is much higher due to its large size and mass. For examples, articulated trucks were involved in an average of 11 traffic fatalities per month and rigid trucks were involved in an average of seven road fatalities per month in 2012-2014 (AustRoads, 2015) and the number of road fatalities resulting from heavy rigid truck crashes had increased by 8.5% per year during this period (BITRE, 2014).

There have been many studies that investigated the factors contributing to the frequency and severity of crashes involving trucks (Mooren et al., 2014). The main variables considered in the previous research include roadway characteristics (Islam, 2015; Islam & Hernandez, 2016), traffic conditions (Duncan et al., 1998; Lee and Li, 2014), temporal characteristics (Islam et al., 2014; Lee and Li, 2014; Pahukula et al., 2015), environmental factors (Pahukula et al., 2015; Islam and Hernandez, 2016), vehicle characteristics (Lemp et al., 2011; Lee and Li, 2014), collision characteristics (Pahukula et al., 2015; Islam and Hernandez, 2016) and occupant characteristics (Zhu and Srinivasan, 2011b).

Although many studies have examined the contributing factors of truck crashes, few have examined the impact of neighbourhood socioeconomic characteristics on crash outcomes. Most studies have focused on the roadway, driver, vehicle, and environmental characteristics. Only a few studies examined the effect of socioeconomic characteristics of the crash locations, and very few studies examined the impact of socioeconomic characteristics of neighbourhoods where the road users live (Warsh et al., 2009; Cottrill and Thakuriah, 2010; Schneider et al., 2010).

1.2. Objectives of study

This research aims to identify the factors contributing to the injury severity of truck crashes. It will focus on the impact of socioeconomic characteristics of the neighbourhood where road users live and where the crashes occur in Victoria.

2. Methodology

2.1. Data

Data on vehicle collisions was obtained from VicRoads and contained information on road, road user, environmental, temporal, and vehicle characteristics. Data on traffic volume and road features were extracted from the Australia Urban Research Infrastructure Network Portal (AURIN). Data on the neighbourhood sociodemographic characteristics at the postcode level were extracted from the Australia Bureau of Statistic (ABS). The ABS data were matched to the postcodes of the road users' addresses and the crash locations reported in the crash data. It should be noted that about 12% of the observations had the same postcodes for both the road user residency and the crash location. The variables used in estimating the final model were summarised and shown in Table 1.

Table 1: Summary of the variables by injury outcomes

Variables	Fatal	Severe	Minor	No injury
Road Users' Residence Neighbourhood Characteristics (mean and standard deviation)				
Education (%)				
University	10.1 (8.3)	12.9 (10.2)	14.1 (10.4)	15.1 (10.7)
Technical or further	7.2 (2.2)	7.2 (2.0)	7.2 (2.0)	7.3 (2.0)
Birthplace (%)				
Overseas	20.2 (15.4)	26.9 (17.1)	28.7 (17.0)	30.6 (16.7)
Australia	78.9 (18.3)	72.2 (18.2)	70.4 (18.2)	68.5 (18.0)
Occupation (%)				
Sales	8.9 (2.3)	8.9 (2.2)	9.1 (2.1)	9.2 (2.1)
Clerical and administrative	12.2 (3.6)	13.2 (3.4)	13.5 (3.3)	13.8 (3.2)
Crash Location Neighbourhood Characteristics (mean and standard deviation)				
Birthplace (%)				
Australia	63.0 (32.5)	61.8 (30.5)	60.9 (30.5)	58.2 (32.3)
Occupation (%)				
Professional	15.0 (9.9)	15.8 (10.3)	15.9 (10.3)	14.2 (9.7)
Sales	8.0 (4.0)	8.0 (3.9)	8.1(3.9)	7.8 (4.2)
English language spoken proficiency (%)				
Not well or not at all	6.9 (7.4)	8.0 (7.8)	8.0 (7.8)	7.4 (7.6)

Crash Characteristics (categorical variables - row percentages shown)				
Road user gender				
Male (reference)	2.4	16.0	25.3	56.3
Female	2.3	23.3	44.8	29.6
Unknown	0.2	6.3	13.0	80.5
Road user age (years)				
0-15 (reference)	3.3	13.8	30.9	52.0
16-24	2.2	19.5	33.9	44.4
25-44	1.8	16.1	30.0	52.1
45-64	2.3	16.9	28.9	51.9
65+	5.2	30.4	33.8	30.6
Unknown	0.4	9.5	12.2	77.9
Driving licence				
Victoria (reference)	2.0	17.3	30.4	50.4
Other Australian states	4.4	20.6	21.1	53.9
Overseas	1.6	20.3	36.7	41.4
Not known/Not available	3.3	18.7	29.8	48.2
Ejected from vehicle				
Yes	14.8	52.5	28.9	3.8
No/Unknown (reference)	1.8	16.3	30.1	51.8
Safety restraint use				
Yes (reference)	1.7	17.1	32.0	49.2
No	10.3	36.0	27.8	25.8
Not fitted / appropriate	7.9	25.5	28.4	38.2
Unknown	2.1	15.8	25.4	56.7
Type of vehicle				
Truck (reference)	2.4	16.5	26.5	54.6
Passenger vehicle	2.0	21.4	40.7	35.9
Other vehicle	2.4	15.5	24.3	57.8
Vehicle age				
New (1995 or after)	2.4	18.5	33.6	45.5
Old (before 1995) (reference)	2.1	16.4	24.8	56.7
Number of vehicle				
One	4.8	32.7	40.8	21.7
Two	2.4	17.8	32.0	47.8
Three and more (reference)	1.3	12.6	22.6	63.6
Vehicle damage				
Minor damage (reference)	1.5	10.4	22.5	65.6
Moderate damage (driveable)	0.5	10.2	36.2	53.1
Moderate (towed)	1.4	16.4	39.5	42.7
Major towed (towed)	1.4	27.7	41.5	29.3
Extensive (unrepairable)	8.0	37.7	35.1	19.2
Vehicle weight (tonnes)				
< 12	1.6	18.0	32.7	47.7
12-20	2.5	15.2	22.7	59.6
> 20 (reference)	1.7	15.0	25.1	58.2
Unknown	2.5	18.0	30.5	49.0

Vehicle maneuver				
Going straight (reference)	2.8	20.7	32.9	43.6
Turn right	1.9	19.2	33.0	45.8
Slow/Stopping	0.6	9.9	33.9	55.6
Turn left	1.3	16.9	34.4	47.4
Others/Not known	2.0	14.5	25.0	58.5
Initial point of impact				
Rear (reference)	0.8	12.7	37.9	48.6
Front	3.4	21.7	28.6	46.4
Right front door and panel	3.2	24.6	35.1	37.1
Right rear door and panel	0.9	15.3	35.8	48.0
Left front door and panel	2.6	19.9	35.4	42.2
Left rear door and panel	1.5	15.4	32.4	50.8
Collision classification				
Run-off-road (reference)	3.0	30.9	44.1	22.0
Head On	8.0	22.7	24.3	45.0
Angle	3.0	20.4	27.1	49.4
Rear end	0.6	12.3	29.6	57.4
Sideswipe	1.7	16.0	27.4	54.9
Type of collision				
Collision with vehicle	2.0	16.1	29.0	52.9
Collision with fixed object	4.8	29.8	41.8	23.7
Collision with pedestrian	7.4	22.4	18.1	52.1
Overturns (reference)	1.4	38.3	48.7	11.6
Others	0.8	13.4	40.9	44.9
Light condition				
Daylight (reference)	2.0	16.6	30.5	50.9
Dark, lighted	2.2	22.0	26.2	49.6
Dark, not lighted	6.5	27.9	27.7	37.9
Unknown light	0.5	15.3	38.6	45.5
Time of day				
Morning peak (7 am - 10 am)	2.1	15.0	31.4	51.4
Off-peak	2.1	16.6	31.2	50.1
Afternoon peak (4 pm - 7 pm)	1.9	17.0	28.4	52.7
Night (reference)	3.5	24.7	27.8	44.0
Season				
Summer (reference)	2.2	17.0	31.8	49.1
Autumn	2.4	18.1	29.2	50.3
Spring	2.3	17.7	28.5	51.5
Winter	2.3	17.8	30.7	49.2
Location				
Metropolitan Melbourne	1.2	15.1	29.5	54.2
Non-Melbourne (reference)	4.2	22.0	30.9	42.9
Road classification				
Freeways or highways	2.4	17.7	29.1	50.8
Main road (reference)	2.1	17.2	31.1	49.6
Others	4.6	28.5	28.8	38.0

Speed limit (km/h)				
≤50	1.2	16.8	34.8	47.2
60-70	1.3	15.9	30.2	52.7
80-90	1.7	16.4	28.6	53.4
≥ 100 (reference)	4.4	21.3	28.8	45.5
Not known	0.7	10.2	39.8	49.3
Police attendance at crash scene				
Yes	2.6	19.6	27.9	49.8
No/Unknown (reference)	0.1	4.8	43.7	51.4
Crash Characteristics ***(continuous variables - mean and standard deviation)***				
Percentage of trucks	17.9 (10.5)	13.8 (9.2)	12.6 (8.6)	11.8(7.9)
Right shoulder	0.9 (1.0)	0.6 (1.0)	0.5 (0.9)	0.6 (0.9)

In this study, trucks in this research included only trucks but not buses and other types of trucks (machinery, farm, etc.). On the other hand, road user in this study is included pedestrians, cyclists, motorcyclists and pillion, driver and passenger of passenger and heavy vehicle. VicRoads classify crash injury severities into four categories: fatal injury (killed or died within 30 days), serious injury (sent to hospital, possibly admitted), other injury (typically requires medical treatment) and non-injury. From 2006 to 2016, there were 20,957 people involved in 8,486 crashes involving trucks in Victoria. Of the 20,957 people involved, 480 (2.3%) were fatal, 3,697 (17.6%) suffered severe injury, 6,298 (30.1%) had minor injury and 10,482 (50.0%) experienced no injury.

2.2. Multinomial Logit Model

Considering the categorical nature of injury severity, the multinomial logit regression model has been widely applied by previous researchers in road safety (Khorashadi et al., 2005: Tay et al., 2011; Eluru, 2013; Ye and Lord, 2014).

Let $P_n(i)$ be the probability of collision *n* ending in injury severity category i,then

$$P_n(i) = P\left(\beta_i \boldsymbol{X}_{in} + \varepsilon_{in} \geq \beta_j \boldsymbol{X}_{jn} \varepsilon_{jn}\right) \forall j \neq i \quad (1)$$

where $\boldsymbol{X}_{in}$ is a vector of measurable characteristics
β_i is a vector of coefficients to be estimated
ε_{in} is an error term accounting for unobserved effects influencing the injury severity.

If the error terms are assumed to be type 1 extreme value distribution, then

$$P_n(i) = \frac{\exp(\beta_i \boldsymbol{X}_{in})}{\sum_j \exp(\beta_j \boldsymbol{X}_{jn})} \quad (2)$$

In this study, crashes involving no injury were selected as the reference category for the dependent variable. Therefore, the estimated coefficients show the impacts of the contributing factors on fatal, severe and minor injury relative to the reference category (no injury). Although the traditional 95% level of confidence was used to select variables, some insignificant variables were retained in the model as long as it was statistically significant for at least one of the injury outcomes. This was done to facilitate the interpretation of the results (Kockelman and Kweon, 2002; Tay et al., 2008; Tay et al., 2009; Tay et al., 2011).

It should be noted that some researchers have chosen to use the random coefficient logit or probit model to allow for heterogeneous effects and correlations in unobserved factors (Milton et al., 2008; Anastasopoulos & Mannering, 2011; Tay, 2015). Random parameter models, especially the random parameter logit or mixed logit models, have increasingly been used in traffic safety studies to analyse both crash frequency and severity (Lord & Mannering 2010; Savolainen et al. 2011). However, preliminary analyses in this study using the random parameters binary logistic model found no statistically significant estimate of the variance for any of the coefficients, indicating that the fixed coefficient binary logistic model is appropriate.

3. Results and Discussion

The results of the estimated model were summarised and presented in Table 2. In general, the model fitted the data well, based on the very large chi-square statistic for goodness-of-fit. Although the traditional 95% level of confidence was used to select variables, some insignificant variables were retained in the model as long as it was statistically significant for at least one of the injury outcomes. This was done to facilitate the interpretation of the results (Tay et al., 2008; Tay et al., 2009; Tay et al., 2011).

Table 2: Multinomial logit estimates of occupant injury severity

Number of Observations	20,957					
Log-likelihood	-18214.0					
Restricted Log-likelihood	-23060.6					
Chi-Square	9693.1					
p-value	<0.0001					
	Fatal Injury		**Severe Injury**		**Minor Injury**	
Variables	**Coefficient**	**Std. Err.**	**Coefficient**	**Std. Err.**	**Coefficient**	**Std. Err.**
Constant	-9.537***	0.873	-4.770***	0.328	-2.098***	0.252
Occupants' Residence Neighbourhood Characteristics						
Education (%)						
University	-0.019**	0.008	-0.016***	0.003	-0.007***	0.002
Technical	0.069**	0.029	-0.023*	0.013	0.007	0.011
Birthplace (%)						
Overseas	0.006	0.007	0.017***	0.003	0.006**	0.003
Australia	0.006	0.005	0.008***	0.003	0.004*	0.002
Occupation (%)						
Sales	-0.066**	0.032	-0.058***	0.015	-0.005	0.013
Clerical and administrative	-0.019	0.023	0.019*	0.010	-0.018**	0.009
Crash Location Neighbourhood Characteristics						
Birthplace (%)						
Australia	-0.012***	0.004	-0.001	0.002	-0.002*	0.001
Occupation (%)						
Professional	0.030***	0.007	0.023***	0.003	0.019***	0.003
Sales	0.085***	0.031	-0.024*	0.014	-0.007	0.011
English language spoken proficiency (%)						
Not well or not at all	-0.001	0.009	0.016***	0.004	0.012***	0.003
Crash Characteristics (categorical variables)						
Road user gender						
Female	1.143***	0.125	1.432***	0.053	1.420***	0.043
Road user age (years)						
16-24	-0.037	0.238	0.536***	0.107	0.483***	0.084
25-44	-0.203	0.215	0.393***	0.097	0.348***	0.075
45-64	0.193	0.214	0.580***	0.099	0.377***	0.077
65+	1.728***	0.233	1.727***	0.116	1.072***	0.098
Driving licence						

Overseas	0.631	0.750	0.803***	0.269	0.699***	0.224
Ejected from vehicle						
Yes	5.562***	0.234	4.521***	0.199	3.024***	0.201
Safety restraint use						
No worn	1.774***	0.214	1.008***	0.144	0.390***	0.140
Not fitted/appropriate	1.919***	0.196	1.042***	0.108	0.651***	0.097
Type of Vehicle						
Passenger car	-0.375**	0.157	0.224***	0.066	0.431***	0.053
Vehicle Age						
New	0.101	0.125	-0.098*	0.052	0.111***	0.042
Number of vehicles						
One	1.726***	0.305	2.824***	0.150	2.768***	0.127
Two	0.585***	0.143	0.763***	0.056	0.897***	0.045
Vehicle damage						
Moderate (driveable)	-0.196	0.347	0.406***	0.095	0.581***	0.064
Moderate (towed)	0.900***	0.229	0.831***	0.084	0.939***	0.064
Major towed (towed)	1.183***	0.218	1.635***	0.079	1.324***	0.065
Extensive (unrepairable)	3.116***	0.185	2.317***	0.087	1.506***	0.076
Vehicle weight						
> 12	-0.473***	0.170	0.172***	0.063	0.216***	0.051
12-20	0.031	0.252	-0.092	0.117	-0.269***	0.097
Vehicle maneuver						
Turning right	-0.159	0.217	-0.171**	0.087	-0.149**	0.071
Slow stopping	-0.076	0.441	-0.284**	0.126	-0.005	0.083
Initial point of impact						
Right front door and panel	-0.084	0.169	0.153**	0.075	-0.013	0.064
Right rear door and panel	-0.741**	0.331	-0.214**	0.105	-0.060	0.080
Collision classification						
Head	0.991***	0.181	0.130	0.095	-0.180**	0.085
Angle	0.394**	0.158	0.122*	0.069	-0.101*	0.058
Rear end	-0.605***	0.200	-0.001	0.070	0.006	0.052
Type of Collision						
Collision with vehicle	1.031***	0.380	-0.016	0.144	-0.160	0.114
Collision with fixed object	1.376***	0.357	0.051	0.147	0.082	0.130
Collision with pedestrian	1.810***	0.409	-1.045***	0.171	-1.954***	0.156
Light condition						
Dark, lighted	0.606**	0.255	0.092	0.102	-0.117	0.089

Dark, not lighted	0.445*	0.240	-0.095	0.118	-0.215**	0.108
Time of day						
Morning peak	-0.077	0.230	-0.589***	0.096	-0.144*	0.081
Off-peak	-0.045	0.222	-0.463***	0.091	-0.146*	0.078
Afternoon peak	-0.185	0.218	-0.388***	0.090	-0.225***	0.077
Season						
Spring	-0.050	0.120	-0.011	0.051	-0.117***	0.042
Location						
Metropolitan	-0.460**	0.192	-0.270***	0.079	-0.088	0.065
Road classification						
Freeway	-0.292**	0.120	0.018	0.050	-0.008	0.041
Speed limit (km/h)						
60-70	-0.377***	0.139	-0.054	0.052	-0.046	0.042
Police attendance						
Yes	2.535***	0.590	1.039***	0.102	-0.609***	0.053
Crash Characteristics (continuous variables)						
Percentage of trucks	0.032***	0.007	0.009***	0.003	0.007**	0.003
Right shoulder width (m)	0.177***	0.061	-0.024	0.028	-0.067***	0.023
Note: ***, **, * denote statistically significant at α = 1%, 5%, 10% levels						

3.1. Road Users' Residential Neighbourhood Characteristics

Road users residing in neighbourhoods with a higher proportion of people having university education were less likely to be associated with fatal, severe or minor injury outcomes compared to the non-injury outcome. If residential neighbourhood characteristics were indicative of road user characteristics, then an increase in education was associated with a decrease in crash severity. This result was consistent with the results from previous studies (Factor et al., 2008; Licaj et al., 2011; Spoerri et al., 2011). Road users living in neighbourhoods with a higher proportion of people with technical education were less likely to experience severe injuries but more likely to experience fatal or minor injuries compared to non-injuries.

Road users living in neighbourhoods with a higher percentage of people born in Australia were more likely to suffer fatal, serious and minor injuries rather than not suffering any injury at all. This result might partly be explained by the risk compensation hypothesis. For examples, Yanko and Spalek (2013) found that route familiarity led to more inattention and Rosenbloom et al. (2007) found that drivers committed more violations and exhibited more dangerous behaviours in well-known locations compared to less known locations. On the other hand, road users from neighbourhoods with a higher percentage of people born overseas were more likely to suffer fatal injury or no injury rather than serious or minor injury. Compared to Australia, some countries might have a better driving culture and road safety record, whereas others might have a worse driving culture and road safety record.

Interestingly, the occupations of people in the neighbourhood where the road users lived and where the crash occurred were found to be correlated with injury severity. Road users residing in neighbourhoods with a higher proportion of people working in the sales were associated with less severe injury (minor and non-injury) rather than severe injury (fatal and serious injury) while a higher proportion of clerical and administrative staff was found to have a non-linear or mixed effect.

3.2. Crash Location Neighbourhood Characteristics

Crashes occurring in neighbourhoods with a higher proportion of people born in Australia were associated with lower probabilities of fatal and minor injury outcomes compared to the non-injury outcome. Similarly, crashes occurring in neighbourhoods with a higher proportion of people not speaking English well or not speaking English at all when they arrived in Australia were also found to have a mixed effect on injury severity. Hence, being born in Australia appeared to be a significant factor, but its effect on safety was rather complex and thus more research should be conducted to better understand this influence on road safety.

Crashes occurring in neighbourhoods with a higher proportion of professionals were associated with higher likelihoods of severe injuries (fatal and serious injuries) rather than less severe injuries (minor or non-injuries), while the proportion of sales people was found to have a mixed effect. The former result was a little surprising because of the higher expected income of professionals and thus a higher demand for safety and better access to health care and emergency services in these neighbourhoods.

3.3. Control variables

Consistent with previous studies (Sivak et al., 2010; Chen and Chen, 2011; Balakrishnan et al., 2017), we found that female road users, relative to male road users, were more likely to be injured (fatal, serious or minor) rather than not injured. As expected, we found that compared to children, young and middle-aged adults had lower likelihood of fatal or non-injury and a higher likelihood of serious or minor injuries, whereas ageing road users had a higher likelihood of injuries (fatal, serious or minor) rather than suffering no injury. Similarly, as expected, drivers with an overseas license tended to suffer injury in collisions involving trucks. Consistent with the literature (Al-Ghamdi, 2003; Chang and Chien, 2013; Lee and Li, 2014), this study found that occupants who did not wear a restraint, wearing a not properly fitted safety restraint, or were ejected from the vehicle were more likely to suffer injuries in a traffic collision.

As expected, compared to vehicles with minor or no damage, vehicles with moderate (towed), major and extensive damages were associated more with injury outcomes (fatal, serious and minor injury) rather than the non-injury outcome. Compared to three or more vehicle crashes, two vehicle crashes were more likely to result in injury outcomes, but the effect of single vehicle crashes was mixed. Similarly, compared to a rear impact, impact on the right rear door was associated with lower a likelihood of fatal or serious injury, while the effect of an impact on the right front was mixed. Likewise, the effects of the type of vehicle, vehicle age and vehicle weight were also mixed.

Compared to run-off-road crashes, head-on crashes and angle-crashes involving trucks were more likely to result in fatal and serious injury rather than no injury due to the larger size and mass. These findings are similar to the results from previous studies (Smith, 2000; Ouyang et al., 2002; Zhu and Srinivasan, 2011a; Chu, 2012; Lee and Li, 2014; Islam, 2015). Relative to the going-straight vehicle movement, turning right was associated with lower likelihood of fatal or serious injuries due to the lower speed involved when executing this movement. Although the types of collisions were found to be statistically significant, their effects on injury severity were mixed.

As expected, crashes occurring on roads with a speed limit of 60 or 70 km/h were less likely to result in injury (fatal, serious injury or minor injury) compared to crashes occurring on roads with a 100 km/h or higher speed limit. Likewise, crashes occurring in metropolitan Melbourne were associated more with lower injury severity (minor injury or non-injury) outcomes. On the hand, crashes occurring on roads with a higher proportion of truck traffic were associated with higher likelihood of injury outcomes (fatal, serious injury and minor injury) rather than a non-injury outcome.

Although most of the temporal influences were found to be statistically significant, their effects of injury severity were mixed. As expected, compared to crashes not attended by the police, crashes attended the police were associated more with severe injuries (fatal or serious injury) because police would be more likely to attend the crash scene if the crash was severe.

4. Conclusions

The safety of road users in crashes involving trucks has drawn considerable attention among transport agencies and the health sector. Trucks have many unique operating characteristics, such as poor deceleration and stopping capabilities, high rigidity, and greater mass compared to passenger cars. These characteristics have partly contributed to their over-representation in traffic fatalities and serious injuries. This study examined factors contributing to the road user injury severity in vehicle collisions involving trucks in Victoria, Australia.

In terms of the neighbourhood characteristics of the crash location, we found that crashes occurring in neighbourhoods with a higher proportion of professionals were associated with a higher likelihood of severe injuries (fatal and serious injuries) rather than less severe injuries (minor or non-injuries), while the proportion of sales people and people born in Australia were found to have mixed effects. Therefore, transport authorities and road safety professionals should concentrate any location specific treatments in these target neighbourhoods. Some examples of location (site, corridor or area) specific treatments include traffic calming, lowering speed limits, speed monitoring and display, roadside safety messaging, and traffic law enforcement. It is important to emphasise that these neighbourhood socio-demographic characteristics should be used as a supplement to the information provided by the standard collision hotspots analysis.

With respect to road user residency neighbourhoods, we found that road users residing in neighbourhoods with a higher proportion of people with university education or a higher proportion of people working in sales were less likely to be associated with injury outcomes compared to the non-injury outcome. Road users residing in neighbourhoods with a higher percentage of people born in Australia were more likely to suffer injuries rather than not suffering any injury at all. The effects of technical education, percentage of people born overseas, and percentage of people working as clerical and administrative staff were mixed. To improve truck safety, transport authorities, road safety professionals and fleet managers, and occupational safety officers in the trucking industry should consider targeting road safety education programs in these neighbourhoods. Education and training campaigns targeted at truck drivers that highlight the safety of other road users, especially passenger vehicles and pedestrians, could be considered. Safety campaigns to increase the proper installation and use of safety restraints should also be considered.

Reference

Al-Ghamdi, AS. Analysis of traffic accidents at urban intersections in Riyadh. *Accident Analysis & Prevention.* 2003; 35(5): 717-24.

Anastasopoulos, PC & Mannering, FL 2011. An empirical assessment of fixed and random parameter logit models using crash-and non-crash-specific injury data. *Accident Analysis & Prevention*, 43(3): 1140-7.

ATC. National Road Safety Strategy, 2011-2020. Australian Transport Council, Canberra, ACT; 2011.

AUSTROADS. Road design for heavy vehicles. Technical report AP-T293-15, Austroads Ltd, New South Wales; 2015.

Balakrishnan, S., Moridpour, S. and Tay, R. Analysis of Injury Severity in Heavy Vehicles Angle Crashes. *The 96th Transportation Research Board Annual Meeting*. United States: Transportation Research Board; 2017.

BITRE. Fatal crashes involving heavy vehicles. Australia Bulletin_March_2014, Bureau Of Infrastructure Transport and Regional Economics, Canberra, ACT;

Chang, L-Y & Chien, J-T. Analysis of driver injury severity in truck-involved accidents using a non-parametric classification tree model. *Safety Science*. 2013; 51(1): 17-22.

Chen, F. & Chen, S. Injury severities of truck drivers in single- and multi-vehicle accidents on rural highways. *Accident Analysis & Prevention*. 2011; 43(5): 1677-88.

Chu, HC. An investigation of the risk factors causing severe injuries in crashes involving gravel trucks. *Traffic Injury prevention*. 2012; 13(4):355-63.

Cottrill, C.D. and Thakuriah, P.V. Evaluating pedestrian crashes in areas with high low-income or minority populations. *Accident Analysis & Prevention*. 2010; 42(6): 1718-1728.

Duncan, C., Khattak, A. & Council, F. Applying the Ordered Probit Model to Injury Severity in Truck-Passenger Car Rear-End Collisions. *Transportation Research Record*. 1998; 1635: 63-71.

Eluru, N. Evaluating alternate discrete choice frameworks for modeling ordinal discrete variables. *Accident Analysis & Prevention.* 2013; 55: 1-11.

Factor, R., Mahalel, D. and Yair, G. Inter-group differences in road-traffic crash involvement. *Accident Analysis & Prevention.* 2008; 40(6): 2000-2007.

Islam, M & Hernandez, S. Fatality Rates for Crashes Involving Heavy Vehicles on Highways: A Random Parameter Tobit Regression Approach. *Journal of Transportation Safety & Security*. 2016; 8(3): 247-65.

Islam, M. Multi-Vehicle Crashes Involving Large Trucks: A Random Parameter Discrete Outcome Modeling Approach. *Journal of the Transportation Research Forum*. 2015; 54: 77-104.

Islam, S, Jones, SL & Dye, D. Comprehensive analysis of single-and multi-vehicle large truck at-fault crashes on rural and urban roadways in Alabama, *Accid Anal Prev.* 2014; 67: 148-58

Khorashadi, A, Niemeier, D, Shankar, V & Mannering, F. Differences in rural and urban driver-injury severities in accidents involving large-trucks: an exploratory analysis, *Accident Analysis & Prevention.* 2005; 37(5): 910-21.

Lee, C & Li, X. Analysis of injury severity of drivers involved in single- and two-vehicle crashes on highways in Ontario, *Accident Analysis & Prevention.* 2014; 71, 286-95.

Lemp, JD, Kockelman, KM & Unnikrishnan, A. Analysis of large truck crash severity using heteroskedastic ordered probit models, *Accident Analysis & Prevention.* 2011; 43(1): 370-80.

Licaj, I., Haddak, M., Hours, M. and Chiron, M. Deprived neighborhoods and risk of road trauma (incidence and severity) among under 25year-olds in the Rhône Département (France). *Journal of Safety Research*, 2011; 42(3): 171-176.

Lord, D & Mannering, F 2010. The statistical analysis of crash-frequency data: A review and assessment of methodological alternatives. *Transportation Research Part A: Policy and Practice*, 44(5): 291-305.

Milton, JC, Shankar, VN & Mannering, FL 2008. Highway accident severities and the mixed logit model: an exploratory empirical analysis. *Accident Analysis & Prevention*, 40(1): 260-6.

Mooren, L, Grzebieta, R., Williamson, A., Olivier, J. & Friswell, R. Safety management for heavy vehicle transport: A review of the literature, *Safety Science*.2014; 62: 79-89.

Ouyang, Y., Shankar, V. & Yamamoto, T. Modeling the simultaneity in injury causation in multivehicle collisions, *Transportation Research Record*. 2002; 1784: 143-52.

Pahukula, J., Hernandez, S. & Unnikrishnan, A. A time of day analysis of crashes involving large trucks in urban areas, *Accident Analysis & Prevention.* 2015;75: 155-63.

Rosenbloom, T., Perlman, A. & Shahar, A. Women drivers' behaviours in well-known versus less familiar locations, *Journal of Safety Research*. 2007; 38(3): 283-288.

Savolainen, PT, Mannering, FL, Lord, D & Quddus, MA 2011. The statistical analysis of highway crash-injury severities: a review and assessment of methodological alternatives. *Accident Analysis & Prevention*, 43(5): 1666-76.

Schneider R., Diogenes M., Arnold L., Attaset V., Griswold J. & Ragland D. Association between roadway intersection characteristics and pedestrian crash risk in Alameda County, California, *Transportation Research Record*. 2010; 2198: 41-51.

Smith, K., 2000. Road safety: past, present and future, Australian institute of traffic planning and management international conference, 2000, Gold Coast, Australia.

Sivak, M., Schoettle, B. & Rupp, J. Survival in fatal road crashes: body mass index, gender, and safety belt use, *Traffic Injury prevention*. 2010; 11(1): 66-8.

Spoerri, A., Egger, M. and von Elm, E. Mortality from road traffic accidents in Switzerland: longitudinal and spatial analyses. *Accident Analysis & Prevention*. 2011(1); 43: 40-48.

Tay, R 2015. A random parameters probit model of urban and rural intersection crashes. *Accident Analysis & Prevention*, 84: 38-40

Tay, R., Barua, U. & Kattan, L. Factors contributing to hit and run in fatal crashes. *Accident Analysis & Prevention*. 2009; 41(2): 227-33.

Tay, R., Choi, J., Kattan, L. & Khan, A. A multinomial logit model of pedestrian–vehicle crash severity, International Journal of Sustainable Transportation. 2011; 5(4): 233-49.

Tay, R., Rifaat, SM. & Chin, HC. A logistic model of the effects of roadway, environmental, vehicle, crash and driver characteristics on hit-and-run crashes, *Accident Analysis & Prevention.* 2008; 40(4): 1330-6.

Warsh, J., Rothman, L., Slater, M., Steverango, C. & Howard, A. Are school zones effective? An examination of motor vehicle versus child pedestrian crashes near schools, *Injury prevention*. 2009; 15(4): 226-9.

Yanko, M.R. and Spalek, T.M. Route familiarity breeds inattention: A driving simulator study. *Accident Analysis & Prevention.*2013; 57: 80-86.

Ye, F. & Lord, D. Comparing three commonly used crash severity models on sample size requirements: Multinomial logit, ordered probit and mixed logit models, *Analytic Methods in Accident Research*. 2014; 1: 72-85.

Zhu, X. & Srinivasan, S. Modeling occupant-level injury severity: An application to large-truck crashes, *Accident Analysis & Prevention.* 2011a; 43(4): 1427-37.

Zhu, X. & Srinivasan, S. A comprehensive analysis of factors influencing the injury severity of large-truck crashes, *Accident Analysis & Prevention.* 2011b; 43(1): 49-57.