ACCIDENT PREDICTION MODEL FOR HIGHWAYS WITH REST AREA BY USING POISSON AND BINOMIAL REGRESSION MODEL

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ABSTRACT

Currently, rest area positively impacts on road users in terms of business points and information providers; however, the important task of rest area is reducing the number of road accident cause of fatigue. In the past, truck drivers in Thailand usually parked their vehicles on roadside or shoulder, which these harmful areas could generate road accidents when parked vehicles move out from the road shoulder to the travelled way. In Thailand, road accident situation is top 10 of the world. Research objectives consist of the determination of influencing factors that affect the road accident within upstream and downstream 16 km of rest areas in Thailand and built the accident prediction models. It was found out that main variables such as serviceability of rest areas and the number of the truck users in rest areas are significantly impacted into the accident prediction model. In summary, rest area could help to reduce the number of road accidents.

Keywords: Rest Area, Accident Prediction Model, Truck, Heavy Vehicle

1. INTRODUCTION

Rest area is the area for road users to rest, sleep, change driver, check goods and/or evaluate their vehicle (AASHTO, 2001). Rest area is the safety countermeasure which can reduce the number of accident, so agencies which related highways could primarily concern road safety. Not only road safety aspect, but rest area also generate revenue and provide information. Rest area is focused on the number of accident reduction related to fatigue; all roads could be provided rest area within an approximate distance. Fatigued drivers would avoid from main travelled way because of stress, especially a very high traffic volume on a road. From the study of National Cooperative Highway Research Program Report on Evaluation of Roadside Rest Areas by King (1989) which stated that interstate highways without rest areas, shoulder-related accidents increased to 52 %. AASHTO (2001) stated that the opportunity of a fatigue-related accident reduced 3.7% for drivers who utilized a rest area.

Fatigue is an important problem of a truck driver, in practice, at least 60% of truck drivers usually continue the work more than 12 hours, and it means that a truck driver works more than 70 hours per week. This work time period affects the rest time of a driver, fatigue could be occurred because of they have 7-8 hours per day. In U.S., at least 20% of accident is related to fatigue which occurred in midnight and 6 A.M. Above-mentioned, it conforms to a research in France that a fatigue-related accident and the overtime work is occurred in the midnight (European Transport Safety Council, 2001)

Banerjee et al (2009) stated that rest areas, which are a countermeasure for fatigue, play a role in fatigue-related freeway collisions. Out of 2,203,789 total collisions occurring between 1995 and 2005, fatigue collisions accounted for more than 1.3 - 9.7 % of total collisions in California. It was also found that the number of collisions due to fatigue tended to decrease immediately downstream of rest areas, while suddenly increasing after about 30 miles from rest areas. This phenomenon is consistent with a possible assumption that drivers become significantly exhausted about 30 miles downstream of rest areas.

Garber and Wang (2004) concluded that the lack of sufficient rest areas are an cause of an accident, drivers' fatigue is a cause of truck accidents about 30-40 %. 31 Percent of fatalities is related with the fatigue because of insufficient rest period within 24 hours. In the past, truck drivers parked their trucks on shoulder or roadside, so the accident will occurred when vehicle move from shoulder/roadside to the travelled way. Blomquist et al. (2004) studied an approximate distance between rest areas, and it was found that 100 kilometers is an approximate distance between rest areas and a driver have to rest at least 10 min for every one work hour.

From accident statistic reports in Thailand, there was found that Thailand is top ranking countries by highest death rate in road accidents. Accident reports from 2009 - 2012 by Department of Highways in Thailand presented the severities, accident costs and hazardous areas. In Table 1, the number of accidents were 61,683, the number of fatalities were 7,101 and the number of injuries were 50,731. In reports also presented that 18.7 % (11,549 accidents) of total number of accidents were relalated with goods transportation sectors for 5 years ago.

Table 1: Number of accident, number of fatality and number of injury on highways in Thailand

Items	Year				
	2008	2009	2010	2011	2012
Accident	14,336	13,673	12,054	10,607	11,013
Fatality	1,513	1,378	1,370	1,291	1,549
Injury	11,680	10,415	9,991	8,970	9,675

Source : Department of Highways. (2013)

Considering in-depth analysis of these data, it was found that, 1/3 of accidents were occurred on truck vehicles such as 4 wheels pick-up, trailer, and less than 10 wheels truck respectively. In addition, the road accidents which occurred on a trailer have been increasing every year. From previous in-depth research in 2009, the number of accidents per 10,000 registered vehicles was Bangkok, southern, central, eastern, northern, and northeast respectively. Which the number of truck accidents were the highest in Northern. From these accident numbers, it presents the importance role of an overview of accidents such as statistic of fatalities and injuries that consist of regional statistic which there was the highest number of truck accident. So, reduction of the number of truck accidents by large rest area services are needed because it presented that a truck-related accidents were 1 of 3 of total accidents.

In study of rest area service, it should include an evaluation of fatigue-related accident, black spots, and accident rates near rest areas. In addition, a good design of a rest area is a part of aesthetic, and life quality of a community because of goods services, markets, tourism, data information services, and information transfer among drivers.

1.1 Objectives

1) To study influencing factors that related to road accidents near rest areas
2) To forecast an average number of road accidents by two cases such as the forced and unforced policy of a rest area service which included the accident reduction number by various size of rest areas?

1.2 Research Assumptions

1) Rest area is a part of an accident reduction countermeasure.

2) Base prediction model is based on the accident data from Department of Highways in Thailand which occurred near four main rest areas
3) Base prediction model is based on the assumptions that customers or drivers who utilize the rest areas were unforced condition
4) The forced policy of a rest area is based on the traffic volume of heavy vehicle parking
5) The size of a rest area depends on number of stalls and customers/drivers
6) Accidents were collected within 16 kilometers of upstream and downstream of a rest area

1.3 Scope of Study

The relationships between road accidents and road physical factors and traffic volume factors to develop the accident prediction model of study areas which consist of four main rest areas of Department of Highways in Thailand. 16 kilometers of upstream and downstream of rest areas were study areas. Rest areas of Department of Highways consist of Khuntal (Highway no.11 section of Lampang-Chiang Mai, KM.33+420 – KM 33+577), Lam Takong (Highway no.2, section of Saraburi-Nakon Ratchasima, KM.193+292 – 193-975), Chainat (Highway no.32, section Chainat intersection-Namsakon intersection,KM185+504 – 185+604), and Khao Po (Highway no.4, section Prajubkirikhun-Chumpon, KM431+400 – 432+200). All rest areas were opened in April 2002.

1.4 Research Methodology

Research methodology begins with the literature review in Thailand and international studies which consists of model formulation development and a factor-related accident. Five main steps of research methodology such as:
1) Literature review of factors and model formulation
2) Study of road accidents between 2000-2010 traffic volume and road geometry were reported by Department of Highways in Thailand. 16 km of upstream and downstream were base data which will be developed to forecast the average number of accidents
3) Data analysis, data were separated by 75:25 which 75% of data is used to develop the prediction model, and 25% of data were used to validate the model. Model formulation was organized by three steps such as Pearson's correlation analysis among dependent variable and independent variables, and correlation among independent variables. Overdisperson test and models formulation based on Poisson regression model and Negative regression model
4) Goodness of fit is tested to select the approximate model
5) Conclusions

2. LITERATURE REVIEW

Author separated literature review in two parts such as the accident prediction model and factor analysis. In previous researches, various statistic models were used such as: Mohamed et al. (2000) used a negative binomial model to predict the road accident. Pongmesa (2002) used a multiple regression model, Poisson regression model, negative binomial regression model and log-normal regression model. Chao et al.(2009) and Littidej (2007) used Poisson regression model. Greibe (2003) developed an accident prediction by Poisson regression model in Italy. Dinu and Veeraragavan (2011) developed Poisson regression model to predict a road accident for two-lane highways. Jintawong (2004) compared a linear regression model, Poisson and negative binomial model; it was found that Poisson regression model is an approximate model to predict the road accident in case of non-overdisperson data. Lalita (2008) concluded that the prediction of number of accidents, injuries and accident costs is suitable with Poisson regression model, and the prediction of fatalities is suitable with the negative binomial model. In contrast with Thipwet (2012) studied the Poisson and negative binomial model and concluded that a negative binomial model is suitable with the prediction of the number of accidents and severities. Therefore, model selection is depended on Maximum Likelihood and a reasonable parameter of a variable (Ciro et al., 2007).

Variables in an accident prediction model could be separated in two parts such as traffic variables and road physical variables. Thipwet (2012) concluded both variables as shown in following:

- Traffic variables such as traffic volume, speed, percentage of passenger vehicles, percentage of two wheel vehicles, percentage of heavy vehicles.
- Physical variables such as road length, lane width, number of travelled lane, shoulder width, number of horizontal curve per road section, minimum radius of curve, slope, number of accessibility, number of vertical curves, median width, available of shoulder, median type, accessibility per kilometer, unsafe sight distance/percentage of banned overtake length
- Time such as April in Thailand

3. MODEL DEVELOPMENT AND APPLICATION

Firstly, author applied the spatial analysis of the number of fatigue-related accidents and total accidents by Banerjee et al. (2009) to presents an overview of a countermeasure efficency cause of a fatigue-related accident. Accident data since 2000-2010 were analyzed. Figure 1 and 2 presents number of accidents in term of total number of accidents and fatige-related accidents . 16 km of upsteam and downstream were compared as same as the suggestion by Banerjee et al. (2009). Four rest areas of Department of Highways were utilized since 2002, number of accidents is reduced suddenly. An average number of accidents was 54.5 times per year before rest areas were opened, and an aveage number of accidents was 46.7 time per year after rest areas were opened. It could be implied that rest areas could reduce the accident 14.3%. It conforms with the fatiuge-related accident that an average number of a fatigue-related accident before rest areas opened was 5 time per year, and an average number of a fatgue-related accident after rest areas opened was 4.2 times per year. It could be implied that 16% of an average fatigue-related accident is reduced by the countermeasre of a rest area. Consideration of both number of an accident reduction were conformed with Banerjee et al.(2009) which rest areas can help to reduce a fatigue-related accident by 12.83%

Secondly, author formulated the accident prediction model, various variables were separated in two groups such as a dependent and independent variables. Influencing variables on an accident prediction is called independent variables, and an independent variable is a number of an average accident per year. The relation between an independent and dependetn variables is described in an equation (1)

Model structures consist of Poisson and negative binomial regression model when an average variance of an accident or the variance of variables is overdispersion effect. TARC (2009) concluded that Poisson and negative binomial regression model were suitable with the accident prediction model because both statictistic models can provide a zero value (non-accident) which Poisson regression model is a suitable model with a rarely accident, but negative binomial model is a suitable model which based on an average number is unequal to variance.

3.1 Model Formulation and Variables

Development of an accident prediction model, a dependent and independent variables were presented in Table 2. Both variables were described in following:

1) Increasing of Annual Average Daily Traffic (AADT) then an accident rate will increased.
2) Increasing of percent of heavy vehicle (HVVEH) then an accident rate will increased.
3) Increasing of number of light vehicle parking (LIGHTPARK) then an accident rate will increased.
4) Increasing of number of heavy vehicle parking (HVPARK) then an accident rate will reduced.
5) Increasing of number of total vehicle parking (TOTALPK) then an accident rate will reduced.
6) Available of a rest area on highway (REST) then an accident rate will reduced.
7) Narrow width of road (RDWD) then an accident rate will reduced.

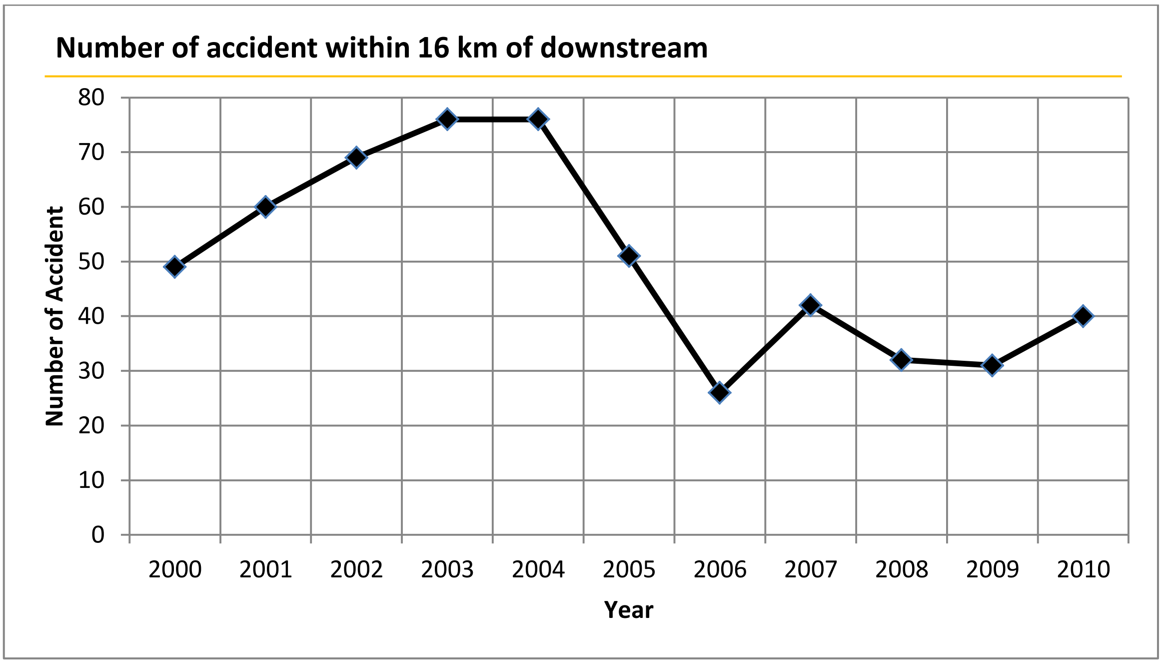

Figure 1: Number of accident within 16 km of downstream

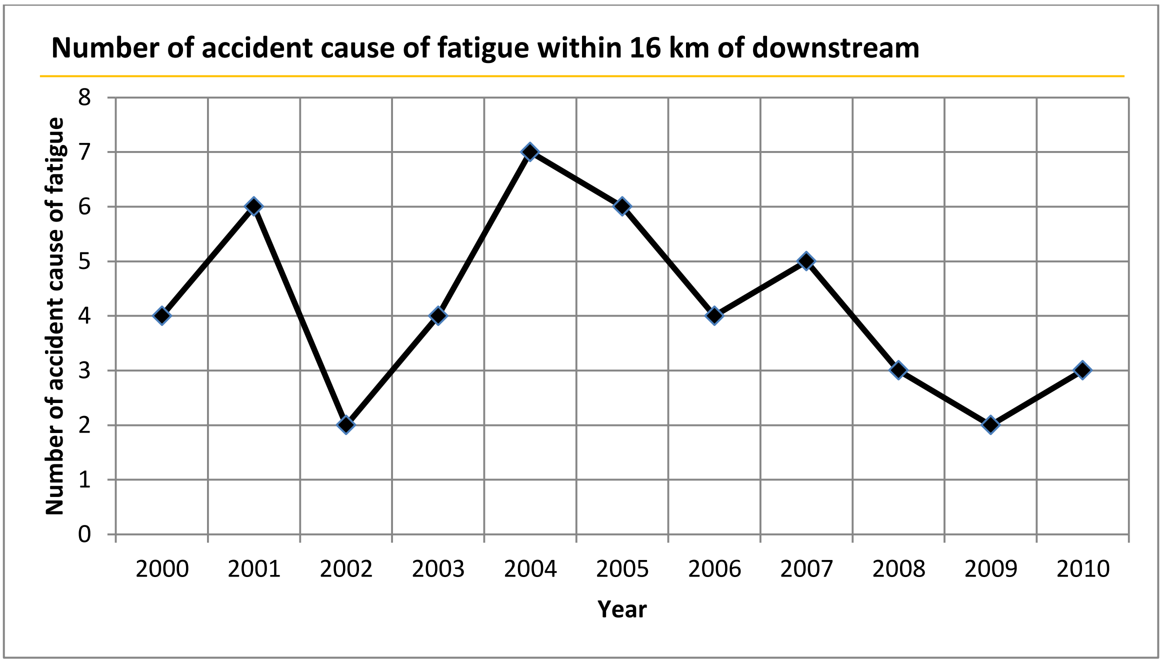

Figure 2: Number of accident cause of fatigue within 16 km of downstream

$$Y = \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n) \quad (1)$$

Where

Y	:	Number of predicted accident per year
β_0	:	Intercept constant of model
$\beta_1, \beta_2, \dots, \beta_n$	:	Parameter of independent variables

Descriptive statistics of both variables types were presented in Table 3. It shown that number of accidents of four rest areas were 148 times per year.

Table 2: Description of variables

Variables		Descriptions
Response Variable (Dependent Variable)		
ACC		Number of accident per year
Explanation Variables (Independent Variables)		
Traffic Variable	AADT	Annual Average Daily Traffic (Vehicle per day)
	HVVEH	Percent of Heavy Vehicle
	LIGHTPARK	Number of Light Vehicle Parking) Vehicle per hour(
	HVPARK	Number of Heavy Vehicle Parking)Vehicle per hour(
	TOTALPK	Total Number of Parking)Vehicle per hour(
Physical Variables	REST	Rest Area Available (0 = Not available, 1 = available)
	RDWD	Road Width (meter)

Table 3: Statistic of response variable and explanation variables

Variables	Min	Max	Average	S.D.
Response Variable (Dependent Variable)				
Number of accident per year	20.00	504.00	147.97	109.71
Explanation Variables (Independent Variables)				
AADT	10,074	42,222	23,074	10,345
Heavy Vehicle (%)	20.69	38.18	26.46	4.61
Number of Light Vehicle Parking (%)	10.00	44.00	22.43	10.23
Number of Heavy Vehicle Parking (%)	12.00	61.00	32.48	15.41
Number of Total Vehicle Parking (Veh/hr)	24.00	100.00	58.83	26.64
Available of Rest Area	0	1	0.80	0.41
Road Width (m)	22.19	27.00	24.55	1.76

Table 4: Pearson Correlation between dependent and independent variables

Dependent \ Independent		REST	AADT	HVVEH	TOTALPK	HVPARK	LIGHTPARK	RDWD
ACC	Pearson Correlation	-.417**	-.126	-.367*	-.147	-.163	-.107	-.490**
	P-value	.005	.415	.014	.340	.290	.488	.001

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5: Pearson Correlation among independent variables

Variables	REST	AADT	HVVEH	TOTALPK	HVPARK	LIGHTPARK	RDWD
REST	1	-.008	-.065	-.031	-.049	.012	.000
AADT	-.008	1	.153	.985**	.942**	.991**	.688**
HVVEH	-.065	.153	1	.307*	.448**	.034	.547**
TOTALPK	-.031	.985**	.307*	1	.985**	.953**	.749**

HVPARK	-.049	.942**	.448**	.985**	1	.889**	.786**
LIGHTPARK	.012	.991**	.034	.953**	.889**	1	.627**
RDWD	.000	.688**	.547**	.749**	.786**	.627**	1
**. Correlation is significant at the 0.01 level (2-tailed).							
*. Correlation is significant at the 0.05 level (2-tailed).							

Table 6: Accident Parameters estimation of Poisson regression analysis

Variables	Parameter
Intercept	8.848 (0.000)
REST	-0.641 (0.000)
AADT	-
HVVEH	-
TOTALPK	-
HVPARK	-
LIGHTPK	-
RDWD	-0.209 (0.000)
Deviance/Degree of Freedom	10.647
Pearson Chi-Square	444.058
Log-Likelihood	-320.081
Akaike's Information Criterion (AIC)	646.161

In parenthesis: P-value

Table 7: Accident Parameters estimation of Negative binomial regression analysis

Variables	Parameter
Intercept	4.119 (0.000)
REST	-0.709 (0.078)
AADT	-
HVVEH	-
TOTALPK	-
HVPARK	-0.009 (0.300)
LIGHTPK	-
RDWD	-
Deviance/Degree of Freedom	0.87
Pearson Chi-Square	22.249
Log-Likelihood	-187.372
Akaike's Information Criterion (AIC)	380.745

In parenthesis: P-value

3.2 Correlation Analysis of Variables

Correlation analysis of related variables was presented in Table 4 and 5. Pearson's correlation analysis was tested among independent variables and a dependent variable. Significant coefficient of Pearson's correlation is implied that it has a significant impact on an average number of accidents coefficient values have two sides such as positive and negative side on a dependent variable. Correlation coefficient between independent variables and a dependent variable were shown in Table 4. Independent variables such as REST, RDWD and HVVEH were included in a model structure at 0.01 and 0.05 significant.

4. MODEL CALIBRATION

Factor analysis in the model formulation was concluded by a commercial software in both of Poisson and negative binomial regression model. Log-Likelihood value by the Maximum likelihood estimator and reasonable sign of parameters were considered.

The accident prediction with Poisson regression model was presented in Table 6. It was found that Deviance/DF is 10.647 which over than 1.00, so it could be implied that Poisson regression is non-fit with these data because of overdisperson effect. Parameters form Poisson regression model have higher error which unacceptable.

Therefore, negative binomial regression model is shown in Table 7 with 70% of confidence. Table 7 shows reasonable sign of parameters form the negative binomial regression model. The model structure is shown in an equation 2

$$Y_{Accident} = Exp(4.119 - 0.709 \times REST - 0.009 \times HVPARK) \quad (2)$$

Where

$Y_{Accident}$ Number of predicted accident per year
$REST$ Rest Area Available (0 = Not available, 1 = available)
$HVPARK$ Number of Heavy Vehicle Parking)Vehicle per hour(

5. MODEL VALIDATION

Accident prediction model in an equation 2 was validated by separated data which it had 9.05 % error. The number of predicted accidents between forced and unforced policy of a rest area were considered, the different thing between forced and unforced policy is the number of heavy vehicle parking in rest areas. So, the number of heavy vehicle parking in case of forced policy is higher than unforced policy. It could be implied that the number of accidents in case of forced policy is less than another case. An average number of accidents are reduced 42% when highways provided a rest area. The large size of rest areas will reduce an average number of accidents 63% and the smaller size of rest areas will reduce an average number of accident 32%.

6. CONCLUSIONS AND RECOMMENDATIONS

From this study, the author focuses on the benefit of rest areas which could reduce the number of road accident especially available of rest area and heavy vehicle factor. Seven variables are tested by the goodness of fit method to select the approximate model. There found out that main variables that significantly effect on an average number of accidents consist of the availability of a rest area, which conforms with the study of Banerjee et al. (2009) that highways with an availability of a rest area, the average number of accidents within 16 kilometers will be reduced.

In previous research, it was found out that the relation between exits from parking places and accident risks seems to be an inverted. Roads with no accesses and roads with a large number of accesses have the lowest accident risk, while roads with a medium number of accesses have the highest accident risk (Greibe, 2003). Therefore, in this research expanded the findings from Greibe (2003). There was found out that large number of heavy vehicle parking will reduce the number of road accidents.
Finally, the suitable model to predict the accident is the negative binomial in this case because of the criterion of Log-Likelihood and overdisperson effect.

Author would like to purpose recommendations for the further research in this area of study such as:

1) In next research, the physical properties of highways and rest areas could be considered, for example: slope, number of horizontal curve, number of accessibility and connection to calibrate the prediction model.
2) Formulation of the flexible of model structures could be considered, for example: a flexible negative binomial regression model. In other word, the computer software could be considered also.
3) The validation and calibration of the accident prediction model for private or non-government rest areas could be considered.

7. ACKNOWLEDGEMENTS

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