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# ACCIDENT RISK ANALYSIS OF ROAD GEOMETRIC COMPONENTS USING FUNCTIONAL WORTHINESS APPROACH

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***The geometric design of the road should be based on the road design criteria and requirements contained in the design guidelines. However, the limitations of natural conditions and considerations during the design make the road design not ideal according to the guidelines. Deviations from the guidelines may indicate that the road is not standard and has potential accident risk. This study intends to analyze the risk of accidents from the geometric aspect of the road. The purpose of this study is to find out how the level of accident risk is due to the geometric conditions of the road. The approach used in this analysis is functional worthiness where each road component is compared with field data and design guidelines. The data collection method was carried out by measuring the geometric components of the road, which included horizontal and vertical alignments. The location of data collection was national roads in the Jambi Province area with a total road length of 1.095 km. For analysis purposes, the road data is divided into 82 segments. The analytical method used is multiple regression with various statistical parameters related to these results. The modeling results show that the regression coefficients for each variable horizontal alignment, vertical alignment, and combination of horizontal and vertical alignment are 0.248, 0.349, and 1.170, respectively. While the constant in this regression equation model is 3.366. The greatest value of the accident risk contribution is in the horizontal and vertical alignment variables with a coefficient of 1.170. The results of statistical tests show that the relationship between accident risk and the geometric aspect of the road has a strong linear relationship***

***Keywords: accident risk, road geometry, horizontal alignment, vertical alignment, modelling***

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## 1. Introduction

Road geometry is a shape that describes the road, which includes a cross-section, a longitudinal section, and other aspects related to the physical form of the road [1]. The longitudinal cross-section, which is part of the road geometry consisting of horizontal alignment and vertical alignment, is a factor that is closely related to the safety and comfort of road users. Therefore, the geometric design of the road as far as possible can meet the technical requirements [2].

Road geometry is part of the road component closely related to the operation of traffic movements. Therefore, at the planning stage, the technical requirements and road technical planning criteria must be met as far as possible according to the requirements. This follows the Minister of Public Works [2]. Fulfilling technical requirements and road technical planning criteria is, of course, very closely related to accident risk. If the road design deviates from the predetermined guidelines, the potential risk of accidents will be higher. Previous research that has been done stated that accident-prone locations called black spots caused by road geometry would trigger the risk of accidents [3].

Inconsistency of the geometric layout on the road accident rate can be a trigger for accidents. The research has been carried out in a mountainous area where the topography has a very dynamic combination of alignments [4]. Consistency with the design criteria is an effort that must be maximized so that road safety can be guaranteed [5]. Thus, road design must pay attention to geometric aspects. This is because the geometric aspect of the road can affect traffic accidents [6].

Previous research on road accidents that has been carried out stated that there is a relationship between non-standard geometric designs and truck accidents [7]. This is due to the geometric conditions of the road that are not up to standard and are not sufficient for maneuvering large vehicles. The geometric design of roads in mountainous areas is certainly not easy to comply with technical requirements. This is due to land limitations and topographic conditions that are not flat [8]. This opinion follows what has been expressed that inconsistent geometric design in mountainous areas with technical requirements will have a high accident risk [9].

Aspects of road traffic safety as a whole must be considered both during design and operation. Previous studies show evidence that various aspects need to be considered to realize road traffic safety. Improving safety performance needs to pay attention to the geometric aspects of the road [8], the existing spatial conditions of the terrain [9], and the behavior of road users [10]. This is very relevant to the importance of road safety because of the factors that cause accidents even though they are caused by various factors [11], but the geometric aspect is very important [12].

Modeling of geometric road factors and their influence on accident risk has been carried out by previous researchers. The research teams have modeled the relationship between road geometric conditions and accidents. Both attribute accidents to geometry and speed and accident-prone locations [13]. Functional worthiness approach is an assessment of road conditions based on road technical requirements. In the context of this research, the assessment of road conditions is only viewed from the geometric aspect [14]. If the road conditions do not comply with the technical requirements, the road is considered to have a high level of accident risk [15].

Therefore, it is necessary to evaluate the geometric condition of the road segment that does not comply with the design criteria. This is to see the extent of the influence caused by deviations from the design standards on the risk of accidents. Thus, it is necessary to identify the field conditions of the road segment geometry and juxtapose them with the predetermined road design standards. Furthermore, the effect of road geometry on accident risk is modeled using multiple linear regression. An independent variable is a component related to road geometry, be it vertical alignment, horizontal alignment, or a combination of the two.

## 2. Literature review and problem statement

A traffic accident occurs when a motorized vehicle collides with another object, causing material loss, minor injuries, serious injuries, or even death, which involves the driver, passenger, or other road users. The road alignment with hilly and mountainous terrain has a tendency to be limited when it comes to geometric design. The previous researcher shows that delineating road along mountain roads indicates that there is a fairly high risk of accidents [16]. This research is in line with the opinion of Wilches, which states that geometric road design that is inconsistent and not under technical requirements will trigger a high accident rate [4].

Accidents caused by geometric factors have been studied by several previous researchers. Predictions of accidents can be caused by geometric factors on two-lane two-way roads with horizontal curves and tangents [17]. Meanwhile, the safety evaluation of the roundabout interchange with the VISSIM software simulation also indicates that the geometric shape of the roundabout is the cause of frequent accidents [18]. Accidents caused by geometric can actually be anticipated at the geometric planning stage of the road [19]. The research that has been done is only trying to relate the accident to the geometric aspect of the roundabout. This study did not look at the geometric aspects of the road specifically regarding the vertical alignment and horizontal alignment.

Accident-prone areas on the road generally occur in horizontal curves accompanied by careless road user behavior [13]. In addition, [20] have conducted a study on the weighting of accident risks on road infrastructure. In this research, the analytical approach used is the analytic hierarchy process method. The study results stated that road infrastructure is the most important component for safe traffic. Road geometry, which is one factor that influences traffic accidents, needs to be considered both at the time of planning and operation.

Road geometric requirements for road planning must follow geometric road rules based on traffic safety. This follows the guidelines issued by the General of Bina Marga in the form of the Regulation of Public Work Ministry [14]. In the regulation, it has been determined that the geometric design elements of the road, which include horizontal alignment, vertical alignment, and road cross-section, are regulated following the provisions of technical road requirements. Exceptions that deviate from the technical specifications are still allowed but must be approved by the road operator. Of course, the approval for tolerance in planning still pays attention to traffic safety.

In the Public Work Regulation, it is stated that terrain conditions involving flats, hills, and mountains are associated with the maximum grade for geometric road design. The foremost quality on freeway, highway, and street, respectively, is 4 %, 10 %, and 10 %. This shows that the planning criteria guidelines have provided good direction for realizing a safe road [20].

Deviations from the geometric design of the road against the technical requirements will have an accident risk [5]. This research states that there is a relationship between the consistency of geometric conditions and road safety. On-road bends that are too sharp and vehicle speeds are high, the potential for accidents will be increased. The study stated that the most dominant factor causing accidents was the geometric condition of the road with road bends and high vehicle speeds [21].

In terms of the category of geometric fulfillment technique requirements, there are provisions as contained in the Public Work Regulation [14]. In these provisions, it has been regulated how the geometric requirements can be met according to the guidelines. Compliance with technical requirements is divided into four levels, namely (1) function worthy, (2) function worthy with downgrade standards, (3) function worthy with terms and conditions apply, and (4) not function worthy. Mulyono explained more clearly about conformity to technical requirements. In the explanation, it is stated that function worthy has a relationship with legal certainty [15].

Modeling the relationship between road geometry and accident risk has been carried out by several previous researchers. Various points of view have been considered, both regarding the geometric design criteria, as well as evaluating the geometric conditions that have existed before [22]. There was a relationship between the frequency of accidents and the geometric aspects of the road. The impact caused by the geometric road that does not comply with the technical requirements [23] is also expressed by Michel. The research that has been conducted in the urban area of Cameroon country shows that there is a model of the impact of the relationship between road geometry and traffic accidents [24]. The modeling that has been carried out in this study, although it has reviewed the geometric aspects, is only seen from the design stage. In fact, comparing the facts on the ground with the existing road conditions with the design criteria is an evaluation step regarding the fulfillment of road conditions. Evaluation of the fulfillment of road design criteria is an important step to review whether the road is safe or not.

Road transportation safety modeling has been made using a conjoint analysis approach. The research was applied to intercity bus public transport safety perception modeling [25]. Meanwhile, research on the effect of geometric parameters associated with the promotion and reduction of accidents can serve as an accident prevention measure. This case study research conducted in the National Park area showed a strong relationship between accidents and accident black spots on suburban roads. In addition, safety promotion can also help solve problems in reducing the incidence of accidents [26].

A model of the relationship between traffic accidents and geometric parameters is made. There are five independent variables, which include the radius of bend, the degree of curvature, superelevation, widening of the curve, and side freedom. Meanwhile, there are three kinds of dependent variables, namely EAN (Equivalent Accident Number), accident level, and accident number. The analysis results using a statistical approach show a strong relationship between EAN and side freedom. The results of this study also indicate that side freedom also proved to have a strong relationship with the accident number [27].

Accident risk has been analyzed using the method of risk index determination on rural four-lane divided highways [28]. The accident risk analysis approach adopts the road safety audit scheme. For the purposes of evaluating the geometric condition of the road, this approach still has weaknesses because it does not compare with the technical requirements of the road. Prediction models of accidents have also been developed using generalized linear model's approach with input data from road and traffic conditions. This method is still less specific for evaluating geometric conditions because it does not relate to geometric conditions that do not meet technical requirements [29].

An accident risk model for this type of truck has been carried out using the logistic regression analysis approach by conducting interviews with truck drivers involved in accidents [29]. The main cause of accidents is caused by the behavior of the driver, which includes the duration of the trip, habits that interfere with concentration, overloading and the behavior of intercity bus public transport drivers [30]. The incidence of accidents on the road geometry that does not comply with the planning standards is actually not a single factor by the road geometry. However, it can be caused by various factors. On horizontal and vertical curves where the behavior of road users is not careful, the potential for accidents will also be high [31]. The previous model still has not correlated the fulfillment of technical road requirements with the accident rate on the highway. The fulfillment of technical road requirements is a guideline that should be a reference in assessing road conditions against very necessary technical requirements. For this reason, this accident risk research will use the functional worthiness approach. This study will describe more specific variables related to the fulfillment of road geometric technical requirements. The review of the geometric aspects of the road includes three variables, namely horizontal alignment, vertical alignment, and a combination of horizontal and vertical alignment [32].

There are four levels of accident risk, namely low accident risk, medium risk, high risk, and very high risk. It is called low accident risk if the value is in the range of less than 25 %. It is called medium accident risk if the value is from 25 % to 50 %. It is called high accident risk if the value is between 50–75 %. While the level of risk is very high if it has a value of more than 75 % [15].

Roads are designed based on technical planning criteria and technical requirements contained in the design guidelines. However, there are often deviations from the guidelines that have been determined for various reasons. Weaknesses in carrying out the design and the limitations of natural conditions that are difficult to accommodate during planning must be different from the guidelines. Therefore, it is necessary to evaluate the geometric problem of the road whether deviations that occur from the geometric aspect have an impact on the risk of accidents. The geometric review of the road includes horizontal alignment, vertical alignment or a combination of the two alignments.

## 3. The aim and objectives of the study

The aim of this study is to analyze the relationship between road geometric conditions and the level of accident risk using functional worthiness approach.

The following objectives have been set to achieve the aim:

– to develop an accident risk model related to the geometric aspects of the road using the functional worthiness approach;

– to determine the factors that have a dominant influence on the accident risk model.

## 4. Material and method

### 4. 1. Model development method

The geometric condition of the road becomes the object of this research. In general, road geometry consists of horizontal alignment, vertical alignment, and a combination of horizontal and vertical alignment. Geometric roads that have been built sometimes cannot meet the technical requirements that have been determined. This is reasonable because there are various obstacles, both related to land limitations, designs that are not optimal or budget constraints, and so on [33].

Road geometry that is not under technical requirements has the potential for a higher accident risk than road geometry that complies with technical requirements. For this reason, the geometric analysis of existing roads requires a review of the technical specifications. The simplest way to review the road geometry is to compare the measurements in the field with the technical requirements of the road. A schematic of the research conceptual framework and comparison between field measurements and technical road requirements is shown in Fig. 1.

Fulfiling technical requirements is the key in reviewing the geometric conditions of the road in the field. If the road geometry has met the technical requirements, the road can be said to be functional and does not have the risk of an accident. However, if, on the contrary, where the road geometry does not meet the technical requirements, the road can be said to be unfit for function and has a risk of an accident. The compliance and non-compliance of the road condition with these technical requirements become the focus of analysis related to accident risk [14].

Functional worthiness approach is a method of assessing the suitability of the condition of roads that have been built by referring to the technical requirements contained in the guidelines. The usefulness of road conditions is associated with efforts to create safe roads. Measurement of road conditions in the field is needed to obtain field condition data. Furthermore, the measurement results are compared one by one for each road component being tested.

Comparison of field conditions with technical requirements is divided into various levels ranging from fully conforming to technical requirements to those that are not. The suitability of field conditions with these technical requirements indicates functional worthiness. If there is a match between the field conditions and the technical requirements, the road is declared safe.

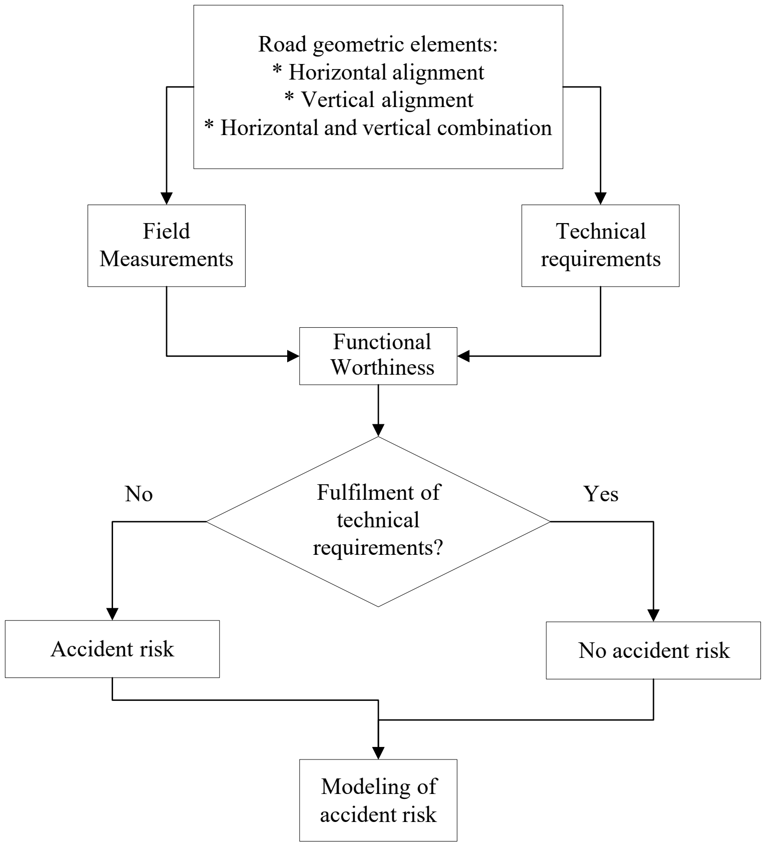


Fig. 1. Conceptual framework of the research

The road section object of this research is the national road in Jambi Province, Indonesia. The number of road segments is 82, with a total road length of 1.095 km. The geometric road data for two years has been surveyed, namely 2019 and 2020.

The geometric road survey includes horizontal alignment, vertical alignment, a combination of horizontal and vertical alignment. The horizontal alignment survey has sight distance, radius, and superelevation. The vertical alignment survey includes grade, sight distance, and climbing lane. The combination of horizontal and vertical alignment survey concerns the overlap between horizontal and vertical alignment. A complete description of the parameters in each variable is included in Table 1.

Data compilation compares the road geometry between field measurements and technical requirements. If the road geometry complies with the technical specifications, it is called function worthy (FW). If the road geometry is not under the technical requirements, but the road is still considered safe, it is referred to as function worthy with downgrade standard (FD). Suppose the road geometry does not meet the technical requirements and needs repair, function decent with terms and conditions applied (FC). Meanwhile, if the road geometry is not under the technical specifications of the road and can endanger road users, it is called not function worthy (NF) [15].

At a level where the road geometry is included in the FW category, it is included in a condition that has a low accident risk level. Meanwhile, if the road geometry is included in the NF category, the road has a very high accident risk. Function worthy (FW) means that it complies with technical requirements. Function worthy with downgrade standard (FD) means that it does not comply with technical requirements, but the road is still safe. Function worthy with terms and conditions applied (FC) means that it does not comply with technical requirements and needs improvement so that it becomes a safe road. Then, not function worthy (NF) means that it does not comply with technical requirements and the road is not safe. A more detailed explanation of the functional worthy category is contained in Table 2.

Table 1

Variables and parameters for data collection

| Variables and symbol | Parameters |
|---|---|
| Horizontal alignment (*X*1) | Length of straight road |
| | Sight distance |
| | Road tangent |
| | Radius |
| | Superelevation |
| | Number of intersections |
| | Access to the main road |
| Vertical alignment (*X*2) | Grade |
| | Sight distance |
| | Environment |
| | Lane width |
| | Climbing lane |
| | Shape of tangent |
| | Direction after tangent |
| Alignment combinations (*X*3) | Overlapping of horizontal alignment and climbing |
| | Overlapping of vertical alignment and turning |

Table 2

Category of geometric fulfillment technique requirement

| Category | Weight | Description |
|---|---|---|
| Function worthy (FW) | 1 | Complies with technical requirements |
| Function worthy with downgrade standard (FD) | 2 | Does not comply with technical requirements but the road is still safe |
| Function worthy with terms and conditions apply (FC) | 3 | Does not comply with technical requirements and needs improvement so that it becomes a safe road |
| Not function worthy (NF) | 4 | Does not comply with technical requirements and the road is not safe |

In the assessment of each road, the road is divided into several segments. The division of road segments is based on the similarity of the physical shape of the road width. If there is a difference in the width of a road, the road must be made into different segments. The assessment of the road condition category with these four levels then the assessment results are presented for each level. Furthermore, from the results of these percentages, it can be determined how large the risk of accidents on the road segment is. Thus, the geometric road condition data have been obtained as many as 82 road segments.

**4. 2. Analysis method of influencing factors**

The approach used in the analysis is multiple regression – the general form of the multiple regression equation. The multiple regression equation consists of three main variables, namely horizontal alignment, vertical alignment, and a combination of horizontal and vertical alignment. The general equation for numerous regressions is shown in equation (1).

$$Y=C+a\cdot X1+b\cdot X2+c\cdot X3, \qquad (1)$$

where $Y$ – accident risk, $X1$ – horizontal alignment, $X2$ – vertical alignment, $X3$ – combination of horizontal and vertical alignment, $a$, $b$, $c$ – regression coefficients, $C$ – constant.

Before performing multiple regression mathematical modeling, the data must be tested for validity and reliability. This test is intended to obtain reliable data and can be analyzed with good results. If the validity and reliability tests have resulted in valid and reliable variables, further testing will be carried out for multiple regression modeling.

The analysis stage begins with seeing whether the model built is good enough or not. From the results of the summary model, the value of determination ($R$) can be seen. If the determination value is more than 0.6, the modeling is quite good.

Next, the model is made by analyzing variance and determining the regression coefficient. If the significance value for the study of variants is less than 0.05, it is said that the regression modeling is significant. Likewise, for the preparation of the regression model, which shows the existence of a regression coefficient, the significance value for each regression coefficient uses a limit value of 0.05. If the significance value for the regression coefficient is less than 0.05, it is declared significant.

In the next stage, the results of multiple regression modeling are tested for model reliability. The model reliability test is carried out to ensure that the model is correct and reliable. There are three kinds of model testing carried out in this analysis, namely linearity test, partial correlation test, and multicollinearity test.

The modeling approach taken has limitations and weaknesses. The basic model of multiple regression is the chosen approach with the assumption that the model pattern is simplified by the regression model, although it is still possible to use other model approaches. In addition, another weakness is that the model only accommodates three main variables, namely horizontal, vertical and a combination of alignments. Meanwhile, of course, there are many other variables that have not been taken into account in this modeling. In this case, the author has an argument that this paper only analyzes the safety model related to road geometry.

## 5. Results of the accident risk model

### 5. 1. Accident risk model

Data has been collected with 82 segments with a length of 1.095 km. Each road segment has identified a code of link based on a database that refers to the national road network system in Jambi Province.

The length of each road segment has also been identified. The determination of the road segment is based on the similarity of the physical condition of the road, especially concerning the width of the traffic lane. The width of the traffic lane is the basis for determining road segments because it is related to the traffic capacity that can be accommodated.

Road classification has also been identified based on the role, function, and class of roads. This classification is important because it is used to determine technical requirements. Each road classification has different technical specifications. The higher the road classification, the more stringent technical requirements must be met.

Each segment identifies geometric conditions that include horizontal alignment, vertical alignment, and a combination of horizontal and vertical alignment. Variable $X1$ horizontal alignment consists of sight distance, a radius of curves, superelevation. The $X2$ vertical alignment variable consists of sight distance and grade parameters. Variable $X3$ combination of horizontal and vertical alignment reviews the existence of overlapping vertical and horizontal alignment. A complete explanation of the number of segments and levels of accident risk is shown in Table 3.

Table 3

Resume of data compilation of accident risk level

| Variable | Description | Parameters | Number of road segments | Average accident risk |
|---|---|---|---|---|
| $X1$ | Horizontal alignment | Sight distance, the radius of curves, superelevation | 82 | Medium risk |
| $X2$ | Vertical alignment | Sight distance, grade | 82 | Medium risk |
| $X3$ | Combination of horizontal and vertical alignment | Overlapping vertical and horizontal alignment | 82 | High risk |

Furthermore, the data from Table 3 is processed using the SPSS software tool to obtain a reliability test. The data has been tested for validity and reliability. The main variables, namely $X1$, $X2$, and $X3$, with the parameters of each variable have been tested. Pushing the fact using a significance value of 0.05 stated that the variable was declared valid. While Cronbach's Alpha reliability test is below 0.5, the three existing variables are declared accepted. Therefore, accurate and reliable data can be used for further regression analysis.

Model summary of accident risk has been generated from the data analysis. The predictor variables include the constant values $X1$, $X2$, and $X3$, while the independent variable is $Y$. From the analysis results, it is obtained that the $R$-squared is 0.892. With this $R$-value, it can be said that $X1$, $X2$, $X3$ can explain $Y$ by 89.2 %. The value of $R$ or the value of determination is included in the large category so that it can be said that the results are very good.

The variant analysis to test the hypothesis has been carried out with the results as shown in Table 4. The research of variant tests shows that the significance value is 0.000. The value is smaller than 0.01 and 0.05, which means that the analysis of variant test results is very significant. Thus, it can be said that hypothesis $H1$ is accepted, and it means that the regression coefficient is significant. This is based on the definition where $H0$ is expressed as the coefficient of the regression equation is not substantial, and $H1$ is defined as the coefficient of the regression equation is significant.

Table 4

Analysis of variance of road accident risk model

| Model | Sum of squares | *Df* | Mean square | *F* | Sig. |
|---|---|---|---|---|---|
| Regression | 10088.42 | 3 | 3362.81 | 213.94 | 0.000 |
| Residual | 1226.02 | 78 | 15.72 | – | – |
| Total | 11314.44 | 81 | – | – | – |

Accident risk modeling has been carried out using a mathematical approach in the form of multiple regression. The modeling results are shown in Table 5. In the table, it can be seen that the significance value for all variables, including *X*1, *X*2, and *X*3 has a value below 0.05. This shows that all variables make a significant contribution to *Y*. In other words, the horizontal alignment, vertical alignment, and combination of horizontal and vertical alignment variables influence accident risk.

The regression coefficient of each variable is 0.248 for *X*1, 0.349 for *X*2, and 1.170 for *X*3. The three coefficients of these variables have positive values. Thus, every change in the value of the *X* variable will increase the value of *Y*. The largest contribution among the three variables is the *X*3 variable, which is stated by a regression coefficient of 1.170.

The results of the multiple regression equation, a *Y* function of the *X* variable, are contained in equation (2). In this equation, it can be seen that the constant is 3.366. With this continuous value, it means that if the variables *X*1, *X*2, and *X*3 are zero, the *Y* value is 3.366.

$$Y=3.366+0.248X1+0.349X2+1.170X3, \quad (2)$$

where *Y* – accident risk, *X*1 – horizontal alignment, *X*2 – vertical alignment, *X*3 – combination of horizontal and vertical alignment.

Table 5

Regression coefficient of the road accident risk model

| Model | Unstandardized Coefficients | | Standardized Coefficients (Beta) | *T* | Sig. |
|---|---|---|---|---|---|
| | *B* | Std. Error | | | |
| Constant | 50.20 | 3.366 | – | 14.92 | 0.000 |
| *X*1 | 4.44 | 0.248 | 0.68 | 17.90 | 0.000 |
| *X*2 | 4.78 | 0.349 | 0.52 | 13.70 | 0.000 |
| *X*3 | 3.55 | 1.170 | 0.11 | 3.03 | 0.003 |

The model as generated in equation (2) is a function of three main variables, namely horizontal alignment, vertical alignment, and a combination of horizontal and vertical alignment. From the three variables, it appears that the *X*3 variable for the combination of horizontal and vertical alignment has the highest coefficient. This shows that this variable has a more dominant influence than the other variables. However, to test the reliability of the model, it is necessary to carry out deeper statistical tests, which include linearity test, partial correlation test, and multicollinearity test.

Testing of the linear regression model was carried out with a linearity test. The linearity test was carried out based on between groups, namely between *Y* and each variable *X*1, *X*2, and *X*3. The results of the linearity test are shown in Table 6.

Table 6

Linearity test between groups

| Between groups | Deviation from linearity | | | | |
|---|---|---|---|---|---|
| | Sum of squared | *df* | Mean square | *F* | Sig. |
| *Y***X*1 | 36.99 | 5 | 7.40 | 0.13 | 0.986 |
| *Y***X*2 | 374.80 | 2 | 187.40 | 2.38 | 0.099 |
| *Y***X*3 | – | – | – | – | – |

Table 6 shows that the variables *X*1 and *X*2 have a significance value of 0.986 and 0.099, respectively. The significance value is above 0.05 so that *H*0 is accepted. This means that the two variables are stated to have a linear relationship to *Y*. This is based on the definition where *H*0 is expressed as linear regression, and *H*1 is defined as non-linear regression. Meanwhile, the test results on *X*3 are declared unable to be calculated. For this reason, to see the results of the *X*3 test in more detail, the partial correlation test was carried out.

**5. 2. Factors that influence the accident risk model**

A partial correlation test has been carried out to test the relationship between variables partially. Partial testing is done by looking at the part by the part where the other variables are considered to control variables. Thus, the partial correlation test can find out how the special relationship between the two variables is by looking at the significance value indicator.

The schematic diagram of the partial correlation test has been prepared, as shown in Fig. 2. In Fig. 2, it can be seen that two-way arrows connect the variables, namely *Y*, *X*1, *X*2, and *X*3. On each arrow line, there is a symbol of the relationship between two variables expressed by correlation (*R*).

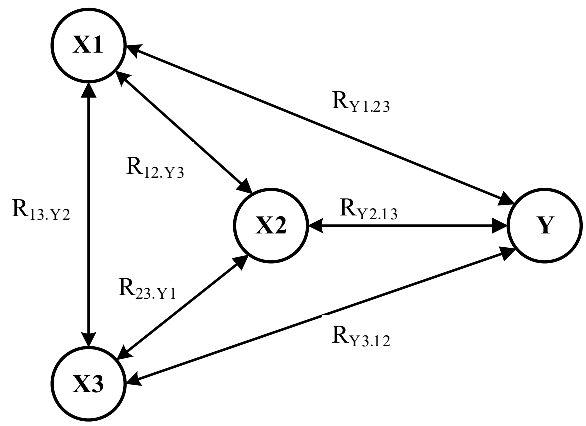


Fig. 2. Diagram of partial correlation test

The results of the calculation of the partial correlation test have been correlated with the results as shown in Table 7. In the Table 7, it can be seen that almost all partial correlation tests have a significant correlation, with the indicated significance value being less than 0.05. Only the variables *X*3 and *Y* with the control variable *X*2 have no significant correlation.

Table 7

Partial correlation test

| Partial correlation test | Control variables | Correlation | Significance (2-tailed) |
|---|---|---|---|
| *X*1&*Y* | *X*2&*X*3 | 0.897 | 0.000 |
| *X*2&*Y* | *X*1&*X*3 | 0.840 | 0.000 |
| *X*3&*Y* | *X*1&*X*2 | 0.325 | 0.003 |
| *X*2&*Y* | *X*1 | 0.829 | 0.000 |
| *X*3&*Y* | *X*1 | 0.222 | 0.046 |
| *X*1&*Y* | *X*2 | 0.889 | 0.000 |
| *X*3&*Y* | *X*2 | 0.200 | 0.074 |
| *X*1&*Y* | *X*3 | 0.786 | 0.000 |
| *X*2&*Y* | *X*3 | 0.653 | 0.000 |

This can be seen from the value where the significance value of 0.074 is greater than 0.05. Thus, in general, it can be said that the partial correlation test between variables has a significant and quite good relationship.

To make the test results more convincing, multicollinearity testing has been carried out. This test is to see if there is multicollinearity. If there is no multicollinearity between the independent variables, the modeling results are considered very good, and there is no need to improve regression testing. The results of the multicollinearity test are contained in Table 8.

Table 8

Results of multicollinearity test

| Model | Collinearity Statistics | |
|---|---|---|
| | Tolerance | VIF |
| $X1$ | 0.963 | 1.038 |
| $X2$ | 0.964 | 1.037 |
| $X3$ | 0.993 | 1.007 |

The table shows that all variables have a VIF value of less than 10. Because the VIF value of all predictor variables $X1$, $X2$, and $X3$ is below 10, it is said that there is no multicollinearity between the independent variables. Thus, the modeling results are good, and there is no need for regression testing again. As the final result, the regression modeling can be continued and interpreted.

## 6. Discussion of the accident risk model

This research has modeled the relationship between road geometry and accident risk. The formula of the modeling results is shown in equation (2). The road geometric independent variable consists of three types, namely horizontal alignment, vertical alignment, and a combination of horizontal and vertical alignment.

In terms of geometric parameters, this research has some similarities with the previous one. The similarity of the variables studied included horizontal alignment and vertical alignment. In this research, there are additional variables that are more specific by reviewing the combination of horizontal alignment and vertical alignment. Meanwhile, the study did not examine the variety of horizontal alignment and vertical alignment. This is what distinguishes the results of this study from previous research [27].

The model approach used in this study is a multiple regression equation with three independent variables ($X1$, $X2$, and $X3$). The results of statistical tests show quite good modeling results. This can be seen from the analysis of variance of the road accident risk model. Analysis test of variant indicates that the significance value is 0.000, meaning that the study of variant test results is very significant.

There are differences in the statistical method used in this study from previous studies. Of course, this difference depends on the focus of the problem raised and the appropriate statistical approach for each situation. However, the results of this study can describe the relationship between road geometry and accident risk. The findings in this study will have implications for the importance of geometric design so that it can provide a safe road [7].

The reliability of the model produced by this study has been sufficiently tested. This is because further tests have been carried out, including linearity tests, partial correlation tests, and multicollinearity tests. These follow-up tests all indicate that the resulting model is very good. Thus, the modeling results can be used to make predictions and interpretations. The same thing as modeling accident-prone locations with a fuzzy expert system approach, this research does not only look at the geometric aspect of accident risk and does not relate it to ITS or expert systems [22].

The novelty of this research is the review of the geometric functional worthiness of the road by comparing it with the technical requirements. Furthermore, a model is made that is associated with accident risk. With the resulting model of the relationship between function-worthy geometric eating, roads make road safety assessments easier and more practical. This convenience is in line with the concept that has been developed in previous research on developing a method of understanding road safety assessment [15].

The modeling results show that the regression coefficients of each variable are 0.248 for $X1$, 0.349 for $X2$, and 1.170 for $X3$. The three coefficients of these variables have positive values; thus, every change in the value of the variable $X$ will increase $Y$. This means that the mathematical model can be used for interpretation.

The final result of modeling shows that among the three geometric variables as independent variables on the dependent variable accident risk, it is stated that the $X3$ variable provides the largest contribution compared to the other variables. The contribution of the $X3$ variable is expressed in the form of a regression coefficient of 1.170. This shows that the combination of horizontal alignment and vertical alignment variables has the largest contribution to accident risk. The combination of horizontal and vertical alignment is a very large grade accompanied by sharp bends. Of course, this combination of alignment conditions will be very risky for road users because the sight distance is very limited.

As a result of mathematical modeling in equation (2), to predict an accident risk, it is enough to enter the value of each variable $X$, $X2$, and $X3$. Of course, the model contains limitations according to field conditions and other restrictions. This modeling only makes predictions from the geometric factors of the road with the variables of horizontal alignment, vertical alignment, and a combination of horizontal and vertical alignment. The other geometric components of the road are still not included in this modeling, such as the cross-road conditions, drainage channels, lane widths, and the like. This modeling is very suitable for the typical topography of the study area in Jambi Province, where the terrain is predominantly hilly. For urban road conditions with flat topography and heavy traffic, this model is not recommended because it is feared that the results will be too large.

The various weaknesses found in the results of this study can certainly be developed for future research. To get optimal results, it is recommended to create an expert system capable of conducting computer-based studies. Of course, it is necessary to prepare user-friendly software to run it smoothly with a small error rate.

This method is the right approach for making modeling with a functional worthiness approach. The previous method using the Generalized Linear Model is only appropriate for predicting accidents on urban roads. Meanwhile, the research conducted is a functional worthiness approach with variables related to road geometry. The geometric aspect of the road is broken down into three variables, namely horizontal alignment, vertical alignment, and a combination of horizontal and vertical alignment, which is representative enough to make modeling [29].

The modeling results can provide convenience in predicting the accident risk level based on functional worthiness. Studies and discussions regarding functional worthiness in order to produce recommendations for road handling can be easily assisted by the results of this modeling [32].

## 7. Conclusions

1. The results of the accident risk modeling using the functional worthiness approach stated that horizontal alignment, vertical alignment, and a combination alignment are variables forming the results of the accident risk model. The modeling contribution of each variable is formed based on the variable coefficients with values of 0.248, 0.349, 1.170 for the horizontal alignment, vertical alignment, and combination alignment variables, respectively. The resulting model can be used to predict the level of accident risk based on a review of geometric aspects.

2. The three variables consisting of horizontal alignment, vertical alignment, and combination alignment variables that have been analyzed have a significant influence, but among the three variables the most influential variable on accident risk is the combination of horizontal and vertical alignment. This can be seen from the coefficient value of the combination of vertical alignment variable, which is the highest among other variables. By knowing that the most dominant factor influencing the accident is the combination alignment, when doing the geometric design of the road, close attention must be paid to these factors.

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