# Road safety analysis on Srondol – Jatingaleh highway, using Crash Modification Factors (CMFs) Case study: Semarang City, Central Java, Indonesia

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**Abstract.** Problem : Toll Roads Section B (Srondol - Jatingaleh) Semarang have facilities and road traffic safety management has been installed, but the number of accidents in 2011 to 2015 still around 16% to 25%. The Road hazard caused by facilities and road safety management such as various issues can be the factors that cause accidents and become a black spot areas. Method : This reseach finds some factors that influence the safety function performance. Safety analysis with CMFs method which uses an analysis by HSM and give some solutions to improve the safety performance of highway. Data were collected by observation for primary data and literature studied for secondary data and It were analyzed with method using Crash Modification Factors (CMFs), Empirical Bayes (EB), and Negative Binomial Regression. The results of the analysis showed the factors that influence the amount of accident is happened and predictive modeling accident toll roads Srondol – Jatingaleh. Accident prediction modeling calibration with data on the number of accidents is 0.1, which means the method CMFs and EB can be used to analysis and predict the accidents on Srondol - Jatingaleh highway.

K**eywords**: *$SPF_S$, CMF method, negative binomial regression method, amenitive, and highwsay safety manual.*

## 1. Introduction

The existence of road hazard, lack of road equipment facilities, lack of road engineering management regarding the use of speed control, safety management on roads and the various problems that exist in the roads become one of the causes of the accident and why the segment of many roads become black spot areas.

Issues regarding the management on roads not only on highways, but also often occur on the freeway. Toll road Srondol - Jatingaleh one class B toll roads located in Semarang as the urban area is often takes victims in considerable numbers, most of the accidents that have occurred on this highway is a collision between a car travel with truckloads of sand on toll roads Section B (*Source: Suara Merdeka.com; December 25, 2014*).

This road most vulnerable point in the STA 10 + 000 exactly in derivatives after the toll gate towards underpass Jangli Tembalang make the riders after them in a long time to travel at a speed that stable, at this point they do braking time long enough so that frequent of brake tension, especially freight vehicles with a heavy load (*Source: Coverage 6; July 21, 2015*).

## 2. Background

### *2.1 Cross-sectional studies*

Cross-sectional studies are commonly used in transportasion safety research to estimate the expected number of crashes on a suburban segment. CMFs derived from cross-sectional data are based on a prescribed time period under the assumption that the ratio of average crash frequencies for sites with and without a feature is an estimate of the CMF for implementing that feature [1]. A weakness of a cross-sectional study is that it is difficult to determine the reason that certain safety countermeasures exist at one location and not at other similar locations. As such, the observed difference in crash experience can be due to known or unknown factors other than the feature of interest [1]. Observed statisti-cal associations are not generally sufficient, what is required is " causal theory sufficiently developed as to permit prediction." *(Webber, 1983)*. For highway safety, important performance meas-ures are the frequency and severity of crashes, which are affected by the designs of roads, by the designs of the vehicles on the roads, and by the behavior of road users. *Shinar (2007, 2012)*

Known factors, such as traffic volume or geometric characteristics, can be controlled for in principle by estimating a multivariate regression model. Lord and Bonneson (2007) developed CMFs for lane width, shoulder width, and edge-line marking presence for frontage roads in Texas. Bonneson and Pratt (2008) recently proposed a procedure to develop CMFs for curve radius along two-lane rural highways. Additionally, Fitzpatrick, Lord, and Park (2008) developed CMFs for median width on freeways and rural multi-lane highways in Texas. Case–control designs are well established in epidemiology where they are used to relate risk factors within a population to a particular outcome or disease. In the highway safety context, their use has often been limited to studies of the road-user and vehicle *(Tsai, Wang, & Huang, 1995; Stevenson, Jamrozik, & Spittle, 1995; Jovanis, Park, Chen, & Gross, 2005)*. The case–control method, in general, is associated with several advantages over alternative safety evaluationmethods, and thematched case–control design has additional distinct advantages as follows: Evaluating multiple risk factors from a single sample: the sample is selected based on outcome status and investigated to determine potential risk factors. Any variables not included in the case definition or matching scheme may be assessed, simultaneously, as individual risk factors (F.Gross, ET.Donnell, 2011;)

Matching is a powerful tool to account for confounding variables, but it also has drawbacks, including:

- Increased complexity of data collection and sample selection, especially when there are many matching variables [1].
- The sample sizes within each matching combination often become small due to the limited number of subjects (sites) that match the criteria exactly. Intransportation, this has been statedas a limitation to cross-sectional studies that involve matching (Hauer, 2010).

## 3. Methode

### *3.1 Researcher Sites*

**Figure 1**. Map of Toll Road Srondol – Jatingaleh

Semarang toll road Session B is (Srondol - Jatingaleh) is a toll road with the aim of the West towards Kendal and Cirebon, east toward the direction of the center of Ahmad Yani Airport. With road segments ranging in 00 + 000 to km 08 + 450 is from the tip to the Jatingaleh Krapyak, from 00 + 000 to km 08 + 450 is from the tip to the Jatingaleh Krapyak.

*3.2 Methods of Data Collection and Data Analysis*

Quantitative descriptive. Researchers use only the relationships between variables, developed a theory that has been proposed and has a universal validity, hypothesis testing and the development of generalization. Primary data in this study include sampling speed of vehicles and observation equipment also road traffic safety management that has been done on these roads by means of observation and field survey. Secondary data were taken from the office PT.Jasa Marga Semarang branch in the form of an accident report data for 5 years (2011 to 2015), the data leger road, the road map placement of production facilities and the volume of traffic for 6 years (2010 to 2015). Furthermore, analysis were performed using the method Crash Modification Factors, Empirical Bayes and Negative Binomial Regression. Furthermore, were found modelers of the two methods were then compared. Prediction average accident frequency for multilane highways rural road segments is shown in the following equation:

$$Nspf = e\ (a + b * \ln (AADT) + \ln (L)) \quad (1)$$

Where :

Nspf = number of accidents on a per segment year a, b = regression coefficient

AADT = Average daily traffic a year segment (vehicles/day) L = length of the road segment (mil)

EB method is used to determine the estimated number of accidents or $N_{ekspektasi}$ expectations by combining real-time accident frequency or $N_{aktual}$ with Nprediksi. EB method using differentiating the factors w that is a function of the parameter k overdispersi. The value of the expected frequency of accidents can be expressed by the following equation:

$$w = \frac{1}{1+k(\sum_{entire\ year\ of\ study} N_{prediction})} \quad (2)$$

The estimated value of the number of accidents or $N_{ekspektasi}$ is to do expectations of a road segment is calculated by the following equation:

$$N_{ekspectation} = \text{w x } N_{prediction} + (1-w)x\ N_{actual} \quad (3)$$

Analysis of the data by performing a regression analysis performed to more deeply investigate the relationship between the various factors that cause accidents with the accident data in the get and there are at least 3 usefulness of regression analysis for description of the phenomenon of data or case that is being investigated, for control purposes, as well as for predictive purposes.

## 4. Data

Semarang highway section B has various accident factors such as a down hills and uphill road, horizontal alignment,

*4.1 Road Condition and Fittings the road alignment curved Vertical*

Semarang toll road section B is a toll road that goes up and down hills or category evidenced by the climbing lane and the large rise and fall in the toll

**Figure 2.** Hiking uphill is not according to standards

*4.2 Horizontal Curvature*


**Figure 3.** Hiking uphill is not according to standards

Based on data from PT. Jasa Marga Semarang Central Java branch road Semarang toll road sections A, B, and C, it is known that there are two types of horizontal alignment, ie Spiral Spiral-Circle- (S-C-S) and Full Circle (FC).

*4.3 Facility Equipment Road*

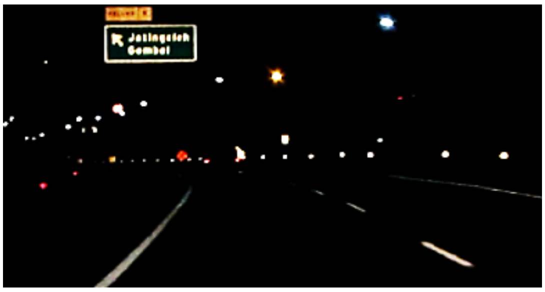

**Figure 4.** Marka Seen At Night motorway section B (Srondol - Jatingaleh)

Road markings based on a survey carried out at night and in rainy conditions the clear markings are still visible.

**Figure 5.** Road Safety Fence form guadrill and concret Barrier

There is also Croncrete Barrier installed but not a separate meeting or terntu course it is dangerous if there are any rammed road users.

*4.4 Rumble Strip*
Rumble strip in Semarang toll road segment is attached at the time to the toll gate and towards the interchange ramp interchanges. Rumble strip has a height of about 2 cm to 15 cm wide. The condition of this rumble strip on the highway is still quite good and can be functioned properly.

*4.5 Virtual Message Sign (VMS)*
Virtual Message Sign is managed by the center for communication in PT.Jasamarga Semarang branch. So if there is something in the road such as traffic jams or road repairs are being made directly VMS can give a message to road users. The factors that related to a method Crash Modification Factors (CMFs) is:

**a) Calculation of Safety Performance Functions (SPFS)**

$$N_{spfrs} = e^{(a+b*ln\,(AADT)+ln(L))} \qquad K = \frac{1}{e^{(c+ln(L))}}$$

where:
AADT : Average Daily Traffic Volume – Average
K : Overdispersi parameters associated with the road segment
L : length of the segment
a, b and c : coefficient regression used to determine parametereter overdispersion

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**Table 1.** Variable Data Toll Roads Section B (Srondol - Jatingaleh)

| Year | Average Daily Traffic | Long Road | Number of Accident | Fatalities Type | Fatalities Number | A | b | c | K *Overdispersion* | $N_{spfs}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 31.97 | 6 | 41 | Fatal and wounded | 52 | - 8.84 | 0.96 | 1.69 | 0.0308 | 0.024 |
| 2012 | 36.876 | 6 | 32 | suffered injuries | 40 | - 9.02 | 1.04 | 1.55 | 0.0354 | 0.032 |
| 2013 | 43.955 | 6 | 35 | Fatal and wounded | 35 | - 8.50 | 0.87 | 2.74 | 0.0107 | 0.033 |
| 2014 | 49.854 | 6 | 27 | Fatal and wounded | 29 | - 8.84 | 0.96 | 1.69 | 0.0308 | 0.037 |
| 2015 | 52.45 | 6 | 25 | Fatal and wounded | 25 | - 8.84 | 0.96 | 1.69 | 0.0308 | 0.038 |

*The level of confidence: 90%*

Judging from the value $N_{SPFs}$ existing accident frequency prediction according to the daily vehicle traffic volume and path length of the segment with overdispersi on value not more than 1.

**b) Calculation Crash Modification Factors (CMFs)**

According to Hauer et al. (2002) in order to develop the CMF for all types of accident causes the data for several years in accordance with the data used to menguhitung SPFS value is needed. The value of the CMF of any facility used road equipment is as follows:

*4.5.1 Installation Median (MD)*

CMFs for mounting the median value with some kind of median installed on roads Srondol - Jatingaleh are as follows:

**Table 2.** Descriptive statistics of treatment and CMF value Median Facility

| Calculation of CMF Value Function | | | | | | |
|---|---|---|---|---|---|---|
| Year | Treatment | Type Of Road | Average of Traffic | Type Of Accident | CMF | Std.Error |
| 2011 | Median concrate barrier | All types of road segments are divided | 31.970 | All types of accidents (Fatal and Death) | 0.57 | 0.1 |
| | | | | All types of accidents (injuries) | 0.70 | 0.06 |
| | Median with Kreb and guadrill | | | All types of accidents (Died and injured) | 1.24 | 0.03 |
| | | | | All types of accidents (injuries) | 0.65 | 0.08 |
| 2012 | Median concrate barrier | | 36.876 | All types of accidents (injuries) | 0.70 | 0.06 |
| | Median with Kreb and guadrill | | | All types of accidents (injuries) | 0.65 | 0.08 |
| 2013 | Median concrate barrier | | 43.955 | All types of accidents (Fatal and Death) | 0.57 | 0.1 |
| | | | | All types of accidents (injuries) | 0.7 | 0.06 |
| | Median with Kreb and guadrill | | | All types of accidents (Died and injured) | 1.24 | 0.03 |
| | | | | All types of accidents (injuries) | 0.65 | 0.08 |
| 2014 | Median concrate barrier | | 49.854 | All types of accidents (Fatal and Death) | 0.57 | 0.1 |
| | | | | All types of accidents (injuries) | 0.70 | 0.06 |
| | Median with Kreb and guadrill | | | All types of accidents (Died and injured) | 1.24 | 0.03 |
| | | | | All types of accidents (injuries) | 0.65 | 0.08 |
| 2015 | Median concrate barrier | | 52.450 | All types of accidents (Fatal and Death) | 0.57 | 0.1 |
| | | | | All types of accidents (injuries) | 0.07 | 0.06 |
| | | | | All types of accidents (Died and injured) | 1.24 | 0.03 |

*4.5.2 Widening the road (PLJ)*

**Table 3.** Descriptive statistics of treatment and the value of CMF Road Widening

| Calculation of CMF Value Function | | | | | |
|---|---|---|---|---|---|
| Year | Widenig | Average Daily Traffic | Type of Accident | CMF | Std. Error |
| 2011 | 0 ft | 31.970 | **Important :** Different types of accidents happen like a single accident, accident two or more than two, front-front, front-side, and vehicle crash from the same direction | 1.5 | 0.1 |
| 2012 | 2 ft | 36.876 | | 1.3 | 0.06 |
| 2013 | 4 ft | 43.955 | | 1 | 0.03 |
| 2014 | 0 ft | 49.854 | | 1.15 | 0.08 |
| 2015 | 2 ft | 52.450 | | 1.3 | 0.06 |

CMF value of widening the road identified from two things: the length and type of road widening widening is done, it is expressed by Zegeer et al (16,17).

*4.5.3 Installation of rumble strips*

Rumble strips required the data of the length that contained on these roads and the length how vehicles that have passed the rumble strip began to accelerate back. From some of the subsequent calculation by using the formula below:

$$\text{CMF}_{9,fs,ac,sv,fi} = (1.0 - \sum_{i=1}^{m} Pci) \text{ x } f_{tan} \text{ x } (\sum_{i=1}^{m} Pci) \text{ x } 1.0$$

$$F_{tan} = 0.5 \text{ x } ([1.0 - [P_{ir}] \text{ x } 1.0 + 0.811) + 0.5 \text{ x } ([1.0 - [P_{ar}]] \text{ x } 1.0 + 0.811)$$

**Table 4.** Descriptive statistics of treatment and value CMF Installation Rumble Strip

| Year | Length of Rumble Strip | Efective Length after Rumble Strip | $F_{tan}$ | $P_{ci}$ | $CMF_s$ | Std. Error | Std. Deviation |
|---|---|---|---|---|---|---|---|
| 2011 | 3 | 5 | 0.244 | 2 | 0.24 | 0.786 | 1.757 |
| 2012 | 3 | 5 | 0.244 | 2 | 0.24 | 0.786 | 1.757 |
| 2013 | 5 | 8 | -0.228 | 2 | -0.23 | 1.417 | 3.169 |
| 2014 | 7 | 10 | -0.606 | 2 | -0.61 | 1.896 | 4.240 |
| 2015 | 8 | 12 | -0.89 | 2 | -0.89 | 2.302 | 5.146 |

*4.5.4 Installation of speed control facility*

Long deceleration performed by the road users average is along more than 690 ft or 230 m and the distance required to accelerate is 300 to 450 m. To determine the value of CMF based fatality factor using the formula below:

For all type of crashing =
$CMF = 1.296 \text{ x } e^{(-2.59 \text{ x } Laccel)}$

For fatalities level (death and injured) =
$CMF = 1.576 \text{ x } e^{(-2.59 \text{ x } Laccel)}$

**Table 5.** Descriptive statistics of treatment and value CMF Speed Control Facility

| Calculation of CMF Value Function | | | | | | |
|---|---|---|---|---|---|---|
| Year | Length of Rumble Strip | All of crashing type and level of fatalities CMF | Fatalities and Injures CMF | CMF | Std. Deviation | Std. Error |
| S2011 | 0.431 | 0.42 | 0.22 | 0.52 | 0.127 | 0.063 |
| 2012 | 0.323 | 0.56 | 0.00 | 0.56 | 0.273 | 0.136 |
| 2013 | 0.377 | 0.49 | 0.28 | 0.58 | 0.131 | 0.065 |
| 2014 | 0.269 | 0.65 | 0.46 | 0.72 | 0.203 | 0.101 |
| 2015 | 0.323 | 0.56 | 0.36 | 0.65 | 0.157 | 0.157 |

*4.5.5 The addition of the edges and the middle marker*

According to tables 13-40 on HSM-1 edition states that the value of the CMFs is 0:55 where the determination of the value of the CMF is not influenced by the presence of various types of collision types or different types of fatality that occurred.

From the results of the calculation data CMFs value by using Empirical Bayes analysis predictions and expectations frequency of accidents to have the results as below:

**Table 6.** Results of the crash prediction calculation with EB method

| Year | N *spfs* | N *predicted* | K | W | N *observed* | N *expected* | Accident Prediction |
|---|---|---|---|---|---|---|---|
| 2011 | 0.024 | 0.0272 | 0.03085 | 0.976 | 41 | 0.0259 | 39.94 |
| 2012 | 0.031 | 0.0358 | 0.03541 | 0.973 | 32 | 0.0304 | 31.03 |
| 2013 | 0.033 | 0.0374 | 0.01 | 0.992 | 35 | 0.0102 | 34.64 |
| 2014 | 0.036 | 0.0416 | 0.0308 | 0.976 | 27 | 0.0261 | 26.30 |
| 2015 | 0.038 | 0.0436 | 0.0308 | 0.976 | 25 | 0.0254 | 24.37 |
| | ∑N predicted | | 0.158393274 | | 119 | 121.668 | |
| | N average total | | | | 0.0236 | | |

From the analysis results that have been obtained the value of the accident number is 0.0236 overall the data five years after the provision of the road equipment.

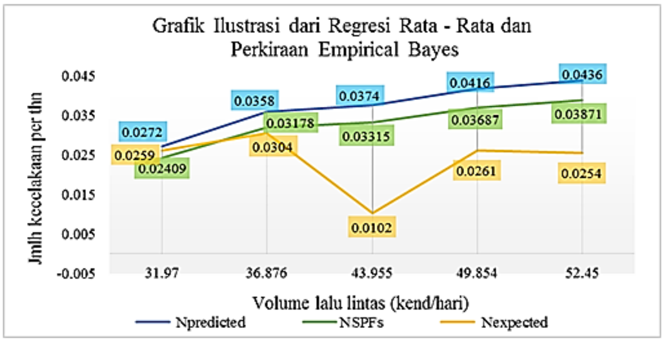


**Figure 6.** Graph Illustration of Regression mean and Empirical Bayes Estimate Method

Based on the graphic illustrations shown that the predictive value of SPFS and the number of accidents related to the volume of traffic and increase along with the number of vehicles annually. Where there is a significant difference between the line number in the accident prediction and the expectation by planners. Safety impact caused by the installation of several production facilities of the road that is equal to 30% which means that after five years the installation of road equipment and do some improvement in facilities road geometry in 2010

*4.5.6 Accident prediction modeling calculations based on value CMFs and SPFS*

Calculation method of SPFS, CMF and empirical Bayes is used to analyze some of these parameters and the calculations used to create the predictive modeling of accidents that are affected by the value of the CMF each treatment is given as follows:

$$Y = \exp(2.359 - 0.006\,\mu 1 + 2.22\,\mu 2 - 0.188\,\mu 3 + 0321\mu 4$$

where =

Y: Prediction Accident Frequency μ1: CMF value of the traffic volume

μ2: CMF value of the median installation μ3: CMF value of their road widening

μ4: CMF value of the Rumble strip installation for speed control

*4.5.7 Accident prediction modeling calculations based on negative binomial regression method*

From the analysis of the first stage value of VIF and Tolerance, showed that where there are five parameters that have VIF <10 and Tolerance value more than 0.1. This shows that Ho is rejected, which means regression model did not have a multicollinearity problem. By using SPSS 16.00 in get the following results:

**Table 7.** Results of calculation colinearity Section B roads Srondol - Jatingaleh, Semarang

Coefficients[s]

| Model | | Unstandardized Coefficients | | 95% Confidence Interval for B | | Collinearity Statistic | |
|---|---|---|---|---|---|---|---|
| | | B | Std.Error | Lower Bound | Upper Bound | Tolerance | VIF |
| 1 | (Contant) | -8.984E-16 | .000 | .000 | .000 | | |

| Model | Unstandardized Coefficients | | 95% Confidence Interval for B | | Collinearity Statistic | |
|---|---|---|---|---|---|---|
| | B | Std.Error | Lower Bound | Upper Bound | Tolerance | VIF |
| Width Road | .000 | .000 | .000 | .000 | .254 | 3.933 |
| Roadside | .000 | .000 | .000 | .000 | .441 | 2.268 |
| Horizontal Alignment | .000 | .000 | .000 | .000 | .163 | 6.139 |
| Traffic Volume | .200 | .000 | .200 | .200 | .779 | 1.284 |
| Speed | 1.215E-17 | .000 | .000 | .000 | .676 | 1.479 |

The second calculation phase is checking the Poisson regression model, while the result of the calculation as follows:

**Table 8.** Results of calculation Statistics Description Section B roads Srondol - Jatingaleh, Semarang

| Statistics | | |
|---|---|---|
| Kecelakaan | | |
| | Valid | 6 |
| | Missing | 0 |
| Mean | | 2.6000 |
| Variance | | 5.440 |

There are overdispertion, The next stage is to examine the case overdispertion or underdispertion by using *Poisson regression model*. The results of the analysis are as follows:

**Table 9.** Results of calculation colinearity Statistics Section B roads Srondol - Jatingaleh, Semarang

**Parameter Estimates**

| Parameter | B | Std.Error | 95% Profile Likelihood Confidence Interval | | Hypothesis Test | | |
|---|---|---|---|---|---|---|---|
| | | | Lower | Upper | Wald Chi-Square | df | Sig. |
| (Intercept) | 1.065 | 3.929E-14 | -90.776 | 87.687 | 7.342E26 | 1 | .000 |
| LB | -.449 | 9.4851E-15 | -21.753 | 20.112 | 2.242E27 | 1 | .000 |
| M | $0^2$ | - | - | - | - | - | - |
| X | .683 | 1.7956E-14 | -38.619 | 41.735 | 1.448E27 | 1 | .000 |
| Y | -.139 | 2.5215E-15 | -6.027 | 5.482 | 3.035E27 | 1 | .000 |
| LHRT | .049 | 3.6306E-16 | -.778 | .847 | 1.846E28 | 1 | .000 |
| V | -.348 | 1.4097E-15 | -4.161 | 3.319 | 6.110E28 | 1 | .000 |
| (Scale) | $1^b$ | | | | | 1 | .000 |

***Source :*** *Source: Analysis of secondary and primary data using SPSS 16.00*

From the results of these calculations can be made a accident prediction modeling based on existing conditions and calculation results of the primary data so the a modeling formula is as follows:

Y= exp (1.065 – 0.449μ1 + 0.683μ2 – 0.139μ3 + 0.494 – 0.348μ5)

where =

Y: Prediction Accident Frequency

μ1: condition and size of road width (m)

μ2: The condition and size of the horizontal alignment (m)

μ3: Conditions and size of the vertical alignment (m)

μ4: Average Daily Traffic Volume - Average (Kend / Day)

μ5: vehicle speed (Km / Jm)

**5. Discussion of Results Analysis Data**

The approach taken is adopting from the analysis and in accordance with the provisions of *Highway Safety Manual 2010* first edition applied in Indonesia and adapted to environmental conditions, equipment facilities of existing roads on the toll roads Srondol-Jatingaleh. According Alkhatni et al. (2014) on the roads of Michigan, to test the effect of the presence of some equipment facilities of existing roads can be seen by comparing the volume of vehicle and road geometry characteristics. According to Khan et al (2014) the effectiveness of rumble strips on the level of road safety where EB method has the analysis results of 14% can reduce all types of accidents. Rusmawan (2011) in his research shows that a range median of the road with a kind of stiff or rigid than the concrete significantly atribute to the accident victim either wounded or died. A study explains that the road shoulder width of 2.1 m is predicted to have the number of accidents by 32.23% lower compared with the roads without shoulders (Suraji, 2010). In this study described the results of data analysis using Negative Binomial CMF nor have the results equally explained that the shoulder of the road has a considerable influence in the prediction of accidents. Predictive modeling estimates were generated using CMF and Empirical Bayes methods have difference of 0.1 greater than the number of accidents as described in Table (11) and for negative binomial regression method has a smaller difference 0.1 of the number of accidents that have been there before. It is very obvious that the CMF and EB methods can be used to develop a predictive modeling accidents on toll roads Srondol-Jatingaleh, Semarang.

*5.1 Recommendations to the cause of the accident-Instalation of Rumble Strips*

The addition of rumble strips laying can be done at a distance of 100 m before the bend, so that road users have an increased level of alertness and decrease their speed at the time, this issue is very important because they see the environmental conditions that are less light exposure at night and there are only reflectors on the median that gives a hint that there will be twists road.

**Figure 7.** Recommended installation of rumble strips at Km 09 + 300

*5.2 Recommendations to the cause of the accident-Installation Wire rope (elastic strap at the median)*

(A) Km 09 + 700 (B) Km 10 + 350 (C) Km 12 + 000

**Figure 8.** Some places need Wire Rope

From picture (A) the round the corner which was followed by a declining path, owned with radius of more than 200 m and width of the road more than 21 m and many road users who use high speed before the curves and the downhill road, so indispensable wire rope needed to maintain and improve the safety of road users. Figure (B) and image (C) on the road straight road user is often feel sleepy and pass through the median to get out on track, Installation of wire rope safety fence types will help reduce the injuries of vehicle crash and return the vehicle back on the track originally.

*5.3 Recommendations to the cause of the accident-Widening the road shoulder repair*

Not all the shoulder of the road on the toll roads Srondol- Jatingaleh have suitable conditions by standard and Safety, below there is a location with the shoulder of the road that needs to be repaired.

## 6. Conclusion

There are five facilities to be factors that has a value of CMF to determine its effect on transport safety on toll roads, among others: a) median installation, b) the widening of the road, c) rumble strip, d) speed control, and e) the facilities and the addition of edge markings middle. Only four factors that have a significaned influence on the safety side, namely:a) The volume of traffic b) Facility median c) Widening of roads and d) Installation of rumble strips to control the speed. The formula using the modeling results CMF and Empirical Bayes methods as follows:

$$Y = \exp(2.359 - 0.006\mu 1 + 2.22\mu 2 - 0.188\mu 3 + 0.321\mu 4)$$

Negative binomial regression method is used to support and prove the results of the analysis method and Empirical Bayes, has predicted results on a number of factors that correspond to real conditions and using observation data to obtain 12 factors used to develop a predictive modeling accident. There are five factors that have the most dominant influence, of these factors are the condition and size of the width of the road, the size of the horizontal alignment, vertical alignment, average daily traffic volume - average, and speed vehicle. The results of predictive modeling accidents by using negative binomial regression method is as follows:

$$Y = \exp(1.065 - 0.449\mu 1 + 0.683\mu 2 - 0.139\mu 3 + 0.49\mu 4 + 0.338\mu 5)$$

The results of the analysis states that the difference in the prediction of accidents with existing data on the number of accidents is 0.1, which means CMF method can be applied to toll roads Srondol-Jatingaleh, where the accident prediction model has a value almost equal to the number of accidents there.

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