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Article

Analyzing Human, Roadway, Vehicular and Environmental Factors Contributing to Fatal Road Traffic Crashes in Thailand

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Abstract. The objectives of this research were to investigate the contributions of risk factors to fatal injuries of severe crash victims and analyze the potential causes of traffic fatalities in Thailand. Two binary logistic regression models were proposed. The first model was conducted for investigating and comparing the impacts among the risk factors. The second model was conducted for further comparing the influence of each category within each factor. The results showed that exceeding the speed limit was the major cause of fatal crashes, especially for motorcycle riders. The odds of death in a crash increased with age. Males were more associated with fatal crashes than females; however, drunk females were more likely to die in crashes. Drunk road users in pick-ups and cars possessed the greatest odds of being fatal crash victims. Better lighting conditions improved safety. Rough and slippery roadway surfaces during the rain greatly increased the fatal risk. Curves on urban streets and local roads induced the greatest fatal risks, followed by conflict points on local roads. Conflict points were the most hazardous locations for drunk road users in accidents. These findings give the policy makers some insights on what traffic safety aspects to improve for reducing the number of traffic fatalities.

Keywords: Accidents, fatal crash, risk, road safety, logistic regression.

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1. Introduction

Road traffic crashes are one of the global leading causes of death, killing approximately 1.35 million road users worldwide each year [1]. Recently, road traffic safety has been included in the UN Sustainable Development Goals (SDGs) as a public health challenge, indicating that the elimination of road traffic deaths and severe injuries is recognized as a key to the global development agenda [2]. Road traffic accidents are also one of the major public health challenges in Thailand, causing extremely high number of road traffic deaths and injuries among road users around the country [1, 3–8]. Furthermore, Thailand is one of the countries which encounters the most serious road traffic fatalities setback, being globally ranked sixth in the reported total annual number of road traffic fatalities and ninth in the road traffic death rate per inhabitants, with an estimated 22,000 death cases annually and 32.7 deaths per 100,000 population per year, respectively [1]. This problem is considered as one of the obstacles for developing the country in terms of social and economic aspects due to the loss in human resource and public health expenditure that the whole country needs to spend for healing road accident victims. Since the contributions of crash-related factors to fatal injuries varies among countries and, thus, should be considered as region-specific due to differences in local characteristics of road users and roadways among different countries. Consequently, a specific analysis needs to be conducted to investigate the factors affecting fatal crashes in Thailand. The objectives of this study are, therefore, to examine influences of the crash-related factors on fatal injury of a crash victim in Thailand using binary logistic regression approach and perform an investigation on the potential causes of the fatal road traffic crashes based on the results obtained.

2. Literature Review

Road traffic crashes were found to occur with respect to interactions between three main crash contributing factors: human-related factors, roadway-related factors, and vehicle-related factors [9]. According to several previous studies, human-related factors were found to contribute the most to road traffic crashes, followed by roadway factors [9, 10].

Most of the previous studies aimed to examine various crash-related factors to determine the correlations between these factors and an occurrence of a fatal road traffic accident in order to seek for solutions for reducing the number of human fatalities [4, 6, 7, 10–25].

A number of previous studies in the literature merely focused on causes of traffic fatalities in terms of human-related factors [5], [26], whereas some research only considered non-human-related factors to predict an occurrence of a fatal road crash [6, 7, 17, 19, 22, 23, 25]. However, most of the previous studies were found to consider roadway-related and environment-related factors, together with human-related factors, as potential factors that affect an occurrence of a fatal road crash [4, 10–12, 15, 16, 18, 20, 21, 24, 27].

Some previous studies on crash-related factor analysis in literature solely adopted descriptive statistics to examine the causes of road traffic crashes [3, 8, 28–30]. Several previous accident studies applied quantitative secondary demographic and geographical data, such as GDP and fuel consumption per capita, to investigate causes of fatal crashes [14, 27].

However, the application of binary logistic regression modeling was the most commonly used method in recent studies for investigating risk factors associated with road traffic crash since the outcome of the model was the dichotomy between the occurrence or non-occurrence of an event of interest [10, 11, 13, 18, 19, 23, 26].

Several studies revealed that older road users were generally more vulnerable to death in road traffic crashes than younger age groups [10, 12, 13, 15, 18, 20, 24, 29, 31, 32], whereas some research concluded that the increase in age did not significantly affect the risk of death [16, 26].

In addition, some of the previous studies also pointed out that female road users were more prone to fatal road traffic crashes than male road users [12, 18], whereas the results from most of the previous studies showed that male road users were found to be more associated with fatal crashes than female road users [13, 14, 24, 27, 29]. However, some recent studies did not distinguish the effect of gender between male and female as a significant factor that contributed to death in a road traffic crash [10, 16, 26].

Most of the recent studies found that road type was one of the influential factors that contributed to fatal road traffic crashes; with the greatest impact came from the type of road with the highest level of mobility and lowest level of access, such as motorway or highway [18, 25]. In addition, previous studies pinpointed speeding as a major cause of fatal crashes [4, 12, 16, 20, 21, 23, 31].

Some research pointed out that the odds of encountering a fatal crash for road users at a non-intersection location were significantly greater than those at an intersection [11, 19, 23]; however, a previous study opposed this conclusion [14]. Road surface condition was also found to be associated with a fatal accident in some previous research [10, 21, 23], while a previous study did not recognize road surface condition as a factor that affected fatal road crashes [16].

Several recent studies concluded that environment-related factors, such as daylight and weather conditions, also had some impacts on an occurrence of a fatal road traffic crash. A number of previous works unveiled that the increase chance of a fatal road traffic crash was correlated with the lack of daylight or lighting conditions to some degree [18, 19, 21, 23, 24, 29, 32, 33], while some research found no correlation between the lighting condition and a fatal accident [16, 17]. Some previous studies also recognized that clear weather condition induced more chance for an occurrence of a fatal crash than adverse weather conditions, such as rain or fog [10, 17, 22, 24]. However, some research did not find a correlation between weather condition and a fatal road traffic crash [16, 18].

There were also some recent domestic studies attempted to investigate risk factors related to traffic crashes in Thailand via similar approaches [4, 34–38]. A study on Thai expressways identified speeding as the predominant factor leading to fatal crashes [4]. A previous study investigated single-vehicle crashes based on age groups and found that alcohol led to the greater risk of fatal crashes among young and elderly drivers, while nighttime driving without lighting induced the greater chance of fatal crashes in mid-age drivers [34]. Another study attempted to examine causes of single-vehicle running off road (ROR) crashes in Thailand found that running off road to the left or right side on tangents increase the odds of a fatal crash, while intersections were found to mitigate the severity of ROR crashes [35]. There were also recent studies attempted to analyze rear-end crashes in Thailand [36–38]. A recent study attempted to estimate frequencies of rear-end crashes on Thai highways via spatial model [36], while a research compared severities of rear-end crashes between those occurred on urban and rural roadways [37]. A recent study analyzed rear-end crashes on Thai highways via decision tree and found that driver age, number of lanes, and median opening area significantly induced occurrences of fatal crashes [38].

3. Data and Methodology

3.1. Data

Two-year traffic accident data collected during 2015 – 2016 used in this study were extracted from the database of the Department of Disaster Prevention and Mitigation, courtesy of the Ministry of Interior of Thailand [39]. The dataset merely contained datapoints of injuries and fatal crashes, while property-damage only (PDO) crashes were not taken into account in this study. Therefore, non-fatal crashes in this study merely referred to injuries in crashes, and all the datapoints in this study were severe crashes. In total, the number of road traffic crashes collected by the agency during this period was 78,218 cases. The data were filtered to omit the incomplete and inaccurate datapoints from the analysis. Pedestrians were omitted from this study since there were some variables, such as speed limit and roadway surface, which were not directly applicable to pedestrians. Therefore, this study merely focused on drivers or passengers in vehicles. However, agricultural vehicles, trishaws and bicycles were also excluded from the analysis due to their small number of cases. Therefore, the remaining sample size of the road traffic victims in this study were shrunken to 57,837 cases (N = 57,837).

3.2. Descriptive Statistics

Descriptive statistics were conducted to summarize the characteristics of the dataset, as displayed in Table 1. In terms of roadway-related aspect, the majority of the road traffic accidents occurred on highways, respectively followed by local roads, rural highways, and urban or municipal streets. Dry road surface was the condition where most of the road accidents occurred. The statistics also showed that road accidents predominantly happened on tangents, followed by conflict points, curves, work zones or obstacles. Conflict points in this study included intersection, crossroad, and median opening areas. In terms of environmental-related aspect, most of the road accidents occurred during the clear weather. More than half of the accidents occurred during the time with daylight condition. In terms of human-related aspect, youths (below 21 years old) and younger adults (21 - 40 years old) comprised about two-thirds of the total number of road accidents, while elderly road users (above 60 years old) accounted for only 8% of all the crash victims, as depicted in Fig. 1. The percentage of male road users in accidents was approximately 2.3 times greater than the percentage of female road users. The proportion of sober road users in accidents was approximately 6.2 times greater than the proportion of drunk road users. The number of crash victims who exceeded the speed limit was slightly greater than those who traveled within the speed limit. In terms of vehicular aspect, road accidents predominantly occurred to motorcycle users, followed by pick-up and car users, respectively. Finally, about one-fourth of all the crash victims in the dataset encountered fatal injury.

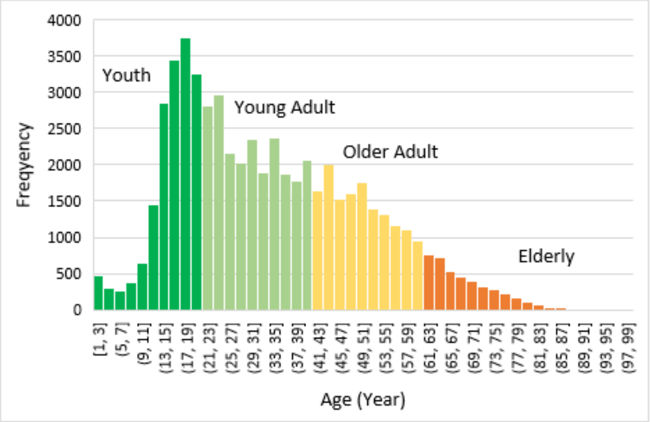

Fig. 1. Road accident frequency by age.

3.3. Methodology

The crash data contained ten determinable factors: road type, road surface, crash location, weather, lighting, age, gender, alcohol, speed limit, and vehicle type. These existing factors were then used to analyze their associations with fatal injury of a road traffic crash victim, which was the dependent variable in this study.

Two binary logistic regression models were then designed to investigate the impacts of these factors on death of a road traffic victim. A generic binary logistic model (Model 1) applied binary logistic regression method for investigating and comparing impacts among – the factors, as well as between the reference category and the other categories within each factor, whether they significantly affected death of a crash victim. All the values of the crash-related factors in the model were set to binary (i.e., in the form of 0 and 1). In addition, a categorical binary logistic model (Model 2) was conducted to further examine the increment impacts of each category within each factor on an occurrence of fatal injury in a crash relative to the reference category, as seen in Table 1.

The IBM SPSS was employed as a tool to perform statistical analyses of these models. Firstly, Pearson correlation coefficients between pairs of independent variables were performed to observe possible significant interactions between variables. Secondly, the omnibus and Hosmer-Lemeshow chi-square tests were performed to assess the goodness of fit of each model. Next, binary logistic regression analysis was performed on each model to examine the influences between the factors and the dependent variable. Finally, the results were then analyzed to investigate the influences of each factor on an occurrence of a fatal crash. The significance level of 0.05 was applied to determine the effects of the crash-related factors on the dependent variable in this study.

Table 1. Classification and descriptive statistics of the independent and dependent variables in the models.

Item	Factor	Category	Coding Value		Frequency	Percentage
			Model 1	Model 2		
Independent Variable - Roadway	Road Type	Highway	0	1	25,921	44.8%
		Rural Highway	1	2	8,922	15.4%
		Urban or Municipal Street	1	3	7,455	12.9%
		Local Road	1	4	15,539	26.9%
	Road Surface	Dry	0	1	54,001	93.4%
		Rough	1	2	1,405	2.4%
		Slippery	1	3	2,431	4.2%
	Accident Location	Tangent	0	1	38,997	67.5%
		Curve	1	2	7,603	13.1%
		Conflict Point	1	3	11,006	19.0%
		Work Zone or Obstacle	1	4	231	0.4%
Independent Variable - Environment	Weather	Clear	0	1	53,742	92.9%
		Foggy or Dusty	1	2	2,010	3.5%
		Rain	1	3	2,085	3.6%
	Lighting	Daylight	0	1	35,037	60.6%
		Nighttime with Lighting	1	2	13,548	23.4%
		Nighttime without Lighting	1	3	9,252	16.0%
Independent Variable - Human	Age	Youth (Below 21)	0	1	15,396	26.6%
		Younger Adult (21-40)	1	2	22,866	39.6%
		Older Adult (41-60)	1	3	14,939	25.8%
		Elderly (Above 60)	1	4	4,636	8.0%
	Gender	Male	0	0	40,502	70.0%
		Female	1	1	17,335	30.0%
	Alcohol	Sober	0	0	49,801	86.1%
		Drunk	1	1	8,036	13.9%
	Speed Limit	Within	0	0	31,004	53.6%
		Exceeded	1	1	26,833	46.4%
Independent Variable - Vehicle	Vehicle Type	Motorcycle	0	1	46,890	81.1%
		Pick-Up	1	2	6,432	11.1%
		Car	1	3	3,105	5.4%
		Truck & Trailer	1	4	820	1.4%
		Bus & Van	1	5	590	1.0%
Dependent Variable	State of the victim	Injury	0	0	43,124	74.6%
		Fatal	1	1	14,713	25.4%

4. Results

The binary logistic regression results of the generic and categorical models were reported along with the corresponding goodness-of-fit results and the other related parameters as follows:

4.1. Interactions between Variables

Prior to analyzing the results, correlations among the variables were observed using Pearson correlation coefficient. A moderate correlation coefficient between road surface and weather condition was found, with a coefficient value of 0.514, while the rest of the correlations between the other pairs of independent variables were relatively weaker. The correlation test indicated that there was no absolute coefficient value of greater than 0.75, which was suggested as a strong cutoff for considering a multicollinearity effect [40]. However, the effects of interactions between variables were observed based on the significances of the interactions in the models, goodness-of-fit indicators, and justifications of the authors. It was found that the interaction between road surface and weather condition significantly affected the dependent variable, which was the state of the crash victims, as suspected. Furthermore, interactions between the other pairs of variables were examined. The tests indicated that there were also other significant interactions between the variables that improved the goodness-of-fit indicators and could provide interesting findings to this study. The recruited interaction terms were road surface and weather condition, accident location and road type, alcohol and gender, vehicle type and alcohol, accident location and alcohol, and speed limit and vehicle type. In summary, six interaction terms were included in the models, in addition to the ten variables introduced earlier.

4.2. Goodness-of-Fit Results

Since low R-Squared values in logistic regression were found to be norm, the R-Squared test was not recommended as an indicator for goodness of fit of logistic regression models [41]. Therefore, the omnibus test and the Hosmer and Lemeshow statistic were adopted for measuring the goodness of fit of each model in this study. However, in reference to the other studies, the Nagelkerke R-square values were then quantified and reported as 0.130 and 0.171 for the Model 1 and Model 2, respectively. The goodness-of-fit results of the Model 1 indicated that the model adequately fit the data at 0.05 significance level, with the significance values of the omnibus test and Hosmer and Lemeshow statistic of <0.001 and 0.062, respectively. Similarly, the Model 2 also showed the acceptable goodness of fit at 0.05 significance level, with the significance values of the omnibus test and Hosmer and Lemeshow statistic of <0.001 and 0.452, respectively. The significance values of the Hosmer-Lemeshow statistic from both models did not indicate a poor fit since these values were not smaller than 0.05.

4.3. Binary Logistic Regression Models

4.3.1. Generic Model (Model 1)

Coefficients of the crash-related factors in both models were tested by using the Wald statistic. The binary logistic regression results of the Model 1 indicated that all 17 factors significantly affected an occurrence of a fatal crash at 0.05 significance level. By comparing the values of B and Exp(B) coefficients among the binary variables, speed limit (exceeded or not) appeared to have the highest influence on contributing to a fatal crash, respectively followed by alcohol (drunk or not), age (younger than 21 or not), lighting condition (daylight or other), road type (highway or other), interaction between surface and weather (dry surface and clear weather condition or other), interaction between alcohol and gender (drunk female or other), gender (male or female), interaction between accident location and road type (highway tangent or other), and interaction between alcohol and vehicle type (sober motorcycle rider or other), as seen in Table 2.

According to the Model 1, a severe crash victim who traveled above the speed limit had more than twice as high odds of encountering a fatal crash as traveling within the speed limit. When considering the interaction between the speed limit and vehicle type, given that the speed limit was violated, a severe crash occurred to any other types of vehicles showed 0.827 times smaller odds of being a fatal crash compared to motorcycle.

A road user who aged at least 21 years old had 1.573 times greater odds of dying in a severe crash, compared to a victim who was under 21 years old. A female crash victim showed 0.545 times smaller odds of dying in a road traffic crash than a male victim. When considering the effects of alcohol consumption with gender, a drunk female had 1.472 times greater odds of being a fatal crash victim than other types of road users.

A severe crash occurred during nighttime, with or without lighting, produced 1.563 times greater odds of being a fatal crash relative to a crash occurred during the time with daylight. Taking into account the effects of accident location with road type, a severe crash occurred at any other locations showed 1.472 times greater odds of being a fatal crash compared to a highway tangent. When considering the effects of road surface with weather, a severe crash occurred on a dry surface under clear weather condition produced 0.663 times smaller odds of being a fatal crash victim than the other types of conditions.

Finally, taking into account the effects of alcohol with accident location, a severe crash occurred to a drunk road user at a location other than tangent had 1.234 times higher odds of being a fatal crash compared to a crash occurred to a sober road user traversing a tangent, as shown in Table 2.

4.3.2. Categorical Model (Model 2)

By classifying each crash-related factor into a categorical variable, the binary logistic regression analysis of the Model 2 highlighted the significance level of each category within each factor relative to the reference category of each factor, as defined in Model 1. All the defined factors indicated their significant impacts on death of a crash victim. While some of the categories within each factor were observed to significantly have various levels of influences on fatal injury of a crash victim relative to the reference categories, some categories did not indicate their different influences on an occurrence of a fatal crash compared to their reference categories, as seen in Table 3.

Table 2. Results of the Generic Model - Model 1.

Factor	B	S.E.	Wald	df	*p*	Exp(B)
Speed Limit (0 = Within, 1 = Exceeded)	0.740	0.023	1032.148	1	<0.001	2.096
Alcohol (0 = Sober, 1 = Drunk)	-0.943	0.046	418.092	1	<0.001	0.390
Age (0 = Younger than 21, 1 = At least 21)	0.453	0.024	351.619	1	<0.001	1.573
Lighting Condition (0 = Daylight, 1 = Nighttime)	0.447	0.021	461.334	1	<0.001	1.563
Road Type (0 = Highway, 1 = Other)	-0.823	0.025	1088.365	1	<0.001	0.439
Gender (0 = Male, 1 = Female)	-0.608	0.024	634.043	1	<0.001	0.545
Vehicle Type (0 = Motorcycle, 1 = Other)	0.219	0.040	30.799	1	<0.001	1.245
Road Surface (0 = Dry, 1 = Slippery or Rough)	-0.252	0.066	14.786	1	<0.001	0.777
Accident Location (0 = Tangent, 1 = Other)	-0.239	0.030	62.228	1	<0.001	0.787
Weather Condition (0 = Clear, 1 = Other)	-0.169	0.057	8.790	1	0.003	0.844
Road Surface by Weather Condition (0 = Dry Surface & Clear Weather, 1 = Other)	0.412	0.100	16.955	1	<0.001	1.509
Gender by Alcohol (0 = Other, 1 = Drunk Female)	0.386	0.110	12.369	1	<0.001	1.472
Accident Location by Road Type (0 = Highway Tangent, 1 = Other)	0.348	0.043	65.490	1	<0.001	1.416
Vehicle Type by Alcohol (0 = Motorcycle & Sober, 1 = Other)	0.331	0.088	14.145	1	<0.001	1.392
Accident Location by Alcohol (0 = Tangent & Sober, 1 = Other)	0.210	0.071	8.868	1	0.003	1.234
Vehicle Type by Speed Limit (0 = Motorcycle within Speed Limit, 1 = Other)	-0.190	0.049	14.931	1	<0.001	0.827
Constant	-1.304	0.031	1780.090	1	<0.001	0.272
Model Goodness-of-Fit Statistics						
Omnibus Chi-Square	5,335.541					
Sig.	<0.001					Nagelkerke R-Square = 0.130
Hosmer and Lemeshow Chi-Square	14.834					
Sig.	0.062					N = 57,837

To begin with, the results from B and Exp(B) coefficients in the Model 2 indicated that a severe crash occurred to a vehicle exceeding the speed limit increased the odds of being a fatal crash by 112.5%. In terms of vehicle type alone, severe crashes occurred to truck/trailer and car users increased the odds of being fatal crashes by 50.5% and 31.2%, respectively, compared to motorcycle; while severe crashes occurred to pick-up and bus/van users did not show significantly different odds of death compared to motorcycle.

However, when considering the interaction between the speed limit and vehicle type, given that the speed limit was violated, severe crashes occurred to motorcycle riders showed the greatest odds of being fatal crashes among the vehicles of interest. Given that the speed limit was exceeded; traveling in a pick-up, car, and bus or van reduced the odds of being a fatal crash victim by 15.6%, 18.9%, and 31.7%, respectively, compared to motorcycle. A severe crash occurred to truck/trailer users did not have significantly different level of odds for being a fatal crash compared to motorcycle, as seen in Table 3.

By categorizing age of the crash participants into four groups: youth (below 21 years old), younger adult (21 – 40 years old), older adult (41 – 60 years old), and elderly (above 60 years old); the results from Model 2 indicated that the older severe crash participants tended to have the greater odds of death. Youths who aged below 21 years old were found to be least involved with fatal crashes among the age groups; while elderly road users had the greatest tendency to be killed in a severe road traffic crash, with the odds of death of 168.5% greater than youths. Younger and older adults were found to moderately increase the odds of death in a crash compared to youths, with the 31.0% and 76.3% higher odds, respectively.

In terms of gender, the odds for female severe crash victims to suffer fatal injuries were 44.7% smaller than the odds for male crash victims. Surprisingly, alcohol alone was found not to increase odds of a fatal crash for road users in general. However, when considering the influence of alcohol consumption with gender, a drunk female had 45.8% greater odds of being a fatal crash victim compared to other types of road users.

Lighting also had significant influence on an occurrence of a fatal crash. Compared to daylight, a severe crash occurred during nighttime without lighting tended to increase the odds of being a fatal crash by 117.9%. In addition, a severe crash occurred during nighttime with lighting showed 40.3% increase in the odds of being a fatal crash compared to a crash occurred during daylight.

Table 3. Results of the Categorical Model - Model 2.

Factor	B	S.E.	Wald	df	p	Exp(B)
Road Type 1 (Highway)	0		1742.919	3	<0.001	1
Road Type 2 (Rural Highway)	-0.172	0.034	25.668	1	<0.001	0.842
Road Type 3 (Urban or Municipal Street)	-1.082	0.046	548.943	1	<0.001	0.339
Road Type 4 (Local Road)	-1.294	0.034	1411.595	1	<0.001	0.274
Road Surface 1 (Dry)	0		17.378	2	<0.001	
Road Surface 2 (Rough)	-0.172	0.080	4.612	1	0.032	0.842
Road Surface 3 (Slippery)	-0.435	0.121	12.955	1	<0.001	0.647
Accident Location 1 (Tangent)	0		74.453	3	<0.001	1
Accident Location 2 (Curve)	-0.117	0.044	7.025	1	0.008	0.890
Accident Location 3 (Conflict Point)	-0.311	0.037	69.609	1	<0.001	0.733
Accident Location 4 (Work Zone or Obstacle)	0.522	0.325	2.582	1	0.108	1.686
Weather Condition 1 (Clear)	0		13.494	2	0.001	1
Weather Condition 2 (Foggy or Dusty)	-0.215	0.063	11.477	1	0.001	0.806
Weather Condition 3 (Rain)	-0.208	0.140	2.209	1	0.137	0.812
Lighting Condition 1 (Daylight)	0		799.742	2	<0.001	1
Lighting Condition 2 (Nighttime with Lighting)	0.339	0.025	177.129	1	<0.001	1.403
Lighting Condition 3 (Nighttime without Lighting)	0.779	0.028	773.495	1	<0.001	2.179
Alcohol (0 = Sober, 1 = Drunk)	-0.904	0.047	373.595	1	<0.001	0.405
Speed Limit (0 = Within, 1 = Exceeded)	0.754	0.024	1024.503	1	<0.001	2.125
Gender (0 = Male, 1 = Female)	-0.592	0.025	578.944	1	<0.001	0.553
Age Group 1 - Youth (Below 21)	0		778.267	3	<0.001	1
Age Group 2 - Younger Adult (21-40)	0.270	0.027	99.521	1	<0.001	1.310
Age Group 3 - Older Adult (41-60)	0.567	0.029	380.286	1	<0.001	1.763
Age Group 4 - Elderly (Above 60)	0.988	0.039	629.951	1	<0.001	2.685
Vehicle Type 1 (Motorcycle)	0		26.441	4	<0.001	1
Vehicle Type 2 (Pick-Up)	0.064	0.050	1.641	1	0.200	1.066
Vehicle Type 3 (Car)	0.272	0.071	14.690	1	<0.001	1.312
Vehicle Type 4 (Truck/Trailer)	0.409	0.119	11.764	1	0.001	1.505
Vehicle Type 5 (Bus/Van)	-0.066	0.140	0.222	1	0.638	0.936
Road Surface by Weather Condition (SF & WE)						
SF & WE 1 (Dry & Clear)	0		17.309	4	0.002	1
SF & WE 2 (Rough & Foggy/Dusty)	0.050	0.210	0.056	1	0.813	1.051
SF & WE 3 (Rough & Rain)	1.094	0.303	13.065	1	<0.001	2.987
SF & WE 4 (Slippery & Foggy/Dusty)	0.110	0.266	0.172	1	0.678	1.117
SF & WE 5 (Slippery & Rain)	0.608	0.193	9.873	1	0.002	1.836
Accident Location by Road Type (LC & RD)						
LC & RD 1 (Highway Tangent)	0		103.486	9	<0.001	1
LC & RD 2 (Rural Highway Curve)	0.225	0.078	8.350	1	0.004	1.253
LC & RD 3 (Urban Street Curve)	0.589	0.117	25.475	1	<0.001	1.802
LC & RD 4 (Local Road Curve)	0.619	0.075	67.603	1	<0.001	1.857
LC & RD 5 (Conflict Point on Rural Highway)	0.175	0.076	5.317	1	0.021	1.192
LC & RD 6 (Conflict Point on Urban Street)	0.068	0.089	0.594	1	0.441	1.071
LC & RD 7 (Conflict Point on Local Road)	0.447	0.078	32.985	1	<0.001	1.564
LC & RD 8 (Work Zone/Obstacle on Rural Highway)	-0.254	0.467	0.294	1	0.587	0.776
LC & RD 9 (Work Zone/Obstacle on Urban Street)	-1.079	0.619	3.040	1	0.081	0.340
LC & RD 10 (Work Zone/Obstacle on Local Road)	-0.187	0.454	0.169	1	0.681	0.830
Gender by Alcohol (0 = Other, 1 = Drunk Female)	0.377	0.111	11.526	1	0.001	1.458
Vehicle Type by Alcohol (VH & ALC)						
VH & AL 1 (Motorcycle & Drunk)	0		19.480	4	0.001	1
VH & ALC 2 (Pick-Up & Drunk)	0.426	0.108	15.690	1	<0.001	1.531
VH & ALC 3 (Car & Drunk)	0.332	0.147	5.097	1	0.024	1.394
VH & ALC 4 (Truck/Trailer & Drunk)	-0.194	0.527	0.135	1	0.713	0.824
VH & ALC 5 (Bus/Van & Drunk)	0.036	1.101	0.001	1	0.974	1.037

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Table 3. Results of the Categorical Model - Model 2 (Cont.).

Factor	B	S.E.	Wald	df	*p*	Exp(B)
Accident Location by Alcohol (LC & ALC)						
LC & ALC 1 (Tangent & Drunk)	0		17.026	3	0.001	1
LC & ALC 2 (Curve & Drunk)	0.013	0.089	0.022	1	0.883	1.013
LC & ALC 3 (Conflict Point & Drunk)	0.391	0.098	16.092	1	<0.001	1.479
LC & ALC 4 (Work Zone/Obstacle & Drunk)	-0.347	0.600	0.334	1	0.563	0.707
Vehicle Type by Speed Limit (VH & SPD)						
VH & SPD 1 (Motorcycle & Exceeded)	0		16.658	4	0.002	1
VH & SPD 2 (Pick-Up & Exceeded)	-0.170	0.063	7.338	1	0.007	0.844
VH & SPD 3 (Car & Exceeded)	-0.210	0.086	5.886	1	0.015	0.811
VH & SPD 4 (Truck/Trailer & Exceeded)	-0.217	0.154	1.990	1	0.158	0.805
VH & SPD 5 (Bus/Van & Exceeded)	-0.382	0.190	4.021	1	0.045	0.683
Constant	-1.323	0.031	1766.239	1	<0.001	0.266
Model Goodness-of-Fit Statistics						
Omnibus Chi-Square	7,114.092					
Sig.	<0.001	Nagelkerke R-Square = 0.171				
Hosmer and Lemeshow Chi-Square	7.816					
Sig.	0.452	N = 57,837				

When assessing the effects of interaction between road surface and weather condition, a severe crash occurred on a rough surface during the rain produced 198.7% greater odds of being a fatal crash than a dry surface during the clear weather. A crash occurred on a slippery surface under rain condition increased the odds of being a fatal crash by 83.6%, compared to a dry surface during the clear weather. However, crashes occurred during the foggy or dusty weather on any types of surfaces did not show significantly different level of fatal odds from the dry surface under clear weather conditions.

By classifying road types into four categories, the results based on the absolute values of Exp (B) coefficients indicated that highway was the type of road that had the greatest influence on contributing to fatal injury of a road user, respectively followed by rural highway, urban or municipal street, and local road. Furthermore, when categorizing accident locations into four categories, the results from the categorical model showed that tangent and work zone or obstacle were among the types of locations that produced the greatest influences on fatal crash contributions, respectively followed by curve and conflict point, as shown in Table 3.

Nevertheless, taking into account the effects of accident location with road type altogether, local road curves were found to be the most dangerous locations for fatal crashes; followed by urban street curves, conflict points on local roads, rural highway curves, conflict points on rural highways, and highway tangents, respectively.

The results indicated that severe crashes occurred on local road curves produced 85.7% greater odds of being fatal crashes compared to highway tangents; followed by crashes occurred on urban street curves, with the odds of 80.2% higher than highway tangents. Next, compared to highway tangents, severe crashes occurred at conflict points on local roads increased the odds of being fatal crashes by 56.4%, while crashes occurred on rural highway curves increased the odds of being fatal crashes by 25.3%. Crashes occurred at conflict points on rural highways showed 19.2% increase in the odds of being fatal crashes compared to highway tangents, as seen in Table 3. However, crashes occurred at work zones or obstacles on any types of roads and conflict points on urban streets did not indicate significantly different level of fatal odds from crashes occurred on highway tangents.

Interestingly, taking into account the effects of alcohol with accident location, a severe crash occurred to a drunk road user at a conflict point provided 47.9% greater odds of being a fatal crash compared to a crash occurred to a drunk road user traversing a tangent, as shown in Table 3. However, curve and work zone or obstacle did not show significantly different odds from tangent in terms of inducing an occurrence of a fatal crash.

Finally, when the effects of vehicle type and alcohol consumption were considered altogether, a drunk road user who traveled by a pick-up and a car had greater odds of being dead in a crash than traveling by motorcycle by 53.1% and 39.4%, respectively. However, drunk travelers in trucks/trailers and buses/vans did not show significantly different odds from motorcycle in being victims of fatal injury, as shown in Table 3.

5. Discussion and Conclusions

The aims of this research were to analyze the contributions of the risk factors to deaths of severe crash victims in Thailand and perform an investigation on the potential causes of the fatal road traffic crashes. Two binary logistic regression models were proposed based on the two-year traffic accident data in Thailand during 2015

– 2016. The first model was conducted for investigating and comparing impacts among the factors whether they significantly affected fatal crashes. The second model was conducted for further examining the impact of each category within each factor on contributing to death in a severe crash relative to the reference category. The proposed study provides a useful contribution to the literature in terms of highlighting the risk factors and their levels of contributions to fatal road traffic crashes. The findings from this research also provide the policy makers some insights on what features to focus for improving traffic safety to reduce the number of fatal crashes in Thailand.

All the ten factors and six interaction terms, as included in the models, were found to significantly influence fatal injuries in road traffic crashes in Thailand. Sorted by the level of influence in descending order, the factors considered in this study were: 1) speed limit, 2) alcohol, 3) age, 4) lighting condition, 5) road type, 6) interaction between surface and weather, 7) interaction between alcohol and gender, 8) gender, 9) interaction between accident location and road type, 10) interaction between alcohol and vehicle type, 11) vehicle type, 12) interaction between accident location and alcohol, 13) surface, 14) accident location, 15) interaction between vehicle type and speed limit, and 16) weather conditions.

Exceeding the speed limit was found to be at the top of the list in terms of influence on contributing to an occurrence of a fatal crash in this study, which complied with the previous studies [4, 12, 16, 20, 21, 23, 31]. The results indicated that a crash victim who traveled above the speed limit had approximately twice as high odds of encountering a fatal crash as traveling within the speed limit. The underlying reason could be the higher speed a road user choose, the greater magnitude of reaction force is applied to his/her body in a vehicle collision and, thus, the level of trauma could increase.

The further analysis in this study found that, given that the speed limit was exceeded, a crash occurred to a motorcycle rider possessed the greatest risk of being a fatal crash among the types of vehicles in this study. This could potentially be due to the feature of motorcycle that lacked the protection structure for passengers, in contrast to the other types of vehicles.

Age was also found to be associated with deaths of crash victims. This study found that the older crash victim led to the greater odds of death. Elderly crash victims (above 60 years old) were the most vulnerable to death in road traffic crashes than the younger age groups. Although the frequencies of crashes occurred to youths and young adults were among the highest, as seen in Fig. 1, the odds of death for them in a crash were substantially lower than the odds for elderly or older adult crash victims. This finding conformed with most of the previous findings in literatures [10, 12, 13, 15, 18, 20, 24, 29, 31, 32]. This could possibly be due to the diminished capability of the elderly to withstand physical harms in crashes, in contrast to the younger road users. AASHTO suggested that traffic facilities should be designed to the extent practical to accommodate elderly road users due to the age-related diminished capabilities. Also, recent findings suggested that by enhancing the highway system to accommodate elderly road users, safety for all other users would also be improved [42].

Males were found to be more involved with fatal crashes than females in this study. In addition, the severe crash frequency for male road users was three times the severe crash frequency for female road users in Thailand. This finding was found to be consistent with the findings suggested by the majority of the previous studies in the literature [13, 14, 24, 27, 29]. However, by digging deeper, this study found that drunk females had higher tendency of being fatal crash victims compared to drunk male or sober road users in general.

Lighting condition also significantly influenced death of road users in severe crashes since more fatal crashes tended to occur during nighttime. Crashes occurred during nighttime without lighting tended to increase the odds of death for crash victims compared to daylight. In addition, a crash occurred during nighttime without lighting was found to have higher odds of being a fatal crash than during nighttime with lighting. The underlying reason could be the diminished vision of drivers while driving on roadways with the lower ambient light levels [33]. In addition, it was found that transitioning from a bright environment to a zone of low light and the intermittent brightness of headlights and streetlights on the roadway tended to cause night vision problems for drivers [43]. These finding are consistent with most of the conclusions from the previous studies [18, 19, 21, 23, 24, 29, 32, 33].

Although some previous studies concluded that clear weather condition produced more chance for an occurrence of a fatal crash than adverse weather conditions, such as rain or fog [10, 17, 22, 24], after assessing the effect of road surface in conjunction with weather condition in this study, we found some interesting different conclusions. The analysis indicated that a severe crash occurred on a rough surface during the rain increased the odds of being a fatal crash by three times, compared to a dry surface under clear weather condition. In addition, a crash occurred on a slippery surface during the rain also reasonably increased the odds of being a fatal crash, compared to a dry surface under clear weather condition. However. a crash occurred on a rough or slippery road surface during the foggy or dusty weather did not pose the significantly greater odds of being a fatal crash compared to a dry surface under clear weather condition. The effect of rough or slippery road surface alone was not found to increase the risk of fatal crash, compared to a dry surface. The underlying reason could be the effect of rainy weather may intensify the risk of driving on a rough roadway surface, especially in terms of vision, since traveling on a slippery surface without rain (i.e., when the rain stopped) was not found to significantly increase such risk.

By classifying roadways into four categories, most of the fatal crashes tended to occur on highways; followed by rural highways, urban or municipal streets, and local roads, respectively. This could possibly be due to the higher speeds of vehicles used on highways compared to the chosen speeds on the other types of roadways, where the lower levels of access control were normal.

However, when evaluating the effect of accident location jointly with roadway type, this study found that local road curves were the most dangerous locations for fatal crashes; followed by urban street curves, conflict points on local roads, rural highway curves, conflict points on rural highways, and highway tangents, respectively. However, crashes occurred at work zones or obstacles on any types of roads and conflict points on urban streets were not found to pose significantly different level of fatal risks compared to highway tangents.

Obviously, the findings suggested that curves on any types of roadways generally possessed the greater risks in terms of inducing fatal crashes. Furthermore, it was found that the risk of triggering a fatal crash on a roadway curve tended to increase as the class of the roadway shifted from rural highway to urban street and local road, respectively (i.e., a superior class to an inferior class).

Interestingly, compared to the specifications of the geometric design of highways recommended by the American Association of State Highway and Transportation Officials (AASHTO) [44], the quality of roadways in Thailand was generally considered to have some deficiencies; especially in terms of curve radius, pavement, lane width, shoulder width, sight distances, and the slope and width of the right-of-way. Many reviews and reports drew similar conclusions with respect to the substandard road safety conditions in Thailand, while the massive improvements were not speculated to be achieved in the near future [2]. Hence, these were the challenges that the highway designers should overcome for reducing road-related fatalities in Thailand.

In addition, the results indicated that conflict points on urban streets were slightly safer than rural highways, and substantially safer than local roads. The underlying reason could be due to the nature of the local roads, where most of the conflict points were crossroad-like, with more precarious geometric design. In contrast, conflict points in urban areas were better equipped with signs or fully signalized and have superior geometric design compared to local roads.

The effect of accident location was further analyzed together with the effect of alcohol consumption in this study. Interestingly, the analysis indicated that conflict points were the most hazardous locations for a drunk road user in an accident since the greatest risk of being a fatal crash was found to occur there. The reason could be due to the diminished consciousness of impaired road users when traversing conflict points, such as intersections, crossroads, and median opening areas.

Finally, by considering the effects of vehicle type and alcohol consumption altogether, this research found that a drunk road user who traveled by a pick-up possessed the greatest odds of being a crash victim, respectively followed by car and motorcycle. However, drunk travelers in truck/trailer and bus/van did not show significantly different odds from motorcycle in becoming victims of fatal injury in severe crashes.

Last but not least, there were some limitations deserved mentioning in this study. The first limitation was, although the road accident data were continuously collected nationwide, there were still some reported cases with incomplete or inaccurate information, which led to exclusion of some datapoints from the analysis. Another limitation was the lack of in-depth information, such as the number of lanes, lane width and shoulder width, included in the current dataset. We found that it would be interesting to collect and include these data ourselves in the future research. Therefore, an extensive study will be performed to investigate the fatal risks related to these factors in the next study.

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