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Understanding relationship between road median type and accident frequency

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Abstract

Road medians play an important role in the design of four or more lanes highways with high traffic volume and the large number of accidents. This study focused on effect of factors (such as traffic volume, road characteristics, land use and road median types) on the number of accidents. The data was collected from nationwide highway, and further used to build the models by using Generalized linear with Negative binomial model distribution classified by road median types including raised-, depressed-, flush- and barrier median. The result found that the increase in traffic volume and truck ratio are positively associated with more number of accidents in all four road median model. The finding also recommends that raised-, depressed- and flush median should be implemented within agriculture and rural area in order to decrease crashes frequency. The contributions of this study could be used as guideline regarding highways median type implementation decision-making to enhance road safety in Thailand.

Keywords: Road median type, Thai highway, Accident frequency, Negative binomial model, Road segment, Road Safety

1. Introduction

Currently, considering the situations of road accidents, Thailand was classified as country with very high death rate due to traffic accident, 32.7 per 100,000 population [1]. According to the Department of Highways (DOH), the main causes of accident is high-speed driving, followed by tailgating driving, insufficiency of safety awareness and driving skill [2]. Therefore, Thailand is in urgent needs to decrease the accidents frequency as well as fatality; therefore, improving the roads way in term of safety and accident blackspot should be given full attention.

Road characteristics including curve radius, road slope, road surface, shoulder width, and road medians were found to affect crash occurrences and injury severity. In regard to road median, Brian and Robert [3] have found that the availability of road median benefits did not only control or prevent head to head collision or turning across traffic flow but also provide landscape area and protect pedestrians. In addition, the road medians was often installed on four or more lanes highway with the advantages and the functions to reduce number of number of accidents and fatalities Bureau of Location and Design [4]. In Thailand, Department of Highways classify road median into four types including (1) flush median, (2) raised median, (3) depressed median, and (4) barrier and guard rail barrier [4] which are illustrated in Figure 1. The different suitability of each median type depends on highways area and other conditions [5] and the criterion of each median types was summaries in Table 1 [4].

Despite the availability of basic criteria for choosing road median types to reduce the number of crashes according to the government policy, the deep understanding of relationship between crash occurrence and median types still lack. Furthermore, there is no previous research study on this matter. Therefore, this research aimed to identify the relationship between various accident related-factors and resulting crash-number; and compare result between each median type accident in Thailand. The results could be helpful for related organizations including Offices of Highways nationwide and others road designer to considerate appropriate road median types for installation.

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Figure 1 Road median type (a) Flush median; (b) Raised median; (c) Depressed median; (d) Barrier [2]

Table 1 Comparison among median types

Criterion	Flush	Raised	Depressed	Barrier
1.Traffic engineering				
1.1 The safety of car straight direction	Middling	Good	Excellent	Excellent
1.2 U-turn and Turn	Middling	Good	Excellent	Not good
1.3 Violating road median area	High	Cannot	Low	Cannot
2.Economic and cost				
2.1 Installed cost	Low	Moderate	High	Moderate
2.2 Maintenance cost	Low	High	Moderate	Low
2.3 Area requirement	Moderate	Moderate	High	Low
3.Environmental				
3.1 During installation	Low	High	Moderate	Low
3.2 Impact to vehicles and pedestrians	Low	Moderate	High	High
3.3 Problem of drainage on pavement	Low	High	Moderate	High

Source: Bureau of Location and Design [4]

2. Literature reviews

Brian and Robert [3] conducted a study on the impact of road medians on road users using poison and negative binomial regression. The considered factors were the number of accidents, the characteristics of land use, the number of traffic lanes, road median width, and other characteristics of road. There are number of researches studied the factor affecting accident frequency [6-9]. Abdel-Aty and Essam Radwan [10] used negative binomial to identify factors affecting crash occurrences using three-years accident data with 1,606 accident cases. Considered factors included road length, annual average daily traffic, curve radius, shoulder width, median width, traffic lane width and urban area were used in the analysis. The result found that the increase of traffic volume, road length, curve radius and urban area result in the larger number of accidents which is consistent with others studies [11-13]. Donnell and Mason [14] conducted a case study of collision with a median barrier to forecast the frequency of road median collision on intercity highways between cities of Pennsylvania in United States of America using the data from Pennsylvania's Roadway Management System (RMS), Highway Performance Monitoring System (HPMS), and Crash Reporting System (CRS). The highways were divided into six section (0.5 mile each). The factors used in the study were barrier-accident frequency, length, Annual Average Daily Traffic (AADT), speed, barrier offset, curve, interchange, alignment, truck, rural and terrain. Negative binomial regression model were used and the result found that (1) high average traffic volume cause more road median accidents, (2) Posted speed limit in each section could reduce the median crashes, (3) Curve could increase the risk of accident occurrences, (4) Straight road could decrease risk of road median collision, and (5) wider offset could reduce the risk median crash. Land use, road condition and other factors such as vehicle speed, road speed limited, and traffic volume were also used in predicting the number of accidents [5, 15-17].

3. Materials and methods

Table 2 show the description of variables used in the current study analysis which is based on the previous literature (remark below the Table 2). The roads in Thailand were separated by organizations in the Ministry of Transportation, including 1) Department of Highway (DOH) 2) Department of Rural Road and 3) Local organization. This study considers the roads under control by only DOH (most of major highways in Thailand are under the responsibility of DOH). The crash sample in this study occurred on the highway segments which were selected only (see Table 3). The variables are divided into five groups including 1 response variable group and other 4 independent variable groups as follow (Table 2):

- The numbers of accidents (response variable)
- Traffic condition
- Road characteristics
- Land use
- Median detail

In data collection process, firstly, each selected highway was divided into multiple road segments (each segment have length of 1 km) continuously (i.e., 100 km will contain 100 segments of 1km section). For example, segment no.1 starts at STA 0+000 - 0+999 (1km in length) and segment no.2 start next to an end of segment no.1 at STA 1+000 - 1+999 (also 1km in length). Secondly, selected detail explanatory variables of each segment including traffic characteristic, roadway characteristic, and land use characteristic were obtained as well as crash frequency (number of crashes occurred on each road segment) which was assigned to be the dependent variable. Lastly, data was separated into sub-datasets based on median types which will further input into statistical analysis to find significant contributing factor.

Table 2 Summary of factors affecting accidents and medians

Variable	Variables (Code)	Value of variables (Code)	Number of works
	Accident (Respondence)		
1	Number of accidents (Accident)		1, 4, 5, 7, 9, 10, 12, 15, 20
	Traffic condition		
2	Annual Average Daily Traffic (AADT)		2,4,9,20
3	Truck ratio (TruckP)		5, 13
4	Motorcycle ratio (MotorP)		
5	Velocity at 85 percentiles (V_85_PT)		5, 16
6	Posted speed limit (Speed_Limit)		2, 5
7	Violation speed ratio (Vio_speed)		2
8	Number of pedestrians (Pedes_N)		16
	Road Characteristics		
9	Number of lanes (Lane_N)		7, 16, 17, 20
10	Lane width (Lene_Width)		5, 16, 17
11	Auxiliary lanes (Aux_lane)		16-18
12	Offset (Offset)		4, 6, 8
13	Shoulder width (Shoulder_Wi)		5, 20
14	Horizontal characteristics	1. Straight (Straight)	4, 5, 7, 9, 20
		2. Curve (Curve)	4, 5, 7, 9, 20
15	Number of U-Turns (UTurn_N)		4
16	Number of connections (Connec_No)		4
17	Number of intersections (No_Inters)		4, 10, 18,
18	Number of bridges (Bridge)		18
	Land use		
19	Region	1. Urban (Urban)	2, 4, 20
		2. Rural (Rural)	2, 4, 20
20	Land use	1. Center of business (CBD)	2
		2. Residents (Residential)	2
		3. General services (Gen_Sev)	2
		4. Terminal (Terminal)	2
		5. Industry (Industry)	2
		6. Agriculture (Agriculture)	2
	Median detail		
21	Median type	1. Raised median	2, 10, 17, 18, 19, 20
		2. Depressed median	5, 10, 14, 20
		3. Flush median	1, 17, 18, 19, 20
		4. Barrier	3-9, 11-13 17, 19, 20
22	Median width (MedianWi)		1, 5, 6, 11, 15, 16, 17, 20
23	Median opening (Median Open)		16

Remark: Number of works 1. Richard, et al [5]; 2. Brian and Robert [3]; 3. Behnood and Mannering [12]; 4. Donnell and Mason [14]; 5. Kim, et al. [18]; 6. Hu and Donnell [19]; 7. Martin, et al. [20]; 8. Zou, et al. [21]; 9. Gabauer and Li [22]; 10. Chen, et al. [23]; 11. [21]; 12. [20], Chitturi, et al. [24]; 13. Wang, et al. [25]; 14. Rungrat and Tipakornkiat [26]; 15. FHWA [15]; 16. Kennaugh [27]; 17. State of Florida department of transport: FDOT [16]; 18. Garcia [28]; 19. Khorashadi, et al. [29]; 20. Serhiyenko, et al. [6].

3.1 Methodology

Many previous research have studied on the road safety by predicting the number of accidents occurring on each section of highways. Donnell and Mason [14] used the Poisson model and found that Poisson model have difficulty in predicting the number of crashes due to the limitation of the prediction variance which had to be equally controlled to the mean value. Instead, Negative binomial regression model (NB) was introduced with the ability of accident number prediction which was higher than mean value or over dispersed [3, 10, 23, 30-32].

In case that the relationship between independent variables (X) and dependent variables (Y) is a linear function, the equation is $E(Y|X) = \beta' X$ and $Var(Y|X) \propto l$ under the condition that the relationship has to be linear, if not, the data has to be transformed. Thus, Generalized linear models (GLM's) is selected to analyse the relationship between the independent and dependent variables which is nonlinear regression models and could be used to confirm the relationship when linear regression analysis is not suitable [33]. The study of Memon [34] found that the prediction of crash number with another variables by using GLM analysis was fairly suitable. Thus, GLM's NB (Generalized linear model Negative Binomial regression) is adopted in this study for identifying the factors influencing the number of crashes occurring on each median type highway separately.

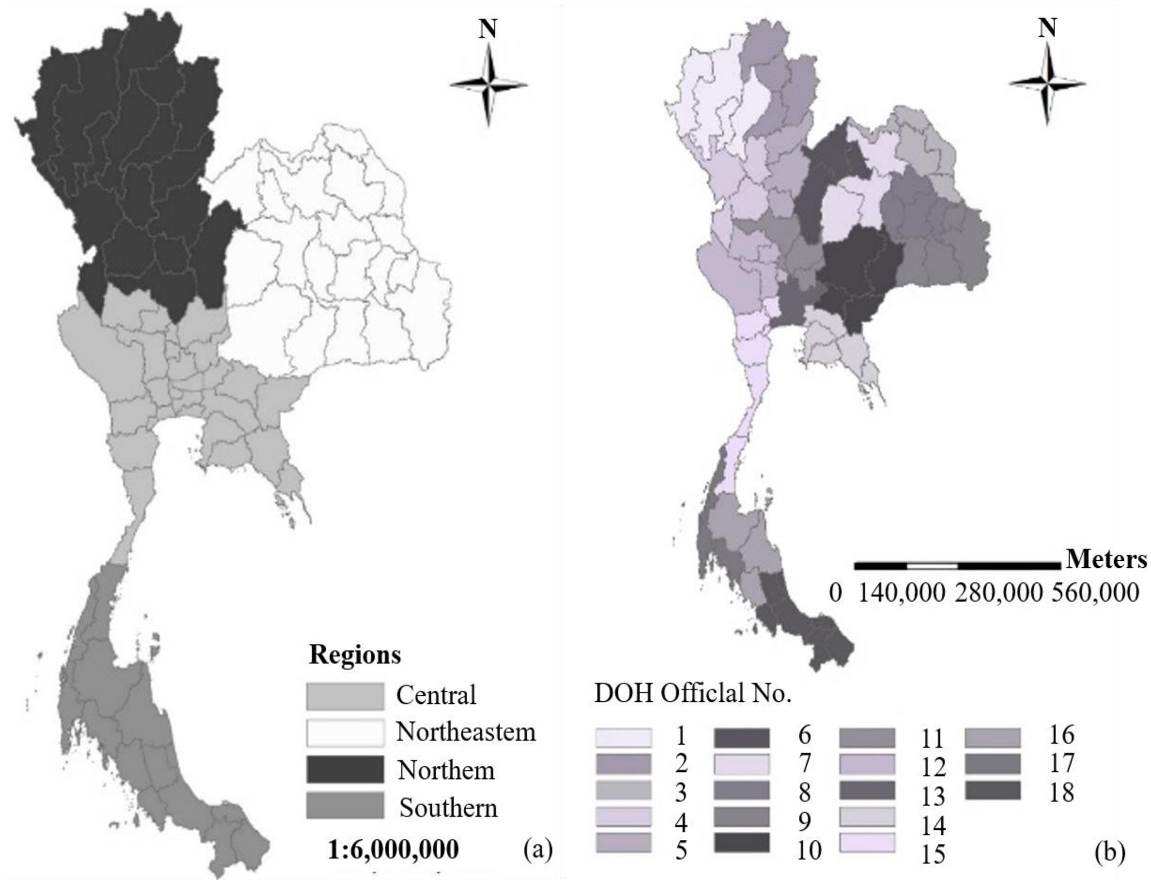

Figure 2 The areas of Thailand (a) The 4 regions of Thailand were separated by administrative district, (b) The areas which were classified by Official of Highways

3.2 Road sampling

The Figure 2 (a) show the four regions of Thailand and (b) showing the area controlled by 18 DOH offices. The representative routes selection for data collection were performed by a series of process. The control segment selection process is shown in Figure 3. For random sampling, multi - stage sampling had 2 steps which consisted of:

(1) According to the danger, "stratified random sampling" which was divided into 2 categories in term of Accident Frequency (AF) including High AF and Low AF (using Median from AF of all roads as the criterion for division) with the consideration of AF calculated by the equation 'AF = Acc/L' where Acc was the number of crashes occurring from 2013-2015, L was the distance of each controlled segment.

(2) Obtain the road representatives nationwide 'Cluster (Area) random sampling' which divided the routes into two categories including (a) routes distributed by 18 DOH offices controlling nationwide roads (b) the important road which is connecting between the important areas throughout the country distributed by four regions. The conclusion of road representatives to be collected was shown in Table 3.

Finally, 50th percentile of accident frequency over three-years (Figure 4) was used to consider whether those road-controlled segments are High AF or Low AF. There are 26 road-controlled segments was selected (Table 3).

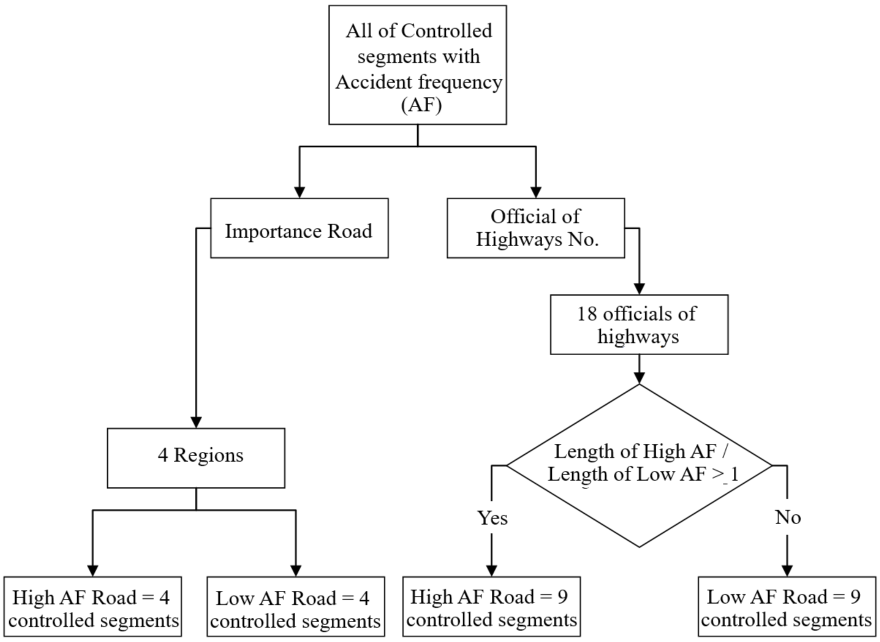

Figure 3 The process of road sampling

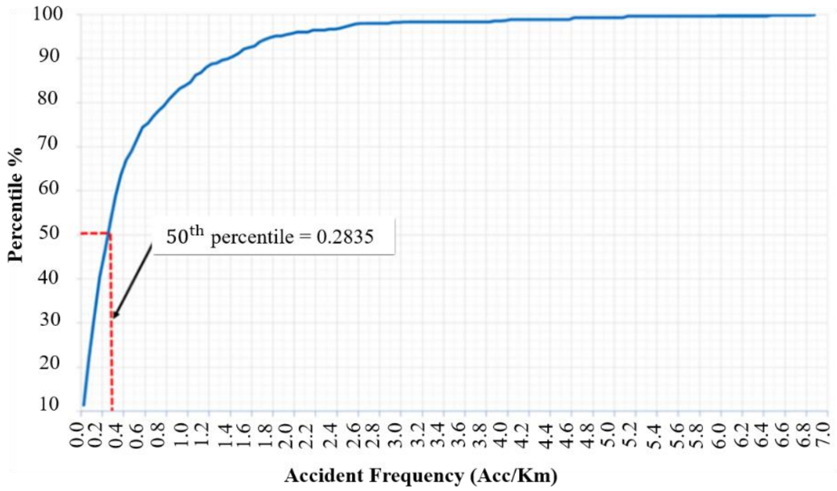

Figure 4 50th Percentile of accident frequency (AF)

Table 1 Road sampling results

	Main Road			Official Highway		
	region	**route No.**	**Controlled phase**	**DOH official No.**	**route No.**	**Controlled phase**
High AF	Northern	1	1001	1	1	1201
	Northeastern	2	302	2	1	1401
	Central	1	700	3	212	103
	Southern	41	400	4	1	901
				5	12	502
				6	21	503
				10	219	301
				13	304	203
				18	4	1404
Low AF	Northern	12	601	7	201	202
	Northeastern	24	701	8	219	102
	Central	3	704	9	23	502
	Southern	4	1103	11	3004	201
				12	33	201
				14	3156	100
				15	3087	100
				16	408	102
				17	4	803

Remark: AF=accident frequency. Number of roads was selected by multi-stage sampling method. Samples from "Official of Highways" was considered by proportion of summary road distance between high AF and Low AF. For instance, distance of High AF divided by distance of low AF, if the result greater than 1, then the sample will be the road which high AF.

3.3 Generalized Linear Model (GLM) with negative binomial distribution

Generalized Linear Model (further GLM) has probability density function for generalizing model concept. In this case, to observe response y, it can be expressed in Eq. (1) as follow: [33].

$$log\, p\,(y_i|\theta,\phi,x_i) = \frac{w_i(y_i\theta_i-\gamma(\theta_i))}{\phi} + \tau(y_i,\frac{\phi}{w_i}) \quad (1)$$

Where: w_i is a known weight,
$\theta_i = g(\beta' X_i)$ is an unknown vector of the regression slopes β,
$g(\cdot)$ and $\gamma(\cdot)$ are the smooth functions,
ϕ is often called a dispersion parameter, and
$\tau(\cdot)$ is a known function.

Then, we set the response variable as the number of accidents, the type as count data, and the probability model for counting data as Poisson distribution [35].

If the accident number which is predicted by Poisson regression has greater value than mean (over-dispersion), the Negative Binominal (NB) is more feasible to use than Poisson regression model. The Eq. (2) is the probability mass function of NB for dependent Y as shown below:

$$\mathrm{P}(Y_i = y|X) = \frac{\Gamma(y+1/\alpha)}{\Gamma(y+1)\Gamma(\frac{1}{\alpha})}\left(\frac{1}{1+\alpha\mu_i}\right)^{1/\alpha}\left(\frac{\alpha\mu_i}{1+\alpha\mu_i}\right)^{y} \quad (2)$$

The form of equation for negative binomial regression has the log of the outcome (prediction) using predictors of linear combination. The log of response variable is shown in the Eq. (3) below, and we can predict the number of accidents using the Eq. (4) as follow:

$$\log(\mathrm{accident}) = \mathrm{Intercept} + \beta_i X_i + \ldots + \beta_n X_n \quad (3)$$

$$\mathrm{accidents} = \exp(\mathrm{Intercept})\exp(\beta_i X_i)\ldots\exp(\beta_n X_n) \quad (4)$$

The model assessment in this section is created for checking the performance of the model that can be predicted accurately. The log-likelihood ratio called as McFadden's pseudo-R squared (ρ^2) is used to measure the overall goodness-of-fit [36, 37]. Besides, Mean absolute deviance (MAD) and Mean squared predictive error (MSPE) were considered to measure the model, the great values of MAD and MSPE models should be small. For Akaike Information Criterion (AIC) was also measure as goodness of fit of the model [36, 37].

4. Results

4.1 Descriptive data

Descriptive statistic of the accident data between 2013-2015 of 967 segments is shown in Table 4. The total number of accidents are 1,363 cases. There are 235 segments of raised median, 452 segments of depressed median, 217 segments of Flush median, and 67 segments of barrier.

For raised median, the average crashes occurred 1.23 times per year with average daily traffic of 10,748.45 vehicles per day, and there was slightly high average truck ratio with 17.88%. Around 76% of raised median road was in urban area. In case of depressed medians, average accident within this three-years was 1.69 times per year with the average daily traffic of 18,685.74 vehicles per day, and the ratio of truck was higher than raised median road with 23.42%. The majority of depressed median was in rural area which was around 96%. Barrier median road has the highest average number of crashes of 3.3 times per year and the high truck ratio of 22.34%. 90% of barrier median road was in rural area with high velocity of traffic flow. Lastly, flush median has the smallest average number of crash rate of 0.45 times per year with 18.77 % of speed violation.

4.2 Model's goodness-of-fit assessment

The Goodness-of-fit of each model was presented in Table 5. McFadden's pseudo-R squared (ρ^2) was 0.194, 0.114, 0.124, and 0.14 for raised-, depressed-, flush- and barrier median respectively which were in acceptance criteria [8]. The MAD values were between 0.521 – 2.251 and in acceptance criteria and consistent with result of past study [38]. MSPE value was between 0.451 – 10.698 and was acceptable in the previous study [39].

Table 4 Descriptive statistics

Variable	Description	Variable type/ Value	Raised			Depressed			Barrier			Flush		
			Mean	Std.	%	Mean	Std.	%	Mean	Std.	%	Mean	Std.	%
Accident	Number of accidents	Continuous	1.23	2.29		1.69	2.27		3.3	3.56		0.45	0.72	
AADT	Annual average daily traffic	Continuous	10,748.45	8,308.47		18,685.74	15,100.68		38,295.40	27,172.56		9,322.53	5,424.07	
TruckP	Number of trucks	Continuous	17.88	5.69		23.42	10.85		22.34	16.81		17.23	9.12	
MotoP	Number of Motorcycle	Continuous	19.17	11.15		15.18	9.58		10.88	6.01		16.14	15.68	
V_85_PT	85th percentile velocity	Continuous	84.86	14.94		92.78	12.43		82.64	10.01		90.94	14.99	
Vio_Speed	Percentage of violation velocity	Continuous	22.25	24.07		29.99	23.34		34.87	27.92		18.77	30.66	
Lane_N	Number of road lanes	4			79			90			49			99
		6			11			4			39			
		8			10			1			12			1
Offset	Offset	Continuous	0.62	0.21		1.16	0.5		0.97	0.46		0.27	0.25	
Shoulder_Wi	Shoulder Width	Continuous	2.33	0.61		2.6	0.64		2.31	0.64		2.33	0.4	
Bridge	Pedestrian bridge	1 = Yes			17			13			31			10
		0 = No			83			87			69			90
Urban	Urban area	1 = Yes			24			4			10			7
		0 = No			76			96			90			93
CBD	Central business district	1 = Yes			17			8			18			12
		0 = No			17			92			82			88
Residential	Residential area	1 = Yes			22			23			19			15
		0 = No			78			77			81			85
Terminal	Transportation Terminal	1 = Yes			1			0			3			1
		0 = No			99			100			97			99
Industry	Industry area	1 = Yes			7			19			27			11
		0 = No			93			81			73			89
Gen_Serv	General service	1 = Yes			17			23			10			19
		0 = No			17			77			90			81
Acc	Agricultural area	1 = Yes			19			18			6			15
		0 = No			81			82			94			85
Median_Wi	Median width	Continuous	4.66	1.79		7.52	3.16		3.18	2.98		2.14	1.24	
UTurn_N	Number of U-turn points	Continuous	0.76	0.77		0.79	0.93		0.57	0.65		0.31	0.5	
Connec_No	Number of connection points	Continuous	14.8	17.6		14	13.68		17.31	17.56		4.3	9.86	

Table 5 Goodness-of-fit measurement

Goodness of fit	Median type model			
	Raised	Depressed	Flush	Barrier
Likelihood Ratio Chi-Square	82.467	84.008	28.595	16.146
Degree of freedom	12.000	9.000	9.000	6.000
Significant	0.000	0.000	0.001	0.013
Log Likelihood at null model	−385.093	−757.839	−213.371	−134.703
Log Likelihood at full model	−310.505	−671.179	−187.000	−115.743
McFadden's pseudo-R squared	0.194	0.114	0.124	0.141
AIC at null model	706.180	1608.749	389.436	316.445
AIC at full model	647.865	1532.235	380.072	308.073
Difference AIC	58.315	76.514	9.364	8.372
MAD	1.098	1.335	0.521	2.251
MSPE	2.892	3.624	0.451	10.698

Note: AIC denotes Akaike In-formation Criteria; MAD

4.3 Model results

Firstly, all variables were used in the model estimation. Then the variables which did not affect accident number at significance level were removed from the model one by one, Pearson's correlation coefficient was used to considered and the value up to 0.7 were eliminated [40]. In crash frequency prediction model, significant variables at 90% confidence level can be used for model interpretation [14]. The estimation results of all models were shown in Table 6.

Firstly, from raised median model, it found that agricultural and rural area with raised median contributed to reduction in number of accidents. This result was consistent with Brian and Robert [3] that found that raised median in rural areas resulted in the decrease of pedestrians accidents. However, the variables that were found to significantly associate with the increase of accident likelihood were general service area, increase of AADT and increase of truck ratio. This result is logical because when the number of vehicle/large truck increase, it increases the traffic density that also increase the likelihood of collision between vehicle. This result is in line with the previous research study [41].

Secondly, in the depressed median model, the variables that significantly associated with the decrease of accident number were agricultural area and offset. These result are consistent with the result of past study [14]. The variables that significantly associated with the increasing accidents were truck ratio which is in line with the result of [42].

Thirdly, the result of flush median accident model showed that the factors that found to have positively significant relationship with the decrease of accident number were rural area and industry area. This might be because when driver travel across the area with number of large factories on the side of the road, driver tend to have more awareness and accident caution due to large trucks access point with the industries.

Lastly, in barrier median accident model, three variables were found to have positively significant relationship with the increase of number accident, namely, residential area, AADT and speed violation. These result are logical and in line with the previous [41] However, the result of variable "Median width" were found to positively associate with the increase of accident occurrence in raised median, depressed median and flush median model. These result are doubtful and contradicted with the previous research finding [41, 43]. A more deep investigation of relationship between median width and crash occurrence should be focus in the future research such as using larger sample size, considering median width variable as dummy code, and other physical detail between traffic lane with median (such as clearance distance) should be taken into consideration.

Table 6 Result of Negative Binomial regression model

Parameter	**Raised median**				**Depressed median**				**Flush median**				**Barrier**			
	Value	**Std. Error**	**Sig**	**EXP**	**Value**	**Std. Error**	**Sig**	**EXP**	**Value**	**Std. Error**	**Sig**	**EXP**	**Value**	**Std. Error**	**Sig**	**EXP**
(Intercept)	−7.83	2.71	0.00	0.00	−1.82	1.21	0.13	0.16	1.15	2.34	0.62	3.17	−6.84	3.04	0.02	0.00
[Rural=1]	−0.43	0.23	0.06	0.65					−0.56	0.29	0.06	0.57				
[Rural=0]	0a			1.00					0a			1.00				
[Gen_Serv=1]	0.46	0.22	0.04	1.58												
[Gen_Serv=0]	0a			1.00												
[Residential=1]													0.67	0.37	0.07	1.95
[Residential=0]													0a			1.00
[Industry=1]									−0.99	0.49	0.04	0.37				
[Industry=0]									0a			1.00				
[agriculture=1]	−0.72	0.31	0.02	0.49	−0.37	0.17	0.03	0.69	−1.08	0.48	0.03	0.34				
[agriculture=0]	0a			1.00	0a			1.00	0a			1.00				
LN_AADT	0.77	0.33	0.02	2.15	0.19	0.21	0.37	1.21	−0.2	0.26	0.44	0.82	0.63	0.27	0.02	1.88
TruckP	0.03	0.02	0.1	1.03	0.03	0.01	0.00	1.03	0.01	0.01	0.41	1.01	0.02	0.01	0.22	1.02
Vio_Speed									0	0	0.56	1.00	0.01	0.01	0.07	1.01
Offset					−0.76	0.14	0.00	0.47					0.43	0.37	0.24	1.54
Median_Wi	0.14	0.05	0.00	1.15	0.11	0.02	0.00	1.11	0.17	0.09	0.05	1.19				
Over-dispersion	0.77	0.19	0.00		0.55	0.097	0.00		0.4	0.19	0.04		0.609	0.2	0.00	

Note: a Reference variable; Bold front illustrate significant at 90% level; EXP illustrate the base of the natural logarithm of "value" Column

5. Conclusion

This study aimed to identify the significant relationship between various accident related-factors and accident frequency by using Negative Binomial regression to analyze three-years accident data. Four model results were obtained based on type of road median namely raised median, depressed median, flush median, and barrier median. The goodness-of-fit of each model were acceptable as in the past studies.

As result, (1) variable rural area was found significant in accident occurrence reduction in both raised median and flush median model. (2) variable general service area was positively significant associated with increase of accident frequency in only raised median model. (3) variable residential area was positively significant associated with increase of accident frequency in only barrier median model. (4) variable industry area was positively significant associated with the decrease of accident frequency in only flush median model. (5) Agricultural area was positively significant associated with the decrease of accident frequency in raised median, depressed median, and flush median model. (6) the increase of AADT was positively significant associated with increase of accident frequency in raised median and barrier median model. (7) the increase of truck ratio was positively significant associated with increase of accident frequency in raised median and depressed median model. (8) the increase of speed violation was positively significant associated with increase of accident frequency in barrier median model. (9) the variable "Offset" was positively significant associated with the decrease of accident frequency in depressed median model. (10) the increase of median width was positively significant associated with increase of accident frequency in raised median, depressed median, and flush median model.

Based on the result, recommendations can be drawn as follow:

(1) For agriculture areas and rural areas, highway designer should consider flush median, depressed median or raised median (not financially effective but increase prevention from serious or fatal injury [44]) implementation to decrease risk of accident occurrence.

(2) For industrial area, flush median type is recommended for installation to reduce risk of accident occurrence.

(3) As AADT and truck ratio increase, related authorities should be consider widening the highway or reduce the speed limit; and enforce the law on speed violation.

Related authorities or organizations could consider these recommendations for highway design median type for difference region characteristic with intention to enhance safety and reduce number of accidents in Thailand. However, the current study also has some limitation regarding the missing of two important accident related factors namely environmental factor and the human factor. The future research should consider obtaining these factors into the analysis and use more accident data to improve prediction accuracy of the estimated result.

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