The Relationship Between Frequency of Accident and Roads Geometric Design Consistency in NTB Province

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Abstract. Investigate and measure the relationship between accident frequencies and the consistency of road geometric designs. Methodology: Several accident prediction models from straight section, curve section, and road segment data from variables that combine design consistency. Poisson and negative binomial regression approaches are used for model development. The model obtained can later be used as a quantitative tool for evaluating the impact of design consistency on road safety. From the model obtained, from all the results of the model, it was decided to use the model of negative binomial regression because the model has proven to be undispersed, so that the model results obtained are better than poisson regression. Obtained the final model with exponential and power forms. In addition, the model of the combined data results represents more existing field data, this is caused by several factors that can affect these results. Then, it was found that the model obtained could consider design consistency so that the model could identify inconsistencies better and accurately reflect the resulting impact on safety. Many road conditions in Indonesia are still incompatible with existing geometric road design standards. Consistency in the geometric design of the road must be considered, given that all elements in the geometric design of the road have an influence on the number of accidents that occur on the road. So more consideration is needed for new roads that are designed according to existing standards so as to produce a good road, hoping to reduce the number of accidents that occur significantly.

1. Introduction
Traffic accidents are one of the leading causes of death in the world and are predicted to be ranked 5th in 2030 if not addressed immediately World Health Organization [1]. Based on the Indonesian Police Corps (Traffic Corps of the Republic of Indonesia) in 2017, the number of traffic accidents in Indonesia increased to 98,414 with 16,410 fatalities and material losses reaching Rp. 212 billion. Where on this human factor high speed is one of the main causes, this factor has a percentage of around 80-90%. The next factor that affects the number of accidents is the condition of the road that has a design that does not follow the standard with a percentage of 10-20% [7]. This study will discuss the relationship between frequency of accident and road geometric design focused on highways in NTB, especially in East Lombok and Sumbawa areas, precisely on the Pringgabaya to Sembalun road segment (Figure 1) and Sultan Kaharuddin road (Figure 2). The selection of this road segment is based on accident data in NTB which occurred in 2013 to 2017 as many as 3739 accidents [9]. While the selection of the Pringgabaya road

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segment to Sembalun and Sultan Kaharuddin road is based on the road has a standard of road safety, marked by the implementation of road audits at the beginning of planning and during road operations, so that the data obtained will produce data that is assumed to be valid enough to use in analyzing the consistency of road design speed against accidents, and can easily see the correlation between the consistency of road design speed against accidents.

![Figure 1: Pringgabaya to Sembalun Segment Road, East Lombok](image1)

![Figure 2: Sultan Kaharuddin Segment Road, Sumbawa Besar](image2)

2. Literature Review
There have been a number of studies on road geometry and the consistency of road design. For the characteristics of traffic accidents caused by 2 main factors namely human factors and vehicle
speed factors. To evaluate the curve section geometric conditions caused by 2 factors, namely the radius of the curve and the vehicle speed factor, while for the model of the relationship the factors causing the accident are caused by vehicle speed and curve radius factors [12]. Besides that, one of the results obtained is that the model obtained is exponential and power form, the variables used for the straight section are: segment length (km), horizontal curve radius (m), vehicle volume (vehicle / h), super elevation (%), and the number of accidents. The curve section variables used are: the length of the road (km), the volume of vehicles (vehicles / hours), super elevation (%), and the number of accidents [14].

The model results obtained in Poisson regression will be compared with negative binomial regression based on the occurrence of overdispersion. The overdispersion value itself can be obtained from the value of deviance / df still more than one. Several studies have shown that the model results from binomial regression are better than Poisson regression. However, to determine this, the feasibility of the model must be tested first so that it can be concluded that the negative binomial model is better than poisson regression. In addition, in this studies proves that the model obtained from binomial poisson processing and negative regression is arranged with the model in the form of exponential and power, the model can interpret the data properly [15].

2.1. Road Geometric Design

The geometric design of the road has a concentration on physical form planning, to fulfill the basic functions of the road and provide optimum service in traffic [22]. The following elements in geometric design:

2.1.1. Horizontal Alignment. Horizontal alignment is a projection of the road axis in the horizontal plane or plan. Horizontal alignment is divided into two parts, namely the straight part and the curved part. In planning horizontal alignments can be related to design speed, radius of curve, super elevation, and side friction force between tires and road surfaces or commonly known as friction [3, 4].

2.1.2. Road Geometric Design Consistency. According to, Lamm et al. (1995,1999) consistency of road speed design is divided into three design classes (good, medium, and bad), while road speed design criteria are used for Design Consistency [13].

Design consistency is the absolute price of the difference in operational speed and design speed ($|V_{85} - V_d|$). Here are three design classes from the design concessions:

(i) Good: $\leq 10$ km / hour

(ii) Medium: 10-20 km / hour

(iii) Bad: $\geq 20$ km / hour

2.1.3. Super elevation. Super elevation is the transverse slope of the road surface in a horizontal curve, which has a function to compensate for centrifugal force when the vehicle crosses a cornering road at a certain speed (Bina Marga, 1997).

2.1.4. Volume/amount of traffic Traffic volume is the number of vehicles that cross an observation point in a certain unit of time (days, hours, minutes). The unit of traffic volume that is commonly used is [16]:

Average daily traffic:

$$LHRR = \frac{\text{Amount of traffic during observation}}{\text{Length of observation time}}$$

(1)
2.1.5. Traffic Accident. According to PP No. 43 of 1993, a traffic accident is an accident or incident on a highway involving a vehicle with or without other road users, and can result in human casualties or property loss. The victims of this traffic accident can be in the form of death victims, serious injuries, and minor injuries and are calculated at the latest 30 (thirty) days after the accident occurred. Following are the factors that cause accidents [5]:

(i) Human Factors
This factor is often the main cause of accidents. The reason can be because the driver is sleepy, disorderly in complying with existing regulations, the driver is not fully concentrated in driving a vehicle (doing other activities while driving), under the influence of alcohol / drugs, psychological conditions (stress, depression, etc.).

(ii) Vehicle Factor
This factor has a percentage of around 15% as a trigger for traffic accidents such as damage to machinery, spare parts, brake linings that are not functioning properly and components in other vehicles. Under-maintained vehicles can cause fatal consequences for the safety of the driver, so the driver must take care of his vehicle by checking regularly to always be in top shape.

(iii) Environment and Road Factor
Bad weather conditions can make visibility decrease, braking distance becomes distant, road surface slippery. So that the driver must increase awareness and be more careful. The road factor as a means of traffic is related to the condition of the road surface, road design that does not lack safety facilities on the road (guard rail, road markings, safety barrier, etc.), visibility, and lighting of road segments. Roads that are damaged or even hollow are very dangerous for road users, especially those who use two-wheeled vehicles.

3. Some Common Mistake
3.1. Poisson Regression
Poisson regression is a method for analyzing discrete data (arithmetic). If the variable Y-Poisson distribution then the function of the Poisson distribution can be approved as:

\[ f(y, \mu) = \frac{e^{-\mu} \mu^y}{y!}, y = 0, 1, 2, \ldots \]  

With \( \mu \), the average Y random variable is Poisson distribution where the average value and variance have more than zero values. Poisson regression equations can be expressed as:

\[ \mu_i = \exp \left( \beta_0 + \sum_{j=1}^{p} \beta_j x_{ij} \right) \quad i = 1, 2, \ldots, n, j = 1, 2, \ldots, p \]  

Parameter estimation is done by using the method of Maximum Likelihood Estimation (MLE) which is formulated as follows:

\[ \ln L(\beta) = -\sum_{i=1}^{n} e^{x_i^{T} \beta} + \sum_{i=1}^{n} y_i x_i^{T} \beta - \sum_{i=1}^{n} \ln (y_i!) \]  

The parameter significance test consists of simultaneous and partial tests using the Maximum Likelihood Ratio Test (MLRT) method with the hypothesis as:

\[ H_0 : \beta_1 = \beta_2 = \ldots = \beta_p = 0 \]  

\[ H_1 : \text{at least there is one } \beta_j \neq 0; j = 1, 2, \ldots, p \]
With test statistics as follows:

\[ D(\hat{\beta}) = -2 \ln \left[ \frac{L(\hat{\omega})}{L(\hat{\Omega})} \right] = 2 \left[ \ln \left( L(\hat{\Omega}) \right) - \ln (L) \right] \]  

(7)

Reject H0 if \( (\hat{\beta}) > X^2_{p,\alpha} \) which means that at least one parameter has a significant effect. Followed by testing parameters partially with the following hypothesis.

\[ H_0 : \beta_j = 0 \]  

(8)

\[ H_1 : \beta_j \neq 0 \]  

(9)

With test statistics as follows:

\[ Z_{hitung} = \frac{\beta_j}{SE(\beta_j)} \]  

(10)

Reject H0 if \( |Z_{hitung}| > Z_{\alpha/2} \) with \( \alpha \) is the specified level of significance. Reject H0 means that the \( j \)-parameter is significant for the poisson regression model.

3.2. Overdispersion Test

Overdispersion is a condition where the value of variance is greater than the mean value, which means that the nature of equidispersion is not fulfilled. Overdispersion causes estimated model parameters to be biased and inefficient. In addition, overdispersion causes the model error rate to increase and Poisson regression becomes inappropriate. Overdispersion is a dispersion value obtained from the deviance value divided by its free degree from Poisson regression, if a value greater than 1 is obtained it can be said that there is overdispersion [8].

3.3. Negative Binomial Regression

The negative binomial regression model has the following distribution functions:

\[ f(y, \mu, \theta) = \frac{(y + \frac{1}{\theta})}{(\frac{1}{\theta}) (y!) } \left( \frac{1}{1 + \theta \mu} \right)^{\frac{1}{\theta}} \left( \frac{\theta \mu}{1 + \theta \mu} \right)^{y} \]  

(11)

The estimation of the negative binomial regression model is stated as follows:

\[ \mu_i = \exp \left( \beta_0 + \sum_{j=1}^{p} \beta_j x_{ij} \right) \]  

(12)

The Maximum Likelihood Estimation (MLE) method is used for parameter estimation, then continued with Newton Raphson iteration from the first derivative of the log likelihood function which is lowered to \( \theta, \beta \) and then zero. The function of the log likelihood from negative binomial regression is as follows:

\[ L(\beta, \theta) \sum_{j=1}^{n} \left\{ y_i (X_i \beta) + \left( \frac{1}{\theta} \right) \ln (1 - exp(X_i \beta)) + \ln \left( y_i + \frac{1}{\theta} \right) - \ln (y_i + 1) - \ln \left( \frac{1}{\theta} \right) \right\} \]  

(13)

Significance testing simultaneously for parameter estimation of negative binomial regression model with the following hypothesis:

\[ H_0 : \beta_1 = \beta_2 = \ldots = \beta_p = 0 \]  

(14)
\[ H_1 \text{: at least there is one } \beta_j \neq 0; j = 1, 2, \ldots, p \] (15)

\[ D(\beta) = -2 \ln \left( \frac{L(\omega)}{L(\hat{\Omega})} \right) = 2 \left[ \ln \left( L(\hat{\Omega}) \right) - \ln \left( L(\hat{\omega}) \right) \right] \] (16)

Reject \( H_0 \) if the test statistic \( \hat{\beta} > X^2_{p, \alpha} \) means that at least one parameter has a significant effect on the model. The test is followed by a partial test with the following hypothesis.

\[ H_o : \beta_j = 0 \] (17)
\[ H_1 : \beta_j \neq 0 \] (18)

With test statistics as follows:

\[ Z_{hitung} = \frac{\beta_j}{SE(\beta_j)} \] (19)

Reject \( H - O \) if the value \( |Z_{hitung}| > Z_{\alpha/2} \) which means that the \( j \)-parameter has a significant influence on the model.

3.4. Model Feasibility Test

Log Likelihood Rasio In this test aims to compare between the two existing models, in this study the two models were obtained from the models produced from Poisson regression and the models produced from binomial negative regression. The following formula is used in the feasibility test of the model in this study:

\[ G^2 = -2 \ln \left( \frac{L_0}{L_1} \right) = -2 \left[ \ln (L_{\text{negative binomial}}) - \ln (L_{\text{poisson}}) \right] \] (20)

The critical distribution value at the 0.05 significance level is 3.84. If the results obtained by \( G^2 < 3.84 \), it can be concluded that \( H_0 \) is accepted, the binomial negative model is better than the Poisson regression model, whereas if \( G^2 > 3.84 \) then \( H_0 \) is rejected and the Poisson regression model is better than the binomial negative model.

3.5. AIC, AICC, BIC Value

To choose the best model after it has been generated by both regressions, poisson regression and binomial negative regression can also be seen by the Akaike Information Criterion (AIC), AICC (Akaike’s Information Criteria Corrected) and BIC (Bayesian Information Criteria) values. The following equation is used:

\[ \text{AIC} = -2 \ln L_\beta + 2k \] (21)
\[ \text{AICC} = -2 \ln L_\beta + \frac{2kn}{n - k - 1} \] (22)
\[ \text{BIC} = -2 \log L_\beta + \log(n)k \] (23)

Where \( L_\beta \) is the likelihood value, while \( k \) is the number of parameters. The best model can be seen from the value of the model that has the smallest AIC, AICC, and BIC values [6].
Table 1: Poisson Regression Modeling Results on Straight Section

| Parameter          | B   | Std. Error | Exp(B) |
|--------------------|-----|------------|--------|
| (Intercept)        | -6.562 | 2.5083    | 0.001  |
| Pjg Segment        | 0.004  | 0.0013    | 1.004  |
| Volume             | 0.012  | 0.0062    | 1.012  |
| Vconsistency       | 0.047  | 0.1155    | 1.048  |

Table 2: Overdispersion Test of Poisson Regression Model on Straight Section

| Goodness of Fit                        | Value | df | Value/df |
|----------------------------------------|-------|----|----------|
| Deviance                               | 23.269| 27 | 0.862    |
| Scaled Deviance                        | 23.269| 27 |          |
| Pearson Chi-Square                     | 31.207| 27 |          |
| Scaled Pearson Chi-Square              | 31.207| 27 | 1.156    |
| Log-Likelihood                         | -24.199|    |          |
| Akaike’s Information Criterion (AIC)   | 56.398|    |          |
| Finite Sample Corrected AIC (AICC)     | 57.936|    |          |
| Bayesian Information Criterion (BIC)   | 62.134|    |          |
| Consistent AIC (CAIC)                  | 66.134|    |          |

4. Model Result

4.1. Straight section model (using poisson regression)

4.2. Overdispersion Test

From poisson regression on straight section data, the model is obtained:

\[ Y_i = \exp(-6.562) \times L^{0.447} \times V^{0.448} \times \exp(0.047(V_{85} - V_d)) \] (24)

Where: L = Segment length (m), V = Vehicle volume (km/h), V85-Vd = Consistency of design speed (km/h). From the model obtained that for segment length has an effect of 1.004 or 0.4% greater for the possibility of an accident, then the volume has an effect of 1.012 or 1.2% greater for the possibility of an accident. While the consistency of road speed design has an effect of 1.048 or 4.8% greater for the possibility of an accident. In processing the data using poisson regression, the results of the straight section overdispersion test have a value / df value of 0.862 and 1.156. From the results of the overdispersion test, it can be seen that there is a value / df value greater than 1, namely 1.156, so it can be seen that the straight section data occurs overdispersion. Because the Poisson regression model is over dispersed, this model is not used and must be reprocessed using binomial negative regression.

4.3. Straight section model (using negative binomial regression)

4.4. Overdispersion Test

From the binomial negative regression on the straight section data, the model is obtained:

\[ Y_i = \exp(-6.678) \times L^{0.4474} \times V^{0.439} \times \exp(0.063(V_{85} - V_d)) \] (25)

Where: L = Segment length (m), V = vehicle volume (vehicle/hour), V85-Vd = Consistency of design speed (km/h). From the model obtained that for the segment length has an effect of
Table 3: Negative Binomial Regression Modeling Results on Straight Section

| Parameter          | B      | Std. Error | Exp(B) |
|--------------------|--------|------------|--------|
| (Intercept)        | -6.678 | 2.8901     | 0.001  |
| Pjg Segment        | 0.005  | 0.0029     | 1.005  |
| Volume             | 0.011  | 0.0073     | 1.011  |
| Vconsistency       | 0.063  | 0.1659     | 1.065  |

Table 4: Overdispersion Test of Negative Binomial Regression Model on Straight Section

| Goodness of Fit                          | Value | df | Value/df |
|------------------------------------------|-------|----|----------|
| Deviance                                 | 14.964| 27 | 0.554    |
| Scaled Deviance                          | 14.964| 27 |          |
| Pearson Chi-Square                       | 23.075| 27 |          |
| Scaled Pearson Chi-Square                | 23.075| 27 | 0.855    |
| Log-Likelihood                           | -25.825|    |          |
| Akaike’s Information Criterion (AIC)     | 59.651|    |          |
| Finite Sample Corrected AIC (AICC)       | 61.189|    |          |
| Bayesian Information Criterion (BIC)      | 65.387|    |          |
| Consistent AIC (CAIC)                     | 69.387|    |          |

1.005 or 0.5% greater for the possibility of an accident, then the volume has an effect of 1.011 or 1.1% greater for the possibility of an accident. While the consistency of road speed design has an effect of 1.065 or 6.5% greater for the possibility of an accident. From the results of the overdispersion test, it can be seen that overdispersion does not occur because this value / df value is less than 1, it can be concluded that the model has not been over dispersed. Therefore, the model used is the model produced by the binomial negative regression model.

4.5. On Curve Section

Table 5: Poisson Regression Modeling Results on Curve Section

| Parameter          | B      | Std. Error | Exp(B) |
|--------------------|--------|------------|--------|
| (Intercept)        | -4.58  | 1.9225     | 0.01   |
| Pjg Segment        | 0.010  | 0.0085     | 1.010  |
| Vconsistency       | -0.011 | 0.0784     | 0.989  |
| Super elevation    | -0.248 | 0.2737     | 0.753  |
| Volume             | 0.010  | 0.0044     | 1.010  |

4.5.1. Curve section model (using poisson regression).
Table 6: Overdispersion Test of Poisson Regression Model on Curve Section

| Goodness of Fit                        | Value     | df  | Value/df |
|----------------------------------------|-----------|-----|----------|
| Deviance                               | 34.156    | 60  | 0.569    |
| Scaled Deviance                        | 34.156    | 60  |          |
| Pearson Chi-Square                     | 50.423    | 60  |          |
| Scaled Pearson Chi-Square              | 50.423    | 60  | 0.840    |
| Log-Likelihood                         | -31.385   |     |          |
| Akaike's Information Criterion (AIC)   | 72.769    |     |          |
| Finite Sample Corrected AIC (AICC)     | 73.786    |     |          |
| Bayesian Information Criterion (BIC)   | 83.641    |     |          |
| Consistent AIC (CAIC)                  | 88.641    |     |          |

4.6. Overdispersion Test
From poisson regression on the curve section data, the model is obtained:

\[ Y_i = \exp(-4.58) \times L^{0.3674} \times V^{0.3674} \times \exp(-0.011(V85 - Vd)) + \exp(-0.248e) \] (26)

Where: \( L \) = Segment length (m), \( V \) = Vehicle volume (vehicle/hour), \( V85-Vd \) = Consistency of design speed (km/h), \( e \) = Super elevation (%), \( R \) = radius curvature of the road (m). From the model obtained that for the segment length has an effect of 1.010 or 1% greater for the possibility of an accident, then the consistency of road speed design has an effect of 0.989 smaller for the possibility of an accident, for super elevation has an effect of 0.753 smaller for the possibility of an accident. While the volume of the vehicle is the same as the length of the segment which has an effect of 1% greater for the possibility of an accident. In processing data using Poisson regression, the results of the straight section overdispersion test have a value of / df of 0.569 and 0.840. From the results of the overdispersion test it can be seen that the two values df values produced are smaller than 1, so it can be seen that the curve section data is under dispersed [2]. Although the results from Poisson regression are not over dispersed, the data must still be further processed into binomial negative regression and validation of the resulting model is carried out. So that it can be concluded that the model of which regression represents more existing data.

4.6.1. Curve section model (using negative binomial regression).

5. Overdispersion Test
From the binomial negative regression on the curve section data the model is obtained:

\[ Y_i = \exp(-4.85) \times L^{0.3676} \times V^{0.3674} \times \exp(-0.011(V85 - Vd)) + \exp(-0.275e) \] (27)

Where: \( L \) = Segment length (m), \( V \) = vehicle volume (vehicle/hour), \( V85-Vd \) = Consistency of design speed (km/h), \( R \) = radius of curvature (m), \( e \) = Super elevation (%). From the model obtained that for segment length has an effect of 1.012 or 1.2% greater for the possibility of an accident, then the consistency of road speed design has an effect of 0.989 smaller for the possibility of an accident, for super elevation has an effect of 0.760 smaller for the possibility of an accident. While the volume of the vehicle has an effect of 1.010 or 1.0% greater for the possibility of an accident. In processing data using binomial negative regression, the results of the overdispersion test of the curve section have a value / df value of 0.453 and 0.710. Obtained
Table 7: Negative Binomial Regression Modeling Results on Curve Section

| Goodness of Fit | Value  | df | Value/df |
|-----------------|--------|----|----------|
| Deviance        | 34.156 | 60 | 0.569    |
| Scaled Deviance | 34.156 | 60 |          |
| Pearson Chi-Square | 50.423 | 60 |          |
| Scaled Pearson Chi-Square | 50.423 | 60 | 0.840    |
| Log-Likelihood  | -31.385|    |          |
| Akaike’s Information Criterion (AIC) | 72.769 |    |          |
| Finite Sample Corrected AIC (AICC) | 73.786 |    |          |
| Bayesian Information Criterion (BIC) | 83.641 |    |          |
| Consistent AIC (CAIC) | 88.641 |    |          |

Parameter Estimates

| B       | Std. Error | Exp(B) |
|---------|------------|--------|
| (Intercept) | -4.85 | 2.1856 | 0.008 |
| Pij Segment | 0.012 | 0.011 | 1.012 |
| Vconsistency | -0.011 | 0.0854 | 0.989 |
| Super elevation | -0.275 | 0.2982 | 0.760 |
| Volume | 0.010 | 0.0048 | 1.010 |

Table 8: Overdispersion Test of Negative Binomial Regression Model on Curve Section

| Goodness of Fit | Value  | df | Value/df |
|-----------------|--------|----|----------|
| Deviance        | 27.178 | 60 | 0.453    |
| Scaled Deviance | 27.178 | 60 |          |
| Pearson Chi-Square | 42.582 | 60 |          |
| Scaled Pearson Chi-Square | 42.582 | 60 | 0.710    |
| Log-Likelihood  | -33.520|    |          |
| Akaike’s Information Criterion (AIC) | 77.041 |    |          |
| Finite Sample Corrected AIC (AICC) | 78.058 |    |          |
| Bayesian Information Criterion (BIC) | 87.913 |    |          |
| Consistent AIC (CAIC) | 92.913 |    |          |

value / df <1, it can be concluded that there is no overdispersion [2]. However, the value of the value / df obtained from binomial negative regression is smaller than poisson regression.

6. Validation Result

Based on the total number of accidents on study location and on the model obtained:

From table 9, the comparison between the number of accidents according to accident data with the number of accidents based on the model, there is a mismatch of the number of accidents based on the model which has a smaller number of accidents than the number of accidents according to existing field accidents. this is because there is little data so that the model obtained is not representative. then there are other factors that influence the number of accidents not reviewed in this study. in addition, 90% of accident data occurred in 2013-2016, where in 2013-2016 there
were no maintenance programs and road audit programs at the study site. Whereas the road maintenance and audit program at the study site was only implemented in 2017. Then the consistency of design factors for the relatively high road speeds on the curve section included in the bad category also added to the factor in the high number of accidents obtained in the model.

6.1. Road Segment Model

Road segment model uses both straight sections and curves data of all segments.

Figure 3: Validation Result On Straight Section

Table 9: Results Validation Number of Field Accidents with Models

| Segment   | Number of Accident on Study Locations | Number of Accident Based on Model |
|-----------|--------------------------------------|----------------------------------|
| Straight Section | 21                                    | 13                               |
| Curve Section    | 15                                    | 42                               |
### Table 10: Poisson Regression Modeling Results on Road Segment

| Parameter Estimates | B     | Std. Error | Exp(B) |
|---------------------|-------|------------|--------|
| (Intercept)         | -4.547| 1.3353     | 0.011  |
| Pjg Segmen          | 0.005 | 0.0011     | 1.005  |
| Vkonsistensi        | 0.01  | 0.0674     | 1.01   |
| Super elevation     | -0.406| 0.2392     | 0.666  |
| Volume              | 0.011 | 0.0036     | 1.011  |

#### 6.1.1. Road segment model (using poisson regression)

From poisson regression on merged data of road segment, the model is obtained:

\[
Y_i = \exp(-4.547) \times L^{-0.1328} \times V^{0.155} \times \exp(0.01(V_{85} - V_d)) + \exp(-0.406e)
\]  

(28)

Where: \( L = \) Segment length (m), \( V = \) Vehicle volume (km/h), \( V_{85} - V_d = \) Consistency of design speed (km/h), \( e = \) Super Elevation (%).

From negative binomial regression on merged data of road segment, the model is obtained:

\[
Y_i = \exp(-4.562)\times L^{-0.14} \times V^{0.155} \times \exp(0.003(V_{85} - V_d)) + \exp(-0.361e)
\]  

(29)

Where: \( L = \) Segment length (m), \( V = \) Vehicle volume (km/h), \( V_{85} - V_d = \) Consistency of design speed (km/h), \( e = \) Super Elevation (%). From the model obtained that for the length of

### Table 11: Overdispersion Test of Poisson Regression Model on Road Segment

| Goodness of Fit | Value | df | Value/df |
|-----------------|-------|----|----------|
| Devience        | 58.425| 91 | 0.642    |
| Scaled Devience | 58.425| 91 |          |
| Pearson Chi-Square | 85.574| 91 |          |
| Scaled Pearson Chi-Square | 85.574| 91 | 0.940   |
| Log-Likelihood  | -56.084|    |          |
| Akaike’s Information Criterion (AIC) | 122.167|    |         |
| Finite Sample Corrected AIC (AICC) | 122.834|    |         |
| Bayesian Information Criterion (BIC) | 134.989|    |         |
| Consistent AIC (CAIC) | 139.989|    |         |

### Table 12: Road segment model (using negative binomial regression)

| Parameter Estimates | B     | Std. Error | Exp(B) |
|---------------------|-------|------------|--------|
| (Intercept)         | -4.562| 1.4106     | 0.010  |
| Pjg Segmen          | 0.006 | 0.0025     | 1.006  |
| Vconsistensi        | 0.003 | 0.0744     | 1.003  |
| Super Elevasi       | -0.361| 0.2609     | 0.697  |
| Volume              | 0.011 | 0.0039     | 1.011  |
Table 13: Overdispersion Test of Negative Binomial Regression Model on Road Segment

| Goodness of Fit                      | Value    | df | Value/df |
|--------------------------------------|----------|----|----------|
| Deviance                             | 42.967   | 91 | 0.472    |
| Scaled Deviance                      | 42.967   | 91 |          |
| Pearson Chi-Square                   | 67.747   | 91 |          |
| Scaled Pearson Chi-Square            | 67.747   | 91 | 0.744    |
| Log-Likelihood                       | -59.758  |    |          |
| Akaike’s Information Criterion (AIC) | 129.517  |    |          |
| Finite Sample Corrected AIC (AICC)   | 130.183  |    |          |
| Bayesian Information Criterion (BIC) | 142.338  |    |          |
| Consistent AIC (CAIC)                | 147.338  |    |          |

The segment has an effect of 1.006 or 0.6% greater for the likelihood of an accident, the consistency of the design of the road speed has an effect of 1.003 or 0.3% greater for the likelihood of an accident, for super elevation has an effect of 0.697 smaller for possible accident. While vehicle volume has an effect of 1.011 or 1.1% greater for the likelihood of an accident. In processing data using binomial negative regression and Poisson regression, the results of the overdispersion of the curve section have df values of 0.940 and 0.744. The value obtained /df < 1, it can be concluded that there is no overdispersion [2]. However, the value of /df obtained from binomial negative regression is smaller than Poisson regression so the data model used is a model of negative binomial results.

7. Validation Result

![Validation Result On Road Segment](image)

Based on the total number of accidents on study location and on the model obtained:

From the results of the negative Poisson and binomial regression models by combining straight section and curve section data, the number of accidents is close to the number of accidents at the study location and the number of accidents obtained from the model. This can be caused by
the amount of data used in the combined data is relatively more, so the data can describe the relationship between the dependent variable with the independent variable better. So it can be concluded that the model of combining straight section and curve section better describes the original data.

8. Conclusion and Recommendation
On a straight section, the geometric elements of frequency that affect accidents are consistency of road speed design, segment length, and vehicle volume. On curve section, geometric elements that affect accident frequency are consistency of road speed design, segment length, super elevation, and vehicle volume. The difference in speed design consistency as one of the independent variables has a significant effect on the results of the straight and curve section models, on curve section that have more consistency in speed design with a bad category causing more accidents predicted by the model. The super elevation variable on a high-elevation curve section is on a curve that has a short subsegment length, resulting in sharp turns that are prone to accidents.

Many road conditions in Indonesia still do not compatible with the standards of existing road geometric designs. Consistency in the geometric design of the road must be considered, remembering that all elements in the geometric design of the road have an influence on the number of accidents that occur on the road. The interference from the authorities is also needed so that new roads are designed according to existing standards so as to produce good roads, with the hope of reducing the number of accidents that occur significantly.

Acknowledgments
The present study was funded by Indonesia University PITTA B Grant 2019, contract number: NKB-0751/UN2.R3.1/HKP.05.00/2019.

Nomenclature
The following models are obtained for straight section:

\[ Y_i = \exp (-6.678) x L^{0.4474} x V^{0.439} x \exp (0.063 \times (V_{85} - V_d)) \]

Where: \( Y_i \) = Frequency of accident, \( L \) = Segment length (m), \( V \) = vehicle volume (vehicle/hour), \( V_{85} - V_d \) = Consistency of design speed (km/h).

The following models are obtained for curve section:

\[ Y_i = \exp (-4.85) x L^{0.3676} x V^{0.3674} x \exp (-0.011 \times (V_{85} - V_d)) + \exp (-0.275e) \]

Where: \( Y_i \) = Frequency of accident, \( L \) = Segment length (m), \( V \) = vehicle volume (vehicle/hour), \( V_{85} - V_d \) = Consistency of design speed (km/h), \( R \) = radius of curvature (m), \( e \) = Super elevation (%).

The following models are obtained for road segment:

\[ Y_i = \exp (-4.562) x L^{-0.14} x V^{0.155} x \exp (0.003 \times (V_{85} - V_d)) + \exp (-0.361e) \]
Where: \( L \) = Segment length (m), \( V \) = Vehicle volume (km/h), \( V_{85-Vd} \) = Consistency of design speed (km/h), \( e \) = Super elevation (%).

References

[1] (WHO), W. H. (2015). Manajemen Kecepatan.

[2] Akin, D. (2011). Analysis of highway crash data by Negative Binomial and Poisson regression models.

[3] Bina Marga. (1997). Tata Cara Perencanaan Geometrik Jalan Antar Kota No. 038/TBM/1997.

[4] Bina Marga. (2011, September). Pengantar Rekayasa Keselamatan Jalan. Jakarta: Kementerian Pekerjaan Umum.

[5] Bozdogan, H. (2000). Akaike’s Information Criterion and Recent Developments in Information Complexity. Mathematical Psychology.

[6] Cameron, A. a. (1998). Regression Analysis of Count Data. New York: Cambridge University Press.

[7] DITLANTAS POLRI. (n.d.). Makalah Diskusi Penyusunan Sistem Surveilans Cedera Akibat Kecelakaan Lalu Lintas pada Pengendara Sepeda Motor pada 15 Agustus 2015. Prevensi dan Reduksi Kecelakaan Sepeda Motor di Jalan Raya. Jakarta: Direktorlal Lalu Lintas Kepolisian Republik Indonesia (Ditlantas POLRI).

[8] G.B, J. H. (1998). Overdispersion: Models and Estimation.

[9] Kepolisian RI. (2018). IRSMS. Retrieved from IRSMS: Kecelakaan di Indonesia Tahun 2013-2017.

[10] Mohabbi, M. A. (n.d.). Geometric Design Consistency Model Based on Speed and Safety In Rural Highways in Some European Countries: A Review.

[11] PRIM-PIUC. (2017, Desember). Monitoring and Evaluation Road Safety Investment For PRIM Project. Kemitraan Indonesia Australia untuk Infrastruktur.

[12] Purwanto, D. (2015). Hubungan antara Kecepatan dan Kondisi Geometrik Jalan yang Berpotensi Menyebabkan Kecelakaan Lalu Lintas pada Tikungan .

[13] R Lam, P. B. (2000). Highway Design and Traffic Safety Engineering Handbook. New York, U.S.A: McGraw Hill.

[14] SARTRE 3 Report. (2004). European Drivers and Road Risk, Report On Principal. Institut de Recherche sur les Transport et leur Securite INRETS .

[15] Setya, R. W. (2016). Pemodelan dan Penetapan Kasus Pneumonia di Kota Padang Tahun 2014 dengan Geographically Weighted Negative Binomial Regression.

[16] Sukirman, S. (1999). Dasar-Dasar Perencanaan Geometrik Jalan.

[17] World Health Organization (WHO). (2013). Global Health Observatory (GHO) data .

[18] World Health Organization (WHO). (2015, September). Manajemen Kecepatan: Manual Keselamatan Jalan untuk Pengambilan Keputusan dan Praktisi. Jakarta, Indonesia: Global Road Safety Partnership.

[19] W. K. M. Brian, W. Gunawan, Real-time Parking Information System with Cloud Computing Open Architecture Approach, IJETER, vol. 8, no.1, pp. 18 – 22, January 2020.

[20] D. M. A. Aaron, M. S. A. Antonio, L. M. B. Grant, M. R. S. Samantha, S. K. U. Jerrick, Computer Vision on a Parking Management and Vehicle Inventory System, IJETER, vol. 8, no. 2, pp. 321 – 332, February 2020.

[21] Hussein W. N., Kamarudin L. M., Hamzah M. R., Hussain H. N., Jadaa K. J. A Methodology for Bi Data Analytics and IoT-Oriented Transportation System for future implementation, IJETER, vol. 7, no. 11, pp 449 – 453, November 2019.

[22] "Merriam Webster," 1828. [Online]. Available: https://www.merriam-webster.com/dictionary/geometric\%20design.