Examining Relationship between Accident Occurrences and Road Characteristics on Yangon - Mandalay Expressway in Myanmar

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Abstract

Traffic crashes on Yangon-Mandalay Expressway in Myanmar become a worse problem resulting in many deaths, injuries, disabilities and damage to both private and public properties. This expressway is the most important one in the country and it passes through Naypyitaw, the capital city of Myanmar, as well as linking Yangon to the south and Mandalay to the north. Although over speeding is the major cause of traffic crash on Yangon-Mandalay Expressway, traffic crashes due to human behavior, road environment and road characteristic are also investigable factors. The purpose of the study is to examine relationships between crash frequency and road characteristics on that expressway. Negative binomial regression model was performed to predict the numbers of crash based on road characteristics variables. These variables include average daily traffic, road geometric variables, presence of bridge and presence of village settlement along the expressway. The last three years traffic crash data were used to develop the crash prediction model. The result shows that accident occurrences are found to be significantly related to average daily traffic, presence of bridge, presence of village settlement, percent downgrade and combination of horizontal curve and slope.

Keywords: Traffic crashes, Road characteristics, Negative binomial regression, Yangon-Mandalay Expressway

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1. Introduction

1.1 Rationale and Background

Road traffic accidents cause injuries, death and losses of properties; it is one of the problems faced by modern societies of the world today. According to the Global status report on road safety 2013, about 1.24 million people globally die each year as a result of road traffic crashes, which means nearly 3400 deaths a day. Without taking action, annual road traffic deaths are likely to increase up to 1.9 million by 2030 and might become the seventh leading cause of death (World Health Organization [WHO], 2013). Therefore, road traffic crashes are prone to be a major socio-economic problem of the world.

In Myanmar, one of the developing countries in Southeast Asia, a new expressway connected between two major cities (Yangon and Mandalay) was constructed in 2005 and it passes through several cities including Naypyitaw, the capital of Myanmar. This expressway is one of the infrastructure development projects undertaken by the former military government in the country and about 40 miles shorter than the existing old highway.

A few funds were invested in safety measure and engineers were instructed by the government to complete the project in a short period. As a result, the project led to be a rush job. Although it was expected to be the most convenient and safest expressway for road users, many traffic accidents have been occurring on that way. Annual number of traffic crash on that expressway has been increasing with the rapid growth of vehicle ownership. The location of Yangon-Mandalay Expressway is shown in Figure 1 and specifications of it are also stated below.

1.1.1 Specifications of Yangon-Mandalay Express way

This is four lane divided expressway with 30 ft wide raised median between the directions of traffic flow. A total length is 366 mile (589 km). Road surface comprises two layers of concrete, 12 inches thick surface layer and 6 inches thick lean concrete layer. The expressway can withstand a vehicle load up to 80 tons and vehicle speed limit is 100 km/hr. There are a total of 905 box culverts, 462 bridges and 116 underpasses along the Expressway. Motorcycle and pedestrian are prohibited to access on the expressway.

Figure 1. Location Map of Yangon-Mandalay Expressway.

1.2 Problem Statement

In all traffic accident reports of Yangon-Mandalay Expressway, road users were mostly criticized (due to over speeding) without thoroughly analyzing other factors such as road surface defect, defective road geometric design, insufficient number of lanes, structural deformation of pavement and other road safety management system. It has been verified by a previous research that speed on a road section is the only factor influencing the severity of crashes on expressway (Ratanavaraha & Suangka, 2014, pp. 130-136). Although speeding is universally recognized as related to traffic crashes, other accident contribution factors are still needed to be considered on Yangon-Mandalay expressway. All accidents on that expressway are listed as due to “driver error”, “over speeding”, “tire bursting” is not a good conclusion that other road characteristics are not involved and no further considerations are required.

1.3 Research Objective

The major objective of the study was to examine relationships between road characteristics and traffic crashes and to support safety improvement program on Yangon-Mandalay expressway.

2. Literature Review

2.1 Model Explanatory Variables

There have been analyzing the relationship between road characteristics and number of traffic crashes in several research papers (Mohammadi, Samaranayake & Blam, 2014; Shenker, Chowksey & Sandhu, 2015; Kassawat, Sarapirome & Ratanavaraha, 2015). The nature of these researches varies with different types of roads, different numbers of road characteristics and different methods of analyses. Many researchers have considered Average Daily Traffic (ADT) in the crash prediction model as the most effective parameter and it has positive relationship with traffic accidents (Saffarzadeh & Pooryari, 2005; Caliendo, Guida & Parisi, 2007; Kumar, Parida & Jain, 2013). Aram (2010) claimed the important of horizontal curve that are more dangerous when combined with gradients and surface with low coefficients of friction. Psarianos, Kontaratos and Giotis (1994) concluded their analysis that there is a strong relationship between the radius of horizontal curve and grade and there should have larger minimum curve radius on longitudinal grade at higher vehicle speed. In addition, Bauer and Harwood (2013) stated that crash frequency increases with decreasing horizontal curve radius and increase with increasing percent grade and grade difference. Apart from the road geometric characteristics, traffic accidents have been found to be associated with other road environment factors. The variable, presence of village settlement, represents the level of pedestrian interference with vehicles on the highway sections and the section which had a village settlement were found to increase injury crashes by 60.3% compared with sections with no settlements (Ackaah & Salifu, 2011). Mohammed, Umar, Samson and Ahmad (2015) also explained that number of towns or villages on the routes seem to play an important role in traffic safety. There have very few recent published literature sources related to traffic accident and presence of bridge. Ogden (1989) reported about bridge crash prediction model and reviewed significant factors associated with bridge crashes.

2.2 Model Form

An Accident Prediction Model (APM) is a mathematical formula describing the relation between the safety level of existing roads (i.e. crashes, victims, injured, fatalities, etc.) and variables that explain this level (road length, width, traffic volume, etc.). The parameter of the model, however, can vary between types of roads and countries due to differences in road characteristics, road user behavior, vehicle type and environment of the road from place to place (Eenink, Reurings, Elvik & Stefan, 2008).

In statistics, the Generalized Linear Model (GLM) is a flexible generalization of ordinary linear regression. GLM allows response variables with error distribution other than a normal distribution. Currently, Generalized Linear Model (GLM) is the popular approach for the development of Crash Prediction Models (Greibe, 2003; Ackaah & Salifu, 2011; Kumar, Parida & Jain, 2013; Zou, Wu & Lord, 2015). Poisson regression model, a family of GLMs, is widely used in modeling count data since accident data are in the form of count and discrete property. However, the use of Poisson regression has been restricted by the limitation; because Poisson regression has a strong assumption of mean equal to variance (Miaou & Lum, 1993). Negative Binomial (NB) Model is the extension of Poisson model and an alternative approach to modeling over-dispersion (variance > mean) in count data. It has been remained as the most commonly used statistical tool among several statistical models that have been proposed for modeling crash data (Kibar, Celik & Aytac, 2013; Zou, Wu & Lord, 2015; Naznin, Currie, Logan & Sarvi, 2016). Oppong (2012) argued that NB model is best fit for the over-dispersion data. Although NB is more general than the Poisson model, it cannot perform well when the data is under-dispersed (Variance < Mean) or characterized by low sample mean and small sample size. Conway Maxwell Poisson Model is one of the integrated Poisson model. The main advantage of this distribution over other model is its ability to handle both the over-dispersion and under-dispersion data. However, it is also noted that the model does not perform well when the mean of the sample is low or the sample size is very small (Lord, Geedipally & Guikema, 2010).

3. Methodology

3.1 Data Collection

The data were specified into three groups; crash data, road data and road geometric data. Crash data consists of several types of collision based on the 2013 - 2015 period. The road data comprises information on AADT, surface roughness and surface type of the road, lane and median width, terrain type of the road, location of bridges, village settlement and guardrails. And the road geometric data contains horizontal and vertical profile of the expressway. Secondary types of data were acquired from the Ministry of Construction of the Myanmar government. The data were then extracted and processed by using Microsoft excel application to perform the crash prediction model.

3.2 Study Location and Defining Road Section

Yangon-Mandalay expressway, whose total length was 366 miles, was selected for study location. Road sections were divided into one mile uniform length segments for analysis process.

3.3 Variable Selection and Description

A total of eight predictor variables were used in the crash prediction model. Their description and range of values were shown in Table 1.

Table 1. Variable Selection and description.

No	variable	Description of variable	Type and Range of values
1	Response variable	Number of accident in three years per road segment	Continuous variable
2	Predictor variables	Average Daily Traffic per road segment	Continuous variable
3		Presence of sharp horizontal curve per road segment	Categorical variable 1= present , 0 = absent
4		Average horizontal curvature per road segment	Continuous variable
5		Percent upgrade per road segment	Continuous variable
6		Percent downgrade per road segment	Continuous variable
7		Combination of horizontal curve and slope per road segment	Categorical variable 1= yes, 0 = otherwise
8		Presence of bridge per road segment	Categorical variable 1= None 2= presence one bridge 3= presence two and more bridges
9		Presence of village settlement per road segment	Categorical variable 1= present , 0 = absent

3.4 Statistical Model Overview

The study focused on traffic accident and road characteristic on Yangon-Mandalay Expressway in Myanmar. It is generally known that there is a complex relationship between crash occurrences and road characteristics. A factor or a combination of factors is an origin of accident occurrences. To control this complexity, accident prediction models can be used as a tool. Accident prediction models are used to predict the number of accidents on highways based on various accident modification factors such as traffic volume, lane width, shoulder width, degree of curvature etc. In this study, Negative Binomial Regression model was performed to examine relationships between traffic crash and road characteristics and Figure 2 displays the procedure of the study.

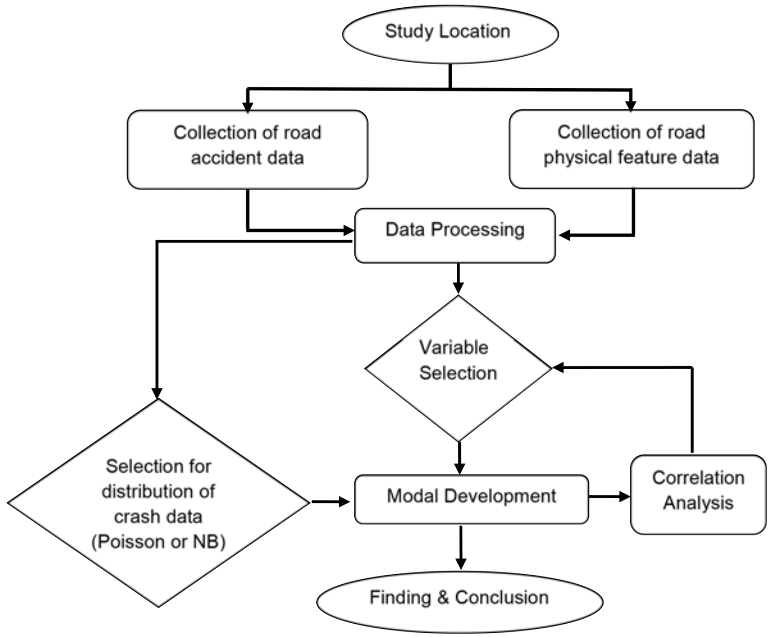

Figure 2. Flow chart for methodology.

3.4.1 Negative Binomial Regression Model

According to the descriptive statistic of the study, the mean and variance of crash data ware 1.33 and 2.60 respectively. Hence, the frequency of crashes was assumed to follow a Negative Binomial distribution as variance of response variable was greater than its mean. And this was consistent with previous research papers (Dissanayake & Ratnayake, 2016; Kibar, Celik & Aytac, 2013; Naznin, Currie, Logan & Sarvi, 2016). Negative Binomial regression is a type of generalized linear model and it is the simple extension of the regular Poisson Regression to allow the variance to differ from its means. The link function of the model is log and model coefficients are estimated by the maximum likelihood approach. The predicted number of crash for each of highway segments modeling in NB regression can be described as follows;

$$\hat{Y} = e^{(\alpha \times \beta_1 \ \ln AADT \times \sum_{i=0}^{n} \beta_i X_i)} \qquad \text{Equation 1}$$

Where; $\hat{Y}$ = predicted number of crash
AADT = annual average daily traffic
X = predictor variables
α = model intercept
β_i = model coefficients

The predictor variable, Annual Average Daily Traffic (AADT) referred to exposure variable in the model and it was transformed into natural log. Transforming exposure variable provided a better fit and was suitable for functional representation of larger AADT values (Valentová, Ambros & Janoška, 2014). Furthermore, transforming exposure measures to the natural logarithm was common practice of crash prediction modeling in previous researches (Ackaah & Salifu, 2011; Ceungnck, T. D., Daniels, S., Brijs, T., Hermans, E. & Wets, G., 2011; Valentová, Ambros & Janoška, 2014).

3.4.2 Model Development

To predict the number of crash on Yangon-Mandalay expressway, Negative Binomial regression model was performed with the help of SPSS (Statistical Package of Social Science) statistical software. Three year's accident data were considered as the response variable. Annual Average Daily Traffic (AADT), presence of sharp horizontal curve, average horizontal curvature, percent upgrade, percent downgrade, combination of horizontal curve and slope, presence of bridge and presence of village settlement within road segment were determined as predictor variables. Correlation analysis had been carried out not only between predictor variables but also between predictor variables and response variable. Low correlation coefficient showed that there was no strongly association between these variables. Variables with high degree of correlation were removed from the model to maintain the reliable result.

3.4.3 Model Evaluation

Two statistical measures were used to evaluate the statistical performance of the model. These were the Pearson Chi-square statistics and the Deviance statistics. Table 2 displays the goodness of fit measures estimated by the SPSS software. The value of Pearson Chi-square and Deviance statistics divided by its degree of freedom were estimated to be 1.081 and 1.088 respectively. This showed that the assumption of Negative Binomial (NB) distribution and the use of NB modal were appropriate for the data since these values were within the acceptable range, between 0.8 and 1.2 (Ackaah & Salifu, 2011; Dissanayake & Ratnayake, 2006). The value of dispersion parameter, estimated from the NB model which has shown in table 3, was found to be significantly different from zero (Ø=0.341); this also suggested that the use of NB model was more suitable than using Poisson model (Naznin, Currie, Logan & Sarvi, 2016).

3.4.4 Model Parameter Estimation

Table 3 represents the parameter estimation of the model. Five predictor variables including presence of bridge, Annual Average Daily Traffic (AADT), percent downgrade, combination of horizontal curve and slope and presence of village settlement were statistically significant with statistical criterions ($P < 0.05$ and 95% confident intervals for the coefficients).

Table 2. Goodness of fit test of the model estimated by SPSS statistical software.

Goodness of fit statistics	Value	df	Value/df
Deviance	787.360	724	1.088
Scaled Deviance	787.360	724	
Pearson Chi-Square	782.464	724	1.081
Scaled Pearson Chi-Square	782.464	724	
Log Likelihood[b]	-1102.3		
Akaike's Information Criterion (AIC)	2220.14		
Finite Sample Corrected AIC (AICC)	2220.34		
Bayesian Information Criterion (BIC)	2256.91		
Consistent AIC (CAIC)	2264.91		

4. Results and Interpretation

The results can be written as following equation;

$$E(Y) = EXP(-4.895+0.275PB+0.609\ lnADT +0.242PD+0.422CHS+0.286PV) \quad \text{Equation 2}$$

Where;

- E(Y) = Predicted number of accident per road segment
- PB = Presence of bridge per road segment
- AADT = Annual Average Daily Traffic per road segment
- PD = Percent downgrade per road segment
- CHS = Combination of horizontal curve and slope per road segment
- PV = Presence of village settlement per road segment
- EXP = Exponential function (e = 2.718282)

Table 3. Parameter Estimation of the Model estimated by SPSS statistical software.

Parameter Estimates							
Parameter	coefficients	Std. Error	95% Wald Lower	95% Wald Upper	Hypothesis Test Wald	Hypothesis Test df	Hypothesis Test Sig.
(Intercept)	-4.859	1.3537	-7.512	-2.206	12.884	1	.000
[Presence of bridge = 3]	.087	.1165	-.141	.316	.560	1	.454
[Presence of bridge = 2]	.275	.0862	.106	.444	10.197	1	.001
[Presence of bridge = 1]	0[a]	.	.	.	.	.	.
Ln AADT	.609	.1780	.260	.958	11.690	1	.001
Percent downgrade	.242	.0635	.118	.367	14.570	1	.000
Combination of Horizontal curve and slope	.422	.0840	.257	.587	25.226	1	.000
Presence of village settlement	.286	.0928	.104	.467	9.474	1	.002
(Scale)	1[b]						
(Negative binomial)	.341	.0602	.242	.482			

One of the predictor variables in the prediction model, presences of bridge, has positive relationship with crash frequency. It has been found out that some of the bridge existing on Yangon-Mandalay Expressway have complex geometric approach, lack of bridge-approach guardrail with proper transition and end treatment. This situation might happen to bridge related crashes on the expressway.

Annual Average Daily Traffic (AATD) has been used as the exposure variable in previous crash prediction models and there is relationship between traffic volume and traffic accidents (Saffarzadeh & Pooryari, 2005; Caliendo, Guida & Parisi, 2007; Kumar, Parido & Jain, 2013). The study result is compatible with these papers indicating that AADT is statistically significant with positive estimation coefficient; meaning that crash frequency increases with increasing traffic volume.

The positive regression coefficient of percent downgrade in the model expresses that crash frequency increases as percent downgrade increases. This situation might concern with the skidding and demand of side friction on downgrade. Downgrade changes the distribution of weight on tires and consequently they can alter the dynamic performance of vehicles in terms of forces and accelerations. As a result, the side friction factor increases as the downgrade increases (Kordani & Molan, 2014).

The variable naming combination of horizontal curve and slope in the model has a considerable influence on the crash frequency as indicated by the positive model parameter. The previous study has shown a similar result reporting that horizontal curves are more dangerous when it combine with gradients and surface with low coefficients of friction (Aram, 2010). Horizontal and vertical curves should not be designed independently when a section of a highway needs to be designed combined alignments. Imperfect combination of horizontal and vertical alignment may pose negative impact on driving comfort and worsen safety effect.

Ackaah and Salifu (2011) have found an increase of injury crashes in road sections which has village settlements compared with segments with no settlements. Likewise, the predictor variable in the model, presence of village settlement, has positive significant coefficient and proved that number of accident increases with increasing village settlement along the expressway. Crash data used for this study include several types of crash such as collisions involving motorcycle and passenger vehicle, vehicle-animals collisions and vehicle-pedestrian collisions. The vast majority of these accidents can be related to the settlement of local people along the expressway.

5. Conclusion

The study examined dominant factors that lead to crash frequency on Yangon-Mandalay Expressway in Myanmar. Negative Binomial regression, a family of Generalized Linear Model, was developed to estimate the model parameters. It was found out that there is relationship between traffic crash frequency and road characteristics variables including presence of bridge, Average Daily Traffic, combination of horizontal curve and slope, percent downgrade and presence of village settlement along the expressway. The finding can be applied as a tool for improving safety performance process on Yangon-Mandalay Expressway.

6. Recommendations

The following recommendations can be provided with regard to the finding. A combination of education, enforcement and engineering measures will be required to eliminate the crash frequencies on Yangon-Mandalay Expressway. The geometric improvements for traffic safety on road sections where horizontal alignment combined with vertical alignment include: (1) widening the lane and shoulder width on sharp horizontal curves, (2) increasing the amount of super elevation (up to maximum allowable rate), (3) increasing the distance of road side clear zone, (4) increasing the value of side friction (up to maximum allowable value) on every downgrade curve site, (5) delineating the pavement at all hazard locations to provide visual information to road users, and (6) providing warning by the use of traffic control devices to reduce vehicle speed limit at every approach to the curve and downgrade.

Safety improvements related to the existing bridges on Yangon-Mandalay Expressway includes: (1) providing speed reduction signs at every approach to the skew bridge and the bridge consists of complex geometric approach, and (2) black and yellow hazard marking should be supplied at the areas surrounding the bridge to enable the driver's awareness on presence of it.

The influence of pedestrians and motorbikes on Yangon-Mandalay Expressway can be determined as the lack of enforcing road rules and road safety education to users. To overcome this problem, road authorities fundamentally need to implement how to educate and enforce road safety to the local people living close to the expressway. In addition, there is needed to constructed other minor roads; i.e., frontage road, roads connect village to village and village to town with interchange if it is required, so that road users are needless to assess the expressway and cross directly any other traffic streams.

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