Effects of Road Users' Behaviour and Road Network Characteristics on Road Safety

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Abstract: Understanding the factors affecting road traffic accident is of utmost importance in deigning road safety improvement measures. This study mainly concentrates to analyse the factors affecting the severity levels of all road accidents in Yangon City using ordered probit model. General characteristics, road characteristics, traffic characteristics, crash regions, manner of occurrences and types of collision were considered as explanatory variables and four categories of accident severity levels namely: Property Damage Only (PDO), slight injury, serious injury and fatal injury have been considered as dependent variables. The study shows that factors such as times of day, days of week, license conditions, crash regions, number of lanes, status of traffic flow, manner of occurrences, and head-on and rear-end collisions-were found to be significantly associated with severity levels. The results obtained can be used in establishing road safety improvement measures for the areas under study.

Keywords: Road Safety, Severity Levels, Ordered Probit Model, Yangon

1. INTRODUCTION

Road accidents are worldwide problems from which road crashes nowadays claim that 1.35 million people around the world have been killed on roadways in each year around the world. Crash injuries are estimated to be the eighth leading cause of death globally for all age groups.

The crash death rate is over three times higher in low-income countries than in high-income countries. Deaths and injuries related to road crashes remain one of the most pressing public health concerns for low and middle-income countries around the world. As reported in the latest WHO Global Status Report on Road Safety in 2015, 90% of road traffic deaths occur in these countries, even if they only possess 54% of the world's vehicles.

In Myanmar, one-third of all injuries reported by hospitals are from traffic accidents. Fatalities are expected to be double by 2020 and reach 15,000 per year by 2025 if the situation remains unchanged. The annual cost of road accidents to Myanmar's economy is estimated about 1.5% of gross domestic product (GDP). Current road crash levels are a major hindrance to the country's economic activity. Expenditure on preventative road safety management needs to be considered not only as a cost, but as an investment in the country's economic development (Asia Development Bank, 2016).

In Yangon, the number of vehicles increased by 2.2 times between 2014 and 2015. Vehicle ownerships increases as an economy develops and household incomes rise. As with other cities, it is expected that vehicle ownership in Yangon will further increase and the impact on roads will become increasingly significant. As the number of motor vehicles and vehicle-miles of travel increase, the exposure of the population to traffic accident also increases.

It is therefore obviously understood that some measures on road safety improvements must be designed and adopted urgently to reduce such fatal accidents. This in turn will need deeper knowledge about factors influencing the levels of severity in road traffic accidents. While several studies examine road accident severity levels in the international literature, few such studies have been carried out in Yangon City. Therefore, it is essential to investigate the contribution of several factors to the injury severity faced by road accidents for road safety improvement.

This study mainly concentrates to analyse the factors affecting the severity levels of all road accidents to establish road safety improvement measures for the areas under study.

Extensive literature has been found that investigated the influence of risk factors related to the road users, the vehicle, environment, the road characteristics, traffic characteristics and crash characteristics on severity in accidents. Manner and Wunsch-Ziegler (2013) analysed the factors that have an effect on the severity of accidents using traffic information, road conditions and road user's characteristics. Garrido *et al.* (2014) examined the influence of a number of factors on the injury severity faced by motor-vehicle occupants involved in road accidents. Explanatory variables comprise the accident victim, vehicle, and roadway and environment conditions. Rifaat and Chin (2007) identified the contributing factors affecting crash severity with broad considerations of driver characteristics, roadway features, vehicle types, pedestrian characteristics and crash characteristics using an ordered probit model. Yuan *et al.* (2020) studied the injury severity of expressways and crash types, crash locations, crash season, vehicle types, road surface, weather condition and general characteristics of drivers were considered as explanatory variables.

In this study, gender of victims, crash time, general characteristics of road users, crash season, crash location, manners of occurrence, collision types, and road characteristics and traffic characteristics were considered as explanatory variables to analyse the factors affecting the severity levels of all road accidents.

The structure of the paper has been organized as follows: literature studies have been covered in Section 2, while in Section 3, the selection of the study area as a case study is identified. In Section 4, brief description of selecting appropriate data and methodology to be used in the study, together with detailed explanation to obtain the contributing factors such as traffic characteristics, were put forward. Further, detailed discussion of the results of the study has been discussed thoroughly in Section 5 and finally, in Section 6, conclusions and recommendations are drawn based upon the findings of the study.

2. LITERATURE STUDIES

There are broad range of factors affecting road accidents. Undivided road sections and urban areas resulted in more severe injuries and night time is higher than day time in fatal and serve injury rate for both multivehicle and pedestrian/bicycle-related accident. The AADT was found to have a significantly negative effect on accident severity levels for multivehicle accidents with higher AADT values tend to be less severe (Hyodo and Hasegawa, 2021). Xu *et al.* (2013b) presented that congested traffic flows lead to less-serve accidents.

As for road users' behaviour, such as seat belt usage, alcohol consumption, age, passengers' impact on drivers might affect road safety (O'Donnell and Connor, 1996; Washington *et al.,* 1999). Other factors such as lighting and weather conditions can affect road safety through both road users and roadway systems (Shankar *et al.,* 1995; Golob and Recker, 2003).

Yang *et al.* (2020) developed the Bayesian multilevel ordered logistic and Bayesian ordered logistic regression model to analyse the injury severity in urban expressway. The results indicated that injury at night time is more severe than that in the day time, and the probability of injury in winter is higher than in the rest seasons.

Generally, speed has been found to have mixed effects on road safety in the literature. Wang *et al.,* (2013) stated that while some study found increased speed reduce safety, other study found the opposite. It was also argued that speed itself may not be a safety problem but speed variation is may be a safety problem. Kockelman and Ma (2007) also described that there was no evidence that speed conditions influence accident occurrence. Lave (1985) found that the fatality rate was strongly related with speed variance rather than average speed. Speed is an important factors affecting traffic road accidents both in terms of accident occurrence and severity (Elvik *et al.,* 2004; Nilsson, 2004; Aarts and van Schagen, 2006; Taylor *et al.,* 2002). Their results showed that increased speed lead to the accidents that have occurred would be more serve, if other factors remain the same.

Golob and Recker (2003) demonstrated how accidents are related to traffic flow conditions. It was stated that accident severity generally tracks the inverse of traffic volume. Martin (2002) investigated the relationship between accidents and traffic flow on French motorways, and found that accident rates are highest in light traffic flow compared to heavy traffic, especially on three-lane motorways. There is no significant difference between day time and night-time accident. The author concluded that light traffic flow (low traffic flow) tend to be a safety problem both in terms of accident rate and severity.

Noland and Quddus (2005) analysed the factors affecting casualties during congested and uncongested period using negative binomial models. The study result showed that traffic casualties are likely to happen on higher speed roads and motorways but not during traffic congestion. Wang *et al.* (2009b) stated that there is little effect of traffic congestion on road accidents on the M25 motorway. In 2011, Wang *et al.* performed their study area by including M25 and their surrounding area. They found that increased traffic congestion is related with more fatal and serious injury accidents and little impact on slight injury accident. Traffic congestion was measured by using a congestion index (ratio of traffic delay by free flow travel time). Wang Chao *et al.* (2013) suggested that future research could focus on testing the effect of different congestion measurements using advanced accident prediction models.

In this study, traffic congestion was considered as one of the independent variables to analyse the factors affecting the severity levels of all road accidents. Therefore, different congestion method was used in this study and congestion level of each segment was measured based on average travel speed and free flow speed.

Some researchers use statistical models, which are independent of Geographic Information System (GIS) models, such as: Poisson, lognormal, negative binomial, etc. Some researchers use GIS tools to carry out spatial analysis of traffic accidents. Li and Zhang (2007), in their study, showed how combined GIS and advanced statistical models can be used to evaluate risks in crash analysis.

In this study, combined model of GIS and statistical model, ordered probit model were used to evaluate severity levels in crash analysis.

3. STUDY AREA

Although there have been 45 townships in Yangon region, only 33 townships (central business district (CBD), inner city, outer city, and new suburban, and old suburban) have been selected as the study area. Yangon is not only the formal capital city but also the hub of the commercial centre of lower Myanmar. The government encouraged the international trade investment to launch the market-oriented economy after 1988 and car import policy was changed after 2011. Therefore, Yangon City is expanded a cross pattern as east-west and north-south axis, and area is increased from about 400 km^2 to 598.750 km^2 with a population of 5.2 million (census, 2014). Due to car import policy changes, numbers of car registration are rapidly increased from 74,000 (1990), to 470,581 (2015), with a 6.4 times growth, and also more developed in the public transportation sector. As the number of motor vehicles and vehicle-miles of travel increase, the exposure of the population to traffic accident also increases. It is therefore, essential to provide traffic road safety improvement measures in urban areas. Keep this purpose in mind, the urban area of Yangon City has been selected as the area to be studied as shown in Figure 1.

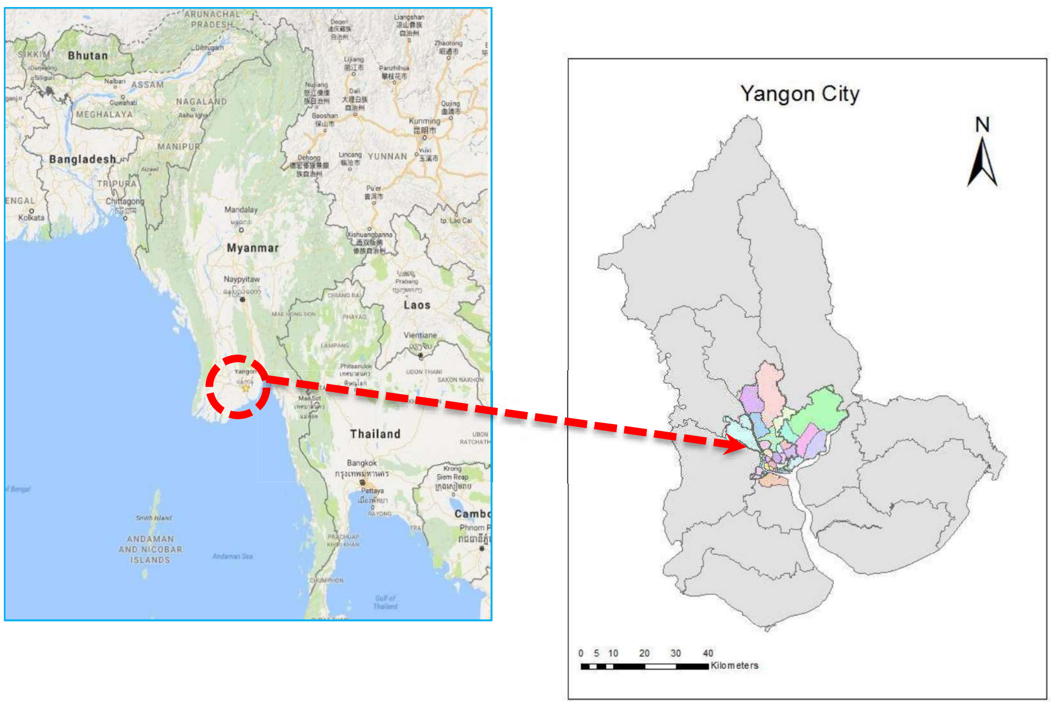

Figure 1. Location of the study area

4. METHODOLOGY

4.1 Data

Three types of secondary datasets have been considered in the study: Road traffic accidents data, Call Detail Record (CDR) data and Global Positioning System (GPS) data of taxis. In addition, population of urban area and road network map of Yangon City were also used and free flow speeds were also considered as a primary data in this study.

4.1.1 Road traffic accident data

These traffic accident data have been collected from Traffic Police Department consisting accident records for the period between 1st January 2015 and 31st December 2015 with the total of 3122 records. These accident records include information such as: location of accidents, time and date of occurrences, gender and age of drivers and victims, drink and drug conditions, status on vehicle and driving license (with or without), types of vehicle involved, numbers of vehicle in accident occurrences, extent of damage of vehicle, person injured and/or fatality, types of collision and manners of occurrences.

4.1.2 CDR data

CDR data can be advantageous in analysing link counts for large scale area like City level and urban areas. CDR data can be obtained from Myanmar Posts and Telecommunications (MPT), which is one of the biggest mobile operators in Myanmar. The available CDR data applied in this study include time between 1st December 2015 and 7th December 2015. All mobile phone voice calls and data such as short message service (SMS) and internet service were involved in this data set and average numbers of record are 2.2 billion and around 2 million anonymous mobile phone users per day. Each entry in the dataset has a CDR comprising Timestamp, Caller's ID, Call duration in second and Caller's connected cell tower ID (Kyaing *et al.,* 2020).

4.1.3 GPS data

GPS data of taxi is also applied to determine the actual travel speed of the vehicle and to classify the level of service (LOS) for each road segment in the study area. The duration of 24-day period from 6th June to 29th June, 2017 of taxis' GPS data has been provided by the Hello Cab taxis company limited. Datasets for 21582 trips of occupied trips from 6680 taxis were used to analyse the travel speed in this study.

4.1.4 Other data

Free flow speeds were collected in road network across the Yangon City using GPS to analyse congestion level. Populations were used to calculate home magnification factors to represent the actual population and road network map of Yangon City was also used as secondary data to analyse link speed, link population, level of service for each segment and to locate road traffic accident location. In addition, Yangon open street map was also used to determine latitude and longitude of accident location.

4.2 Model Approach

In cases where evaluation of risks of road accidents is to be undertaken, combined model of GIS and statistical models can be used (Li and Zhang, 2007). In this study, GIS model would be used for all data preparation, segmentation, and screening for traffic accident analysis and ordered probit model with STATA 14 would be used to analyse and investigating the factors affecting the severity levels of all road accidents in urban areas.

The theoretical framework of the ordered probit model including the model specification and method of evaluation was discussed thoroughly in several studies (i.e., O' Donnell and Connor, 1996; Long, 1997; Duncan *et al.*, 1998; Rensky *et al.*, 1999; Kockelman and Kweon, 2002; Khattak *et al.*, 2002).

4.3 Method of analysis

First, road traffic accidents data were collected as ~~a~~ secondary data because road accident occurs in unexpected place and time conditions. Accidents were grouped into four categories based on the severity of accidents, namely: Property Damage Only (PDO), slight injury, serious injury and fatal injury. The database contains accident location, date and time of crash occurrence, genders, manner of occurrence, types of collision, numbers of slight injury and serious injury, numbers of fatal and their gender, drink and drug conditions, and status on vehicle and driving license (with or without). Accident times were categorized from hourly to days and nights, locations were grouped into 2 regions such as, CBD and Non-CBD, and Seasons were grouped from occurrence of months, weekdays and weekends were divided from occurrence of days for analysis.

Then, each accident location was located on Yangon open street map/goggle map to specify its respective coordinates, latitude and longitude using QGIS 3.16. The points located in Yangon open street map file were saved as comma-separated value file to be able to import to GIS as a spatial database. These accidents locations are shown in Figure 2 showing four categories of severity level: green circle for PDO, orange colour for slight injury, red colour for serious injury and black colour for fatal accident.

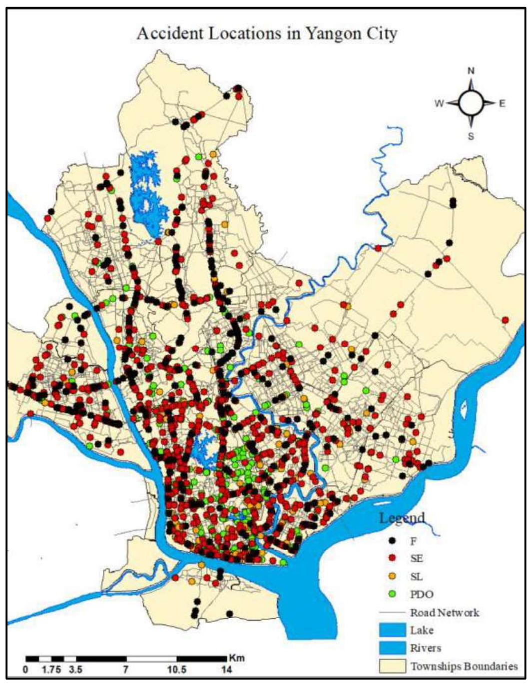

Figure 2. Road traffic accidents based on severity level in study area

In addition, directresses of crash occurrence location were analyzed with Yangon road network file using ArcGIS 10.3.1. And, number of lanes, numbers of way and classification of roads for crash locations were also specified using Yangon road network. Moreover, hourly link population, link speed and congestion level were also analysed for explanatory variables.

4.3.1 Analysis of link population from CDR data

CDR data were used to estimate link person trip in the areas under study. First, all Cell-ID locations were moved to the nearest road nodes to locate start and end points. Then, O-D pairs were extracted for individual persons by pairing their successive calls or data usages after pre-processing and processing of CDR data. Route paths and directions between each O-D pair were also determined using shortest-path analysis based on GIS road network data model. Unique

PIDs by each road link were computed and home magnification factors were also used to represent the actual population from mobile users (Lwin *et al.* 2018).

4.3.2 Analysis of link speed from taxis' GPS data

In this research, taxi GPS data are used for obtaining of actual travel speed of taxis. Speeds of taxis are considered to be the actual operating travel speeds in the areas under study. Cleaning and screening processes are needed to be carried out for taxi GPS data using BigGIS-RTX (Big Data Research Toolbox) (Lwin *et al.* 2018). After pre-processing of GPS data, hourly average travel speeds of taxis for each segment were calculated in this study.

4.3.3 Classification of congestion level

In addition, congestion levels of road links were used as one of the explanatory variables in this analysis. A level-of-service (LOS) provides an index to quality of traffic flow. LOS for each road segment was measured on the basis of direct field measurement of the free flow speed, street's class and average travel speed (Highway Capacity Manual (HCM) 2000 guideline).

After analysing the hourly link population, link speed and congestion level in terms of LOS for the study areas, the related values of accidents locations with their specific time intervals are determined to use as the explanatory variables in analysing the factors affecting the level of severity in all road traffic crashes. Figures 3 through 5 show the hourly link populations, link speeds and LOS of each accident location with related time intervals.

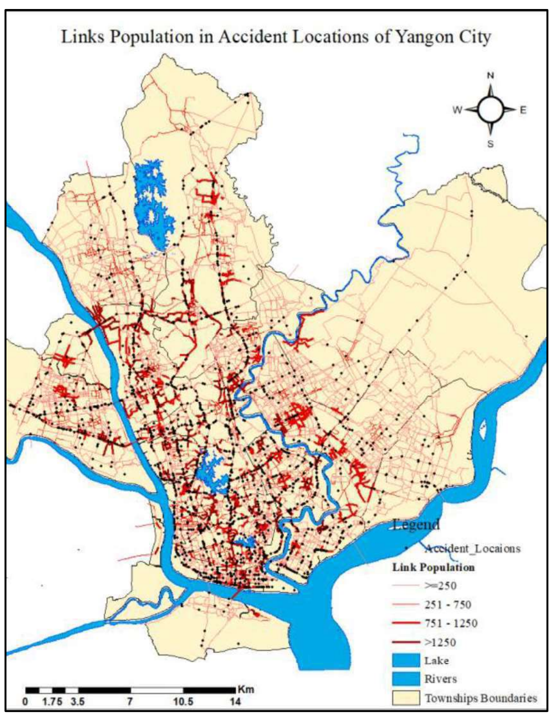

Figure 3. Link population of each accident location related to occurrence of time interval

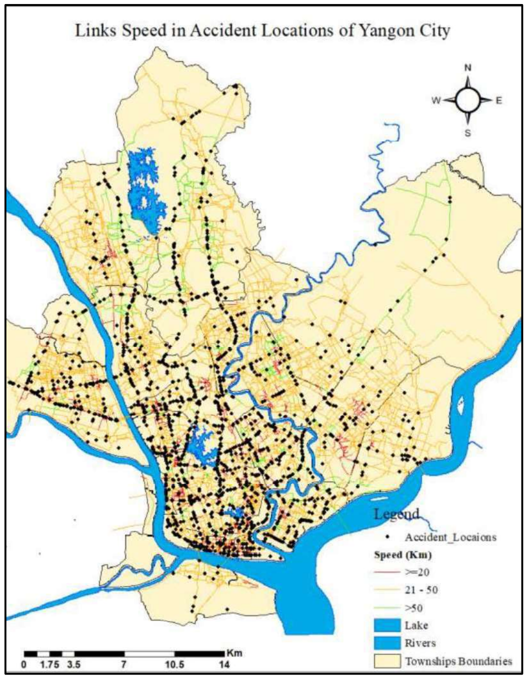

Figure 4. Link speed of each accident location related to occurrence of time interval

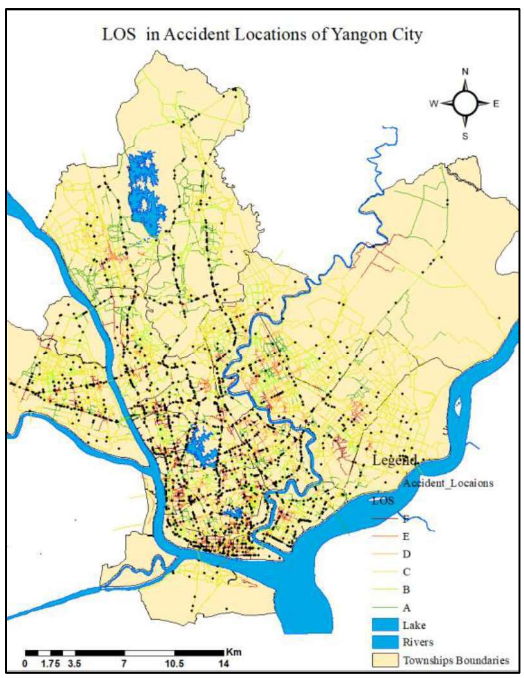

Figure 5. Congestion Level (LOS) of each accident location related to occurrence of time interval

4.4 Model Formulation

Total sample of 3122 observations involved with 280 (8.97%) PDO, 765 (24.5%) slight injury, 1705 (54.61%) serious injury and 372 (11.92%) fatal accidents during this period after filtering of uncompleted data. This study focus on analysing of the factors that affect the occurrence of accidents mainly in severity level.

Four categories levels of severity namely: Property Damage Only (PDO) (y=1), slight injury (y=2), serious injury (y=3) and fatal injury (y=4) were considered as dependent variables in the study.

Explanatory variables considered in the study are: gender of victims, crash time (day time and night time), days of the weeks (weekdays and weekends), driving with or without license, drink and drug conditions, crash season (winter, summer and rainy), crash location (CBD and Non-CBD), manners of occurrence (with pedestrian, with other motor vehicle, with slow vehicle, with other motor vehicle > 2, with fixed object and other), collision types (rear-end, head-on, sideswipe and others), and road characteristics (i.e. traffic way, road alignment, numbers of lane, road class) and traffic characteristics (link population, link speed and congestion level). Table 1 shows the characteristics of explanatory variables and their means and standard deviations. All explanatory variables are binary and dummy variables with mean values between 0 and 1.

Table 1. Explanatory variables

Explanatory variables	**Type**	**Coding**	**Mean**	**SD**
Gender	Binary	1 if male, 0 if female	0.762	0.426
Time	Binary	1 if night time, 0 if day time	0.567	0.496
Day	Binary	1 if weekends, 0 if weekdays	0.714	0.452
License	Binary	1 if yes, 0 if no	0.627	0.484
Drink and drug	Binary	1 if yes, 0 if no	0.004	0.062
Crash seasons				
Summer	Dummy	1 if summer, 0 if otherwise	0.251	0.434
Winter	Dummy	1 if winter, 0 if otherwise	0.347	0.476
Rainy	Dummy	1 if rainy, 0 if otherwise	0.402	0.490
Crash location (Region)				
CBD	Binary	1 if CBD, 0 if Non-CBD	0.048	0.215
Manners of occurrence				
with pedestrian	Dummy	1 if with pedestrian, 0 if otherwise	0.233	0.423
with other motor vehicle	Dummy	1 if with other motor vehicle, 0 if otherwise	0.340	0.474
with slow vehicle	Dummy	1 if with slow vehicle, 0 if otherwise	0.083	0.275
with other motor vehicle > 2	Dummy	1 if with other motor vehicle > 2, 0 if otherwise	0.105	0.306
with fixed object	Dummy	1 if with fixed object, 0 if otherwise	0.086	0.280
other	Dummy	1 if other, 0 if otherwise	0.154	0.361
Collision types				
Rear-end	Dummy	1 if rear-end, 0 if otherwise	0.160	0.367
Crossing	Dummy	1 if crossing, 0 if otherwise	0.220	0.414
Head-on	Dummy	1 if head-on , 0 if otherwise	0.349	0.477
Sideswipe	Dummy	1 if sideswipe, 0 if otherwise	0.063	0.243
Others	Dummy	1 if others, 0 if otherwise	0.208	0.406
Road characteristics				
Traffic way	Binary	1 if one-way, 0 if two-way	0.012	0.110
Roadway alignment	Binary	1 if segment, 0 if curve	0.865	0.341
Number of lanes				

one lane	Dummy	1 if one lane, 0 if otherwise	0.094	0.291
two lanes	Dummy	1 if two lanes, 0 if otherwise	0.234	0.424
four lanes	Dummy	1 if four lanes , 0 if otherwise	0.395	0.489
six lanes	Dummy	1 if six lanes, 0 if otherwise	0.278	0.448
Road class				
Highways	Dummy	1 if highways, 0 if otherwise	0.032	0.175
Major roads	Dummy	1 if major roads, 0 if otherwise	0.561	0.496
Minor roads	Dummy	1 if minor roads , 0 if otherwise	0.160	0.367
Other roads	Dummy	1 if other roads, 0 if otherwise	0.247	0.431
Congestion level (LOS)				
LOS A	Dummy	1 if LOS A, 0 if otherwise	0.192	0.394
LOS B	Dummy	1 if LOS B, 0 if otherwise	0.202	0.402
LOS C	Dummy	1 if LOS C , 0 if otherwise	0.379	0.485
LOS D	Dummy	1 if LOS D, 0 if otherwise	0.059	0.235
LOS E	Dummy	1 if LOS E , 0 if otherwise	0.100	0.300
LOS F	Dummy	1 if LOS F, 0 if otherwise	0.069	0.254
Link_speed (kph)				
>4 & ≤ 20	Dummy	1 if >4 & ≤ 20, 0 if otherwise	0.130	0.336
>20 & ≤ 50	Dummy	1 if >20 & ≤ 50, 0 if otherwise	0.748	0.434
>50	Dummy	1 if >50 , 0 if otherwise	0.122	0.327
Link_pop (person trip/hr)				
≤ 250	Dummy	1 if ≤ 250, 0 if otherwise	0.601	0.490
>250 & ≤ 750	Dummy	1 if >250 & ≤ 750, 0 if otherwise	0.210	0.407
>750 & ≤ 1250	Dummy	1 if>750 & ≤ 1250 , 0 if otherwise	0.087	0.282
>1250	Dummy	1 if > 1250, 0 if otherwise	0.102	0.302

5. RESULTS AND DISCUSSIONS

Ordered probit model was used to analysis the factors that affect the occurrence of accidents in particularly its severity level. STATA 14 software was employed and collinearity was assessed the dataset in this analysis. Table 2 shows the frequency and percentage of four dependent categories of severity level.

Table 2. Frequency and percentage of severity level

Severity	Frequency	Percent	Cumulative
PDO	280	8.97	8.97
Slight injury	765	24.50	33.47
Serious injury	1,705	54.61	88.08
Fatal	372	11.92	100.00

Gender of victim, traffic way, road class, road alignment (i.e., straight or curve), link speed, congestion level (LOS), link population (i.e., > 250 & ≤ 750, and >750 & ≤ 1250), crash season, collision types (i.e., crossing, sideswipe and other collision) and drink and drug were not significant in this analysis.

Table 3 shows the results of ordered probit model that only the variables significant at the 95% (p=0.05) and 90% (p=0.10) significance level were described. According to the results, it was found that this model is fit as Prob > chi2 value equal 0.000 and it is less than 0.05.

Table 3. Ordered probit model estimation results

Variable	Coef.	p	Marginal effects			
			PDO	Slight injury	Serious injury	Fatal
General characteristics						
Time	0.161	0.001**	-0.020	-0.038	0.032	0.026
Day	0.109	0.017**	-0.014	-0.025	0.022	0.017
License	-0.255	0.000**	0.030	0.059	-0.045	-0.044
Region						
CBD	-0.368	0.000**	0.058	0.081	-0.091	-0.049
Road characteristics						
One-lane	0.290	0.010**	-0.030	-0.067	0.041	0.056
Two-lane	0.201	0.009**	-0.023	-0.047	0.034	0.036
Traffic characteristics						
Link population ≤ 250	0.135	0.071*	-0.017	-0.032	0.027	0.022
Manner of occurrences						
with pedestrian	0.428	0.000**	-0.045	-0.098	0.061	0.082
with other motor vehicle	-0.319	0.001**	0.043	0.073	-0.067	-0.049
with slow vehicle	0.395	0.000**	-0.038	-0.090	0.048	0.081
with other motor vehicle >2	-0.506	0.000**	0.084	0.109	-0.129	-0.064
with fixed object	-0.708	0.000**	0.133	0.140	-0.194	-0.079
Type of collision						
Rear-end	-0.619	0.000**	0.105	0.131	-0.158	-0.078
Head-on	0.182	0.041**	-0.022	-0.042	0.033	0.031
LR chi^2	636.03					
Prob > chi^2	0.000					
Pseudo R^2	0.0890					
Cut 1	-1.30971					
Cut 2	-0.25064					
Cut 3	1.54497					

Note: ** Significant at 5% level; * Significant at 10% level

Times of the day, days of the week, number of lanes (i.e., one-lane, two-lane), link population, manner of occurrences (with pedestrian and with slow vehicle) have positive sign in explanatory variables. License, crash region, manner of occurrences (i.e., with other motor vehicle, with other motor vehicle > 2 and with fixed object), and head-on collision are negative relationship with severity levels. This means that positive sign shows that particular explanatory variable is more likely to be involved in severity level and negative sign represents that the particular explanatory variable is less likely to be involved in severity level. Similarly, in marginal effects, positive sign indicates that more likely and negative sign shows that less likely to be related in particular severity level.

Martin (2002) investigated that there are no significant effects between day time and night time accidents. But in this analysis, it was found that night times are more likely than day times to be involved in accident severity levels, which is in line with Jiang *et al.* (2013), Yuan and Chen, (2017), Garrido *et al.* (2014), and Yuan *et al.* (2020). Based on the results of marginal effects as shown in Table 3, it has been noted that night time is associated with 3.2% and 2.6% more likely to be involved in the serious injury and fatal injury severity levels, while occurring 2% and 3.8% less likely to be involved in PDO and slight injury levels respectively. Therefore, this can be concluded that, hourly accidents were much worse in night times. Low visibility and late night drowsiness may delay the driver's reaction at the impending collision with pedestrian or with other motor vehicle or with fixed object or with slow vehicle. According to accident records, about 30% of drivers ran away without attending the victim. It may cause the delay of crash notification and medical support and leads to high severity level.

The results also indicate that weekends are more likely than weekdays to be involved in accident severity levels. It is found that weekends are more likely than weekdays to be involved in serious and fatal injury severity levels, while less effect in PDO and slight injury levels. This may be because of the light traffic flow conditions and high travel speeds on weekends (kyaing *et al.* 2020).

The results also indicate that drivers with license are less likely to be related in severity and have more impact in PDO and slight injury levels than in serious and fatal injury severity levels.

For crash location, CBD region is less likely to be occurred in severity level as negative relationship occurs. In other word, Non-CBD region is more likely to be involved in accident severity levels. According to results from Table 3, CBD region tends to be 5.8% and 8.1% more likely to be suffered in PDO and slight injury levels while 9.1% and 4.9% less likely to be suffered in serious injury and fatal injury severity levels respectively. High density of traffic flow and low travel speed lead to decreased severity levels in CBD region.

Road characteristics, such as number of lanes, is the one of the most influencing factors in crash occurrence analyses. In this study, it is also noticed that one-lane and two-lane are more likely to be involved in accident severity levels and more likely to be related in serious and fatal injury severity levels, and less likely to be associated in PDO and slight injury severity levels.

According to the results, population with ≤ 250 (person per hour) has positive sign with 90% significant level. This means that link population with ≤ 250 (person per hour) is more likely to be involved in severity levels with 90% significant level. This indicates that accident severity levels are higher especially in light traffic conditions. This finding is consistent to other studies (Golob and Recker, 2003; Martin, 2002). Golob and Recker (2003) concluded that accident severity tracks the inverse of traffic volume. Martin (2002), in his study, conducted on French motorway, found that accident rates were the highest in light traffic flow compared to heavy traffic flow especially in three lane motorways. Based on marginal effects, the probabilities of the lower and upper severity levels and effect of explanatory can be provided in findings results. From these results, crash location which link population with ≤ 250 is associated with 1.7% less likely to be involved in the PDO severity level, 3.2% less likely to be involved in slight injury level, 2.7% more likely to be involved in serious injury level and 2.2% more likely to be involved in fatal injury level.

In manner of occurrence, the results indicated that collision with pedestrian, and collision with slow vehicle are more likely to be involved in severity levels of road accidents; and collision between motor vehicles, collision with fixed object, and collision between more vehicles (i.e., > 2 vehicles) are less likely to be involved in severity levels of road accidents. With regards to the marginal effects as shown in Table 3, the study reveals that collision with pedestrian, and collision with slow vehicles are more likely to be associated in serious and fatal injury and less likely to be involved in PDO and slight injury severity levels. On the other hand, collision between motor vehicles, collision with fixed object, and collision between more vehicles are less likely to be related in serious and fatal injury, and more likely to be associated in PDO and slight injury severity levels of road accidents. Garrido *et al.* (2014) stated that injury risk is increasing aggravated by collision against fixed-objects.

Types of collisions such as head-on and rear-end are significant factors in crash characteristics. Head-on collision is more likely to be involved in accident severity levels, which is in line with other studies (Rifaat, 2007; Garrido *et al.,* 2014) and rear-end collision is less likely to be related in accident severity levels. From these results, it can be seen that head-on collision is higher fatality and serious injury than PDO and slight injury levels. This is because of a careless driver trying to move his vehicle forcefully and unlawfully at the traffic light point while the red traffic light is on and then take the left-turn immediately without taking any account of traffic care, and this in turn leads the situation an accident-prone to head-on collision with the vehicle coming from the opposite direction. On the other hand, rear-end collision is more likely to be involved in PDO and slight injury levels and less likely to be involved in serious and fatal injury severity levels. This may be due to the sudden stoppage of the vehicle at the traffic light point while the red traffic light is on and this would also lead the situation an accident-prone to rear-end collision with another vehicle coming from back.

Speed was insignificant factor in severity level of all road traffic accident in this analysis. In most literatures, speed has been found to have mixed effects on road safety. Wang Chao *et al.* (2013) stated that while some studies found increased speed reduces safety, others found the opposite findings. Speed leads to the accidents that have occurred would be more serve (Elvik *et al.,* 2004; Nilsson, 2004; Aarts and van Schagen, 2006; Taylor *et al.,* 2002) while Kockelman and Ma (2007) indicated that there was no evidence that speed conditions influence accident occurrence.

Although different congestion measurement was used as suggested by Wang Chao *et al.* (2013), traffic congestion was not significant factor in severity level of all road accidents in this study. The result is not in line with Wang *et al.* (2011), and but, Noland and Quddus (2005) stated that traffic casualties are likely to happen on higher speed roads and motorways but not during traffic congestion.

6. CONCLUSIONS AND RECOMMENDATIONS

This paper concentrated to investigate the factors affecting the severity level of all road traffic accident occurrences in Yangon City. Ordered probit model was employed with STATA 14 in this study. According to the results, it is noticed that times of day, days of week, license conditions, crash regions, number of lanes (i.e., one-lane, two-lane), light traffic flow, manner of occurrences, and head-on and rear-end collisions were found to be significantly associated with severity levels, whereas average link speeds and congestion levels were found to be insignificant.

It has been found that night times have the greatest impact on the serious and fatal injury severity levels of road traffic accidents and night time crashes are the severest. This is because of drivers driving at low visibility, late night drowsiness of drivers during night times. Hence, drivers driving in night times should be alert with night visibility.

The results also indicate that weekends are more highly effected than weekdays in serious and fatal injury severity levels while have less effect in PDO and slight injury levels. This may be due to light traffic flows and higher travel speeds on weekends, hence law enforcement should be set up to restrict the speed limit and punishment would be given to those who drive more than the restricted speed limits.

It has been found that one-lane and two-lane are more likely to be involved in accident severity levels. From marginal effects (Table 3), it was found that both one-lane and two-lane are more likely to be involved in serious and fatal injury severity levels, and less likely to be involved in PDO and slight injury severity levels. From accident records, it was found that most of the vehicles arrive opposite lane when rear-end collision and then collided with head-on type in opposite lane. So, raised median should be provided especially in two-lane highway as a physical separation.

Drivers driving with license are less likely to be related in severity and have more impact in PDO and slight injury levels than in serious and fatal injury severity levels. Therefore, law enforcement measures should be adopted to restrict drivers driving without license.

Non-CBD regions are more likely to be involved in serious and fatal injury severity levels than in PDO and slight injury severity levels. This may be because of high speed–driving. Therefore, speed limiting signboards should be provided, and law enforcement measures should be adopted to restrict high speed driving in Non-CBD regions.

Link population with ≤ 250 (person per hour) is more likely to be involved in severity levels. Light traffic flow suffer more serious and fatal injury and less PDO and slight injury severity levels. This is because of high speed driving along the road with light traffic flow. Hence, speed limiting signs should be provided, and law enforcement should be adopted to restrict high speed driving.

It was found that collision with pedestrian, and collision with slow vehicles are more likely to be involved in serious and fatal injury levels and less likely in PDO and slight injury severity levels. This may be because of pedestrians walking on the travel lane and crossing the lane where no lane-crossing facilities are provided across the travel lane, and slow vehicles driving on the travel lane. Therefore, better pedestrian walkways and/or lane crossing facilities (e.g. zebra lines, overhead pedestrian walkways, and underground passageways), that will discourage unlawful walking and crossing along the road, should be provided. Bicycle lane also should be provided to prohibit using travel lane.

Collision between motor vehicles, collision with fixed object, and collision between more vehicles are more likely to be related in PDO and slight injury than in serious and fatal injury severity levels. Most of the fixed objects are median, utility poles, signal posts, trees and road side objects. Although median and guardrails are provided for safety purpose, they are hazardous in themselves. To minimize crash related fixed object damages, innovative designs and proper placement should be provided. Road side objects should be relocated to safer place and design of utility pole and signal post should be flexible to be broken down during the collision.

It can be seen that head-on collision is higher fatality and serious injury than PDO and slight injury level. According to accident records, some vehicles took unlawful left-turn at the traffic light point while the red signal light is on and this in turn leads the head-on collision with the vehicle coming from the opposite direction. Therefore, to improve road safety and to minimise head-on collision, red light camera should be installed by law enforcement to take action against those who broke the law. In rear-end collision, it is more likely to be involved in PDO and slight injury than in serious and fatal injury severity levels. Drivers should take care while approaching the traffic signal light point.

This study will provide information to the policy makers as well as transportation engineer or planners about the factors affecting in severity level of all road accidents. Based on these information, proper counter measures and road safety improvements can be provided for the reduction of crashes for the areas under study.

Speed has been found to have mixed effects on road safety in the literature. It was also argued that speed itself may not be a safety problem but speed variation is may be a safety problem. In this analysis, average link speed was not significant factor in severity level of all road traffic accident. Therefore, speed variation should be considered in future severity levels analysis.

In this study, it was found that the traffic congestion levels are statically insignificant. This may be due to the use of average travel speeds in measurement of congestion measurement. Speed is also insignificant factor in this analysis. It is suggested that future research should focus on testing the effects of different congestion measurements using advanced accident prediction models. That is, different measures (e.g. volume to capacity ratio and traffic density) should be used to obtain congestion levels for future studies.

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