Computational Research Progress in Applied Science & Engineering

ISSN 2423-4591

CRPASE Vol. 02(04), 168-172, October 2016

Development of Accident Modification Factors in Two-Lane Highways

Mehdi Jahangir Samet*

Center of Traffic and Safety Studies Management at Municipality of Rasht,Rasht, Iran

Keywords

Accident predictive algorithm,
Accident modification Factors,
Poisson regression Model,
Roadside hazard rating.

Abstract

Base model and accident modification factors play an important role in the accident predictive algorithm for two-lane highways used in the interactive highway safety design model (IHSDM). One of the main approaches of obtaining the accident modification factor associated with each geometric or traffic feature of the highway is the utilization of before and after studies. If there exists no sufficient statistics of before and after studies in the region, the available approved resources in the aforementioned algorithm may be used. In this research, the non-related-intersection accident statistics within the timeframe of 2014-2015 are implemented for 18 two-lane highways in Guilan province, Iran. Comparing the sensitivity analysis of the obtained results from the regression models, one is able to analyze the final achievements. The functions of accident modification factors obtained via Poisson regression model of the present study are compared with the available accident modification factors. Our achievements indicate the probable improvement of accident modification factor related to the roadside hazard rating (RHR) and calibrated base model in the flat and rolling areas of Guilan province, Iran.

1. Introduction

The accident predictive algorithm for two-lane highways, investigates the interactive effects of the amount of non-related-intersection accidents and the geometric and traffic features. The results obtained are due to the environmental effects and other factors which are related to a particular country or region. Results of this approach can be useful for making a comparison among several proposals for a two-lane highway project or for modifying and improving an old project. This algorithm is depicted in Figure 1.In this algorithm, the empirical bayes (EB) method, which is implemented in order to scrutinize the accidents prediction, is not the subject of the present study.

Here, a specific parameter as an accident modification factor (AMF) is defined for an important feature of the highway which is measured against the nominal conditions. The value of each AMF for the nominal condition is equal to 1. If the AMF value corresponding to a specific parameter exceeds 1, it points out to expectation of more accidents to the same amount rather than one for the nominal conditions. However, the AMF value below 1, brings about expectation of fewer accidents to the same amount rather than one for the nominal conditions. The base model , which is used in the accident predictive algorithm for two-lane highways, is obtained via the regression analysis. Base model is the result of the obtained regression model in the nominal conditions. This method of roads safety study has many advantages compared to the utilization of regression model alone.

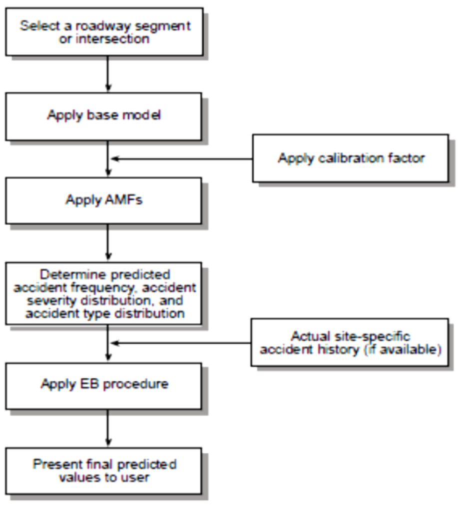

Figure 1. Accident predictive algorithm for two-lane highways [1]

The computation of each AMF via before and after studies is in the forefront of importance. Since, before and

*Corresponding Author:
E-mail address: mjahangirsamet@gmail.com – Tel, (+98) 9111496353 – Fax, (+98) 1333613356

Received: 14 August 2016; Accepted: 22 September 2016

after studies conducted till now are encountered with specific limitations, in some cases, the analysis of regression models will be used for determining the AMF in this study. Finally, the expert opinions play an important role in summing up the AMF determination. Eq. (1) illustrates the overall definition of AMF, while, Eq. (2) states its definition through the regression model.

$$\text{AMF} = 1 - \frac{\text{Accident}_{\text{Before}} - \text{Accident}_{\text{After}}}{\text{Accident}_{\text{Before}}} = \frac{\text{Accident}_{\text{After}}}{\text{Accident}_{\text{Before}}} \quad (1)$$

$$\text{AMF} = \frac{\text{Model function by putting variables in the nominal conditions except } x_1}{\text{Model function by putting all the variables in the nominal conditions}} \quad (2)$$

According to Eq. (3), one is able to determine the amount of accidents improvement results for a specific segment of highway by changing one of the highway's feature which has its specific AMF.

$$\Delta\text{N} = \text{N}_{w/o}\left(\frac{AMF_w}{AMF_{w/o}} - 1\right) \quad (3)$$

In which ΔN denotes the change in the number of accidents due to the change in the geometric conditions or each parameter with obtained AMF value from the literature and $\text{N}_{w/o}$ stands for the number of accidents before changing the corresponding geometric or traffic feature (foregone values). Also, $AMF_{w/o}$ is the AMF value achieved via the existent conditions and AMF_w stands for the AMF value corresponding to the new conditions of geometric and traffic conditions. The positive value of ΔN indicates an increment in the number of accidents due to the performed change and the negative value points out the decrement [2].

The present study aims to develop the AMF values obtained via an appropriate regression model called Poisson model and by using the accidents statistics within the timeframe 2014-2015 in 18 two-lane highways of Guilan province.

2. Methodology

2.1. Statistics and Information Accumulation

The statistics of occurred accidents in 18 different two-lane highways are gathered from the police station. Furthermore, released geometric highway reports from the Department of Roads and available 2D-maps have been also used in this regard. Since the available 2D- map (with scale 1:50000) does not meet the sufficient accuracy to determine important geometric parameters such as horizontal and vertical parameters of highways , these parameters are ignored in the present study. The other parameters are completed with the field research. The accidents statistics have been variably accessible for one to two year of select two lane highways. These statistics have been variably reported from 2014 to 2015. This information includes only the non-related-intersection accidents with no distinction for type of accident in terms of severity (fatal, injury and property damage only). It is worthwhile to mention that the aim of this study is to investigate the total number of accidents and there is no need to distinct them in terms of severity.

2.2. Introduction of the Variables

Since only 11 permanent automatic traffic recording stations are available in the province and only one of the selected axis highway has a permanent automatic traffic recording station, therefore, in order to apply ADT (average daily traffic volume) corresponding to each highway, short-term traffic count is performed in a specified time range for each of them. Then, ADT estimation is used according to the approach presented in the appendix of road safety manual [3].

The field survey consists of defining several independent variables such as lane width (LW: measured in meter), shoulder width (SW: measured in meter and mainly consists of a combination of 50% turf and 50% gravel) , driveway density (DD : number in kilometer), roadside slope (S : classified from 1 to 5 based on the slope), average distance of roadside object from the edge of pavement (DO: measured in meter), shoulder falling (SF : values of 1 and 0 corresponds to the presence and absence of the falling, respectively), terrain type (TER: flat or rolling). Further to these, the roadside hazard rating (RHR) is directly deduced from S and DO values (between 1 and 7). The definition of RHR has been presented by Zegeer and his co-authors for the safety study and roadside design [4].

2.3. Modeling Approach

After gathering the statistics, Poisson regression model is fitted for them. According to Miaou's studies [5] and other later studies, the fitted regression models to the accident predictive models was suggested to follow a log-linear pattern under the assumption of a Poisson error structure. Nowadays, it is still being used as a separator model of various variables effects especially in the road accidents analysis. Poisson model is governed by the following form

$$\mu_i = \exp(\beta_0 + \textstyle\sum_{j=1}^{n} x_{ij}\beta_j) \quad (4)$$

where μ_i is the average expected accidents in the *i*th site and within a specific time period, $x_{i1}, x_{i2}, \ldots, x_{in}$ denote the road variables in the ith site during the time period and $\beta_0, \ldots, \beta_n$ stand for the estimable coefficients of the model.

The verification process and the final model selection is performed in several stages and during this process, the evaluation criteria of the final model are P-Value (based on the significant test of statistic Z) of each effective variable on the model, value of R-squared (R^2) as a goodness-of-fit measurement of the model, each parameter's coefficient magnitude and its standard error as well as consideration of direct engineering judgment.

3. Simulation Results

The statistical results obtained from the independent variables and number of annual accidents are briefly given in Table 1. The 18 axes are 246 km long from which 65 km are rolling and the remaining parts are placed in the flat terrain. 107 km of these ways meet the shoulder falling while falling is not seen in the other.

Table 1. Summarized statistical report of the variables in all the studied axes

Variables	Average	Median	Standard deviation	Minimum	Maximum	25th percent	75th percent
Average annual accidents	51.79	39.12	51.75	5.99	202.21	16.69	58.94
L	13.65	12	11.04	1.7	41	5	19.5
ADT	9013	8073	6454	2580	26357	51977	99297
LW	3.38	3.35	0.29	3	4	3.2	3.525
SW	1.64	1.75	0.76	0	2.5	1	2.5
SF	0.39	0	0.50	0	1	0	1
DO	2.75	2.5	1.60	0.5	6	1.375	3.625
DD	5.78	5	1.59	4	9	4.75	7
S	2.17	2	1.25	1	5	1	3
RHR	4.17	4	1.25	3	7	3	5
TER	0.28	0	0.46	0	1	0	1

The final model obtained via the statistics of 18 highways is introduced as

$$N = LADT^{1.8349} \exp(-10.4873 - 0.4094\,SW - 1.587\,LW + 0.2886\,RHR + 0.84\,TER) \quad (5)$$

in which TER is set to 0 for flat terrain and it is considered as 1 for rolling terrain. Therefore, according to Eq. (5) and for the same conditions of lane width, paved shoulder width and RHR, one can expect an amount of exp (0.84) more accidents for rolling terrain rather than the rolling terrain. However, this conclusion is solely achieved from the study of 18 highways from which only 65 km is rolling. During the simulation, several variables were discarded. The comparison between the effects of SF, S and DO with RHR, illustrated that the model including RHR is much better than the other one. For this reason, the three parameters S, SF and DO have been ignored from the final model due to the magnitude of their covariance value resulting from their intensive dependency to the RHR.

DD has been also calculated as another parameter in the statistics where its average measurement was different for these highways in different segments. By adding this parameter to the final model, no desired results were obtained in terms of Z statistic (p-value=0.137) significant test. The independency of the model to this variable may be due to the diversity of the access points and also the differences among the each access's traffic volume. In addition, the attraction for tourists in the holidays due to the fascinating landscape causing multiple stops beside the highways, so the number of accidents may not be sensitive to the mentioned variable. Eventually, this variable has been ignored from the final model. Table 2 gives the results obtained via the final model of Eq. (5) which resulted in the R^2 value equal to 0.939.

Table 2. The results obtained via the final model in the regression modeling

	Constant	Ln(ADT)	SW	LW	RHR	TER
Standard error	1.1280	0.1225	0.0690	0.2265	0.0391	0.1221
P-value	0.000	0.000	0.000	0.000	0.000	0.000

4. Base Model Calibration in the Accidents Prediction Algorithm and Their Comparison

In the report release by Harwood and others [6], the calibration approach of the model is suggested for two different cases: with the availability of a comprehensive database with geometric design features related to the accidents or without such information for road agencies.

The collected data for 18 highways during this research lack the information of the horizontal and vertical geometric parameters. However, they are classified regarding to the type of terrain (flat or rolling). According to the presented method in [6], the suggested number of accidents in this study was 677.45 per year, and while the average annual accidents has been predicted 932.23 per year. Dividing the total number of suggested accidents by the total number of predicted accidents (non-related-intersection accidents) in these highways, the calibration factor (Cr) would be obtained. Cr is obtained as 1.3628 and the calibrated base model is achieved by converting L in kilometer and applying Cr as

$$Nbc = 1.3628 \times 365 \times 10^{-6} \times 1.61^{-1} \times L \times ADT \times \exp(-0.4865) \quad (6)$$

in which L is the highway's segment length in kilometer and ADT is the average daily traffic volume in terms of number of vehicles per day. In the nominal conditions, the base model obtained via the present regression approach for flat and rolling terrain cases are given as

$Nbr = L.ADT^{1.8349} \exp(-16.0716)$ for Flat

$Nbr = L.ADT^{1.8349} \exp(-15.2316)$ for Rolling (7)

The nominal conditions for the above two cases are Lane width of 3.6 m length, shoulder width of 1.8 m length and RHR=3.

4.1. Comparison Between the Base Models Obtained Via the Calibration and Present Regression Approaches

In order to arrive at the base model of Eq. (6), about 2000 km of two-lane highways of the United States of America have been investigated. Whilst, only 246 km of two-lane ways are considered in the present study. For this reason, the model stated by Eq. (6) may statistically present better model in comparison with the model of Eq. (7). This is due to the available information extent for determining Eq. (6) which is likely to yield a more correct function of statistical sample from population in its area. By investigating the accidents rate within the frame of the accident number per million vehicle-kilometers as in Eqs. (8) and (9), one can indicated the better comparison.

$N\,bc$ / million vehicle - km= $\exp(-0.6532)$ (8)

$N\,br$ / million vehicle - km = $ADT^{0.8349} \exp(-8.1560)$ for Flat (9)

$N\,br$ / million vehicle - km = $ADT^{0.8349} \exp(-7.3160)$ for Rolling

As would be observed, Eq. (9) is a function of ADT while Eq. (8) indicates a constant value. This means that for different values of ADT, the number of accident per million vehicle-kilometers of the highways changes and in fact, this number varies by the power of 0.8349 as ADT increases.

4.2. The Comparison BetweenAccident Modification Factors Used in the IHSDM With Accident Modification Function Obtained From the Recent Regression For the Lane Width

Regarding the regression modeling results and knowing that the AMFs may be achieved via the regression modelling according to Eq. (2), one can benefit from the model presented in Eq. (5) as a function for determining the modification factors. By introducing the available results corresponding to the AMFs of the variables used in the algorithm, the modification factors could be improved.

Using Eqs. (5) and (2) under the aforementioned nominal conditions, the accident modification function of the band width is defined as

$$AMF\,(LW) = \frac{\exp(-1.587\,lw)}{\exp(-5.713)} \quad (10)$$

In order to compare the modification factors used in the prediction algorithm and accident modification function obtained via the regression, results are reported in terms of Table 3. Since the AMF value corresponding to the Lane width in the applied prediction algorithm in IHSDM software [7] is considered to be constant for the daily traffic volume amounts higher than 2000 vehicles per day, the results of the regression model are also given for traffic volume over this value. For comparison, Table 3 gives the results for four different values of lane widths which are equivalent to 9, 10, 11 and 12 ft, respectively.

As can be seen from Table 3, there is a significant difference between the AMF values of the base algorithm (regarding to the relative accidents) and modification factors function. In the accidents modification function of Eq. (10), no effect of ADT is seen and this can be a big issue for determining the modification factor associated with the lane width which shows varying behavior in different traffic volumes toward safety. Therefore, the obtained results from Eq. (10) do not separate the values for the traffic amount and the achievements are much greater than those obtained via IHSDM as a consequence. For this reason, the use of this AMF is not suggested for improving the results in the accidents prediction algorithm of IHSDM. Furthermore, the AMF values of the lane width which have been used in IHSDM are mainly based upon the before and after studies which was considered to be the best way of studying the AMFs.

Table 3. Comparison of the modification factors corresponding to the lane width

Lane Width (m)	2.7	3	3.3	3.6
AMF values used in IHSDM	1.18	1.11	1.02	1
AMF obtained via the regression model	4.17	2.59	1.61	1

4.3. The Comparison BetweenAccident Modification Factors Used in the IHSDM With Accident Modification Function Obtained From the Recent Regression for the Shoulder Width

Using Eqs. (2) and (5) under the mentioned nominal conditions, the AMF function corresponding to the shoulder width is given as below

$$AMF\,(sw) = \frac{\exp(-0.4094sw)}{\exp(-0.7369)} \quad (11)$$

Table 4 gives the comparison of the modification factors used in the prediction algorithm and accident modification function obtained via the regression.Similar to the case of Lane width, the AMF value corresponding to the shoulder width in the applied prediction algorithm in IHSDM software is considered to be constant for the daily traffic volume amounts higher than 2000 vehicles per day [7]. The results of this table are given for shoulder widths of 0, 0.6, 1.2, 1.8 and 2.4 m and considering a composite shoulder (50% turf and 50% gravel). It is saying that the nominal condition is assumed to be the paved shoulder and width of 1.8m. The coefficients obtained from Eq. (11) are converted to the values of Table (4) for the shoulder pavement using the available coefficients in [6].

Table 4. Comparison of the modification factors corresponding to the shoulder width

Shoulder width (m)	0	0.6	1.2	1.8	2.4
AMF values used in IHSDM	1.18	1.13	1.09	1.04	1.02
AMF obtained via the regression model	2.09	1.67	1.32	1.04	0.72

As it is observed, the difference between the results corresponding to the zero shoulder width is significant (about two times). The effect of ADT is also ignored in calculating this modification factor in the regression model. However, generally speaking the differences between AMF values are not so much and this would not conclude that the obtained results are unreasonable. Also, the studies carried out for determining AMF corresponding to the shoulder width and the type of used shoulder in IHSDM are mainly based upon the before and after accident studies which was considered as the best way of studying AMFs.

4.4. The Comparison BetweenAccident Modification Factors used in the IHSDM With Accident Modification Function Obtained From the Recent Regression for the RHR

Using Eqs. (2) and (4) and under the mentioned nominal conditions, the AMF function corresponding to the RHR is given as below

$$\text{AMF (RHR)} = \frac{\exp(+0.2886RHR)}{\exp(0.8658)} \qquad (12)$$

A comparison between the modification factors used in the prediction algorithm in IHSDM [1, 7] and accident modification function obtained via the regression model of Eq. (12) is illustrated by Table 5. The important point during the calculation of this modification factor is the implementation of the applied regression models for the base model which has been performed in both procedures instead of before and after studies. The results of Table 5 clarify that the AMF values obtained via the regression model are higher and the roadside design has more significant role in the accident numbers of these highways.

Table 5. Comparison of the modification factors corresponding to the RHR

RHR	1	2	3	4	5	6	7
AMF values used in IHSDM	0.87	0.94	1	1.07	1.14	1.22	1.31
AMF obtained via the regression model	0.56	0.75	1	1.33	1.78	2.37	3.17

5. Conclusions

The value of calibration coefficient obtained via the calibration procedure of the understudy highways (1.3628), points outs to the risk-taking pattern of the driving style and difference in vehicles type and also some unknown factors considered here compared to the base model obtained from the United States of America [1]. The comprehensive form of the base model with powered ADT is capable of predicting the accident rates per million vehicle for various traffic volumes. In fact, the presence of the powered ADT (ADT to the power of 1.8349 in Eq. (7)) in the base model can present a better graph of the safety behavior of the two-lane highways in this region. The AMF obtained via the present regression model related to the roadside design meets more validity rather than the modification factor used in the accidents predictive algorithm of the two-lane highways in the flat or rolling terrains of this region. This further credit is in terms of the extraction way of this AMF, as the two procedures are based on the regression model used in the base model. The difference is that the regression model obtained from Guilan district meets more credits for this area.

References

[1] D.W. Harwood, F.M. Council, E. Hauer, W.E. Hughes, NCHRP Web Document 62 (Project 17–18[4]): Contractor's Final Report (2004).

[2] D. Lord, J. Bonneson, Role and Application of Accident Modification Factors (AMFs) within the Highway Design Process, The 85th Annual Meeting of the Transportation Research Board (2005)

[3] M. Noori, M. Ghorbani, Piarc Technical Committee on Road Safety, Translated by: Road Safety Manual 1 (2004) 461–463.

[4] C.V. Zegeer, D.W. Reinfurt, J. Hummer, L. Herf, W. Hunter, Safety Effects of Cross-Section Design for Two-Lane Roads, TransportationResearch Record 1195, Transportation Research Board (1988).

[5] S.P. Miaou, Measuring the Goodness-of-Fit of Accident Prediction Models, Report No.96-040, Federal Highway Administration, December (1996).

[6] D.W. Harwood, F.M. Council, E. Hauer, W.E. Hughes, A. Vogt, Prediction of the expected safety performance of ruraltwo-lane highways, No Report: FHWA-RD-99-207, Federal Highway Administration (2000).

[7] Ch.M. Monsere, R.L. Bertini, A. Breakstone, C. Bonner, P. Bosa, Z. Horowitz, D. Houssaye, Update and Enhancement of ODOT's Crash ReductionFactors, Federal Highway Administration, Report No. FHWA-OR-DR-(2006), (2006)06–11.