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POISSON REGRESSION MODELING GENERALIZED IN MATERNAL MORTALITY CASES IN ACEH TAMIANG REGENCY

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ABSTRACT

Maternal Mortality Rate (MMR) is the number of maternal deaths due to pregnancy, childbirth, and postpartum, which is used as an indicator of women's health degrees. The number of maternal deaths in Aceh Tamiang Regency in 2021 is a discrete random variable distributed by Poisson. The purpose of this study is to find out what Poisson regression model was generalized in the case of MMR in Aceh Tamiang Regency in 2021 and what factors affected the AKI in Aceh Tamiang Regency in 2021. The research data was obtained from the Aceh Tamiang District Health Office. This type of research is quantitative by using the Generalized Poisson Regression method. The data used are maternal mortality rates and data on factors affecting MMR in Aceh Tamiang Regency in 2021. Influencing factors are the percentage of visits by pregnant women in K1 (X_1), percentage of visits by pregnant women K4 (X_2), percentage of maternity assistance by health workers (X_3), TT immunization of pregnant women (X_4), pregnant women who get Fe tablets (X_5), and puerperal ministry (X_6). Based on the results of research, the factors that affect the maternal mortality rate in Aceh Tamiang Regency in 2021 are TT immunizations for pregnant women (X4) with a p-value of 0.009 which states that for every additional TT immunization of pregnant women by 1%, the average maternal mortality rate also decreases by 15,13%. The form of the generalized Poisson regression model obtained is $\hat{\mu} = exp\,(4{,}378 - 0{,}164X_4)$.

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1. INTRODUCTION

The Maternal Mortality Rate is the number of maternal deaths due to pregnancy, childbirth, and postpartum processes, which are used as indicators of women's health degrees. MMR in the world is 303,000 people. MMR is one of the global Sustainable Development Goals (SDGs) targets in reducing MMR to 70 per 100,000 live births by 2030 [1]. According to the Indonesian Demographic and Health Survey (SDKI), data MMR in Indonesia increased from 228 per 100,000 live births in 2002-2007 to 359 per 100,000 live births in 2007-2012. The number of maternal deaths collected from the family health program registry at the Ministry of Health in 2020 showed 4,627 deaths in Indonesia. This number represents an increase compared to 2019 of 4,221 deaths [2].

AKI gave birth in Aceh in 2020 is included in the category of lacking. The birth AKI continues to experience movements unlike what was targeted, the figure tends to increase in 2017 to 143/100,000 LH in 2018 again down to 138/100,000 LH. In 2019, MMR giving birth in Aceh again experienced an increase of 172/100,000 LH and the same condition again occurred in 2020, namely 172/100,000 LH [3]. MMR in 2019 in Aceh Tamiang Regency reported the number of maternal deaths was 10 people or 10/100,000 live births, and in 2020, it was reported that the number of maternal deaths decreased to 7 people or 7/100,000 live births [4].

Regression analysis is a method used to model the relationship between response variable Y and predictor variable X. In data analysis with response variables, continuous data can be used. Thus, there is also analysis data used in the form of discrete data. The regression method used to analyze the relationship between the response variable Y and the predictor variable X is the Poisson Regression model [5]. One of the assumptions that must be met in the Poisson Regression model is the variance of the variable Y given by $X = x$ equals the mean. In discrete data analysis with the Poisson Regression model, there is sometimes a violation of this assumption, where the overdispersion of Poisson regression can be seen from the deviation value divided by the free degree or it can also be seen from the Pearson Chi-Square value divided by the free degree, if the result is more than 1 it means that there is an overdispersion and if the result is less than 1 then underdispersion [6]. Handling overdispersion or underdispersion in Poisson Regression can be handled with a wide selection of regression models. In this study, the case of Poisson Remission overdispersion will be overcome using a generalized Poisson Regression model and then the selection of the model using AIC (Akaike Information Criterion) will be carried out.

Based on the above problems, the formulation of the problem is how the Poisson Regression model is generalized in the case of AKI in Aceh Tamiang Regency and what factors affect the number of MMR in Aceh Tamiang Regency by using the generalized Poisson regression. The purpose of this study was to determine the generalized Poisson Regression model in AKI cases in Aceh Tamiang Regency and what factors affect AKI in Aceh Tamiang Regency.

2. RESEARCH METHODS

2.1 Maternal Mortality Rate

Maternal Mortality Rate (MMR) is the number of deaths of women during pregnancy or death within 42 days of termination of pregnancy, regardless of the length of pregnancy or the place of delivery. The calculated death can occur due to her pregnancy, childbirth, and puerperium, not due to other causes, such as accidents, falls, etc. [7].

The main indicators of MMR can indicate the success of maternal health programs. In this indicator, maternal mortality is defined as all deaths during pregnancy, childbirth, and puerperium that are not due to other causes, such as accidents or incidents, and are caused by those events or their handling. In addition, to improve the accessibility and quality of health services, this indicator is able to assess the degree of public health and maternal health programs.

2.2 Poisson Distribution

The Poisson distribution is the distribution of a random variable expressed by the number of experimental results that occur in a certain interval of time or in a certain region [8], [9]. Poisson's distribution

function can be written in the form of $Y \sim P(\mu)$ which is a Poisson-distributed random variable Y with Poisson Regression Model parameters μ where the distribution function is:

$$f(y) = \Pr(Y = y) = \frac{e^{-\lambda}\lambda^{y}}{y!}, \qquad y = 0,1,2,\ldots \tag{1}$$

The data that Poisson distributes can be seen by conducting the Kolmogorof-Smirnov test. The hypotheses used are:

H_0 : Poisson distributed data

H_1 : Poisson undistributed data

The level of signification used (α) as large as 5% (0.05). The test criteria in this Kolmogorof-Smirnov test are H_0 Rejected if significance value $<$ α.

2.2 Multicollinearity

A correlation between predictor variables in a linear regression model or commonly referred to as multicollinearity will cause a large error in the estimation of the regression parameter [10]. The explanatory variable, in this case, is the predictor variable (X). The consequence if a model contains multicollinearity is that the variant will continue to rise or enlarge. If the variant is increasing or enlarging, then the default error β_1 and β_2 also rises or enlarges.

To detect the presence or absence of multicollinearity by looking at the Tolerance and VIF (Variance Inflation Factor) values [11]. VIF is a way of detecting multicollinearity by looking at the extent of an explanatory variable that can be explained by all other explanatory variables in the regression equation. If the Tolerance value is more than 0.1 and the VIF (Variance Inflation Factor) is less than 10, multicollinearity does not occur.

Hypothesis:

H_0 : Regression models have multicollinearity problems.

H_1 : Regression models have no multicollinearity problems.

Using a degree of significance $\alpha = 0.05$

Test Statistics:

$$VIF = \frac{1}{(1-r_{i,j}{}^2)} \tag{2}$$

$$Tolerance = \frac{1}{VIF_J}\left(1 - R_j{}^2\right) \tag{3}$$

Test Criteria i.e., reject H_0 if the entire predictor variable has a VIF value of less than 10 and a *Tolerance* value of more than 0.1. Conversely if the entire predictor variable has a VIF value greater than 10 and a *Tolerance* value of less than 0.1 then accept H_0.

2.3 Poisson Regression

Poisson regression is one of the nonlinear regressions often used to model the relationship between response variables in the form of discrete data and predictor variables in the form of discrete and continuous data [12]. Generalized Linear Model (GLM) is an extension of the common regression model for response variables that have an exponential distribution. Poisson regression is used to analyze cunt data (discrete type or numerator data). In Poisson Regression, it is assumed that the response variables are Poisson distributed and there is no multicollinearity between each predictor variable.

The Poisson Regression model can be written as follows:

$$\ln(\mu_i) = \beta_0 + \beta_1 X_{i1} + \cdots + \beta_k \beta_{ik}$$

$$\mu_i = \exp\left(\beta_0 + \beta_1 X_{i1} + \cdots + \beta_k X_{ik}\right) \tag{4}$$

with μ_i is the value of expectations y_i and $i = 1, 2, \cdots, n$.

2.4 Overdispersion and Underdispersion

One of the assumptions that must be met in Poisson regression model is the equidispersion assumption, where the mean value of the dependent variable is equal to the value of the variance. Overdispersion can occur due to the presence of excessive zero values in the dependent variable, the presence of other modifier influences that result in the chances of an event depending on the previous event [13]. Overdispersion or underdispersion causes the model's deviants value to be very large, resulting in an inefficient resulting model. The value of deviance is obtained from the value of deviance divided by the degree of freedom. If the deviance value divided by degrees of freedom produces a value greater than one, then the model is said to be over dispersed [14].

There are two ways to detect cases of overdispersion and underdispersion, namely:

1. Deviance

$$\theta_1 = \frac{D}{db} > 1; D = 2\sum_{i=1}^{n}\left\{y_1 log\frac{y_i}{\mu_i}\right\} \quad (6)$$

2. Pearson Chi-Square

$$\theta_2 = \frac{x^2}{db} > 1; x^2 = 2\sum_{i=1}^{n}\frac{(y_i-\mu_i)^2}{\sigma_i} \quad (7).$$

If θ_1 and θ_2 worth more than one then there is an overdispersion of data where as if θ_1 and θ_2 less than one then underdispersion occurs.

2.5 Parameter Estimation on Poisson Regression Models

In the Poisson Regression model, there are several violations of the assumption that g errors are not normally distributed and the error variances are not the same. To avoid this, the method used to estimate the parameters $\beta_0, \beta_1, \dots, \beta_p$ is Maximum Likelihood Estimation (MLE) method. MLE is a method to find out which parameter value maximizes the likelihood function. The mean in Poisson regression is modeled as a function of a number of predictor variables. To estimate the parameters, use the likelihood function and the likelihood equation based on the Poisson distribution. Estimated maximum likelihood for parameters β expressed with $\hat{\beta}$ which is the completion of the first derivative of its likelihood function, namely:

$$\begin{aligned} L(\beta) &= \prod_{i=1}^{n} P\,(y_i, \beta) \\ &= \prod_{i=1}^{n} \frac{[\,\mu\,(x_i,\beta)]^{y_i}\exp(-\mu(x_i,\beta)}{y_i!} \\ &= \frac{\{\prod_{i=1}^{n}[\,\mu\,(x_i,\beta)]^{y_i}\}\exp(-\sum_{i=1}^{n}\mu\,(x_i,\beta)}{\prod_{i=1}^{n} y_i!} \end{aligned} \quad (8)$$

From the equation above, the ln likelihood function is obtained:

$$\ln L(\beta) = \sum_{i=1}^{n} y_i \ln[\,\mu\,(x_i,\beta)] - \sum_{i=1}^{n}\mu\,((x_i,\beta) - \sum_{i=1}^{n}\ln(y_i!) \quad (9)$$

The equation is then derived against β equated with zero which can then be solved using the numerical iteration method, namely Newton-Raphson. The purpose of this numerical iteration method is to maximize the likelihood function [15].

2.6 Generalized Poisson Regression Model

A generalized Poisson Regression (GPR) Model is a regression model used to analyze the relationship between a dependent variable in the form of data on one or more independent variables. It can be used in the state of underdispersion, equidispersion, or overdispersion. GPR model is a model developed from Poisson regression used to address overdispersion conditions so it is almost similar to Poisson regression but the GPR model assumes that its random components are generalized Poisson distributed [16]:

Poisson Regression Model, conditional probability function Y_i given value $x_{1i}, x_{2i}, \dots, x_{pi}$ be:

$$f(y_i|x_{1i}, x_{2i}, \dots, x_{pi}; \mu_i(x_i, x_{21}, \dots, x_{pi})) = \frac{[\mu_i x_{1i}, x_{2i}, \dots, x_{pi})]^{y_i} \exp[-\mu_i(x_{1i}, x_{2i}, \dots, x_{pi})]}{y_i!} \quad (10)$$

To $y_1 = 0,1,2, \dots, n$

GPR conditional probability function Y_i given value $x_{1i}, x_{2i}, \dots, x_{pi}$ is [17]:

$$P(y_i|x_{1i}, x_{2i}, \dots, x_{pi}; \mu_i \alpha) = \left(\frac{\mu_i}{1+\alpha\mu_i}\right)^{y_i} \frac{(1+\alpha y_i)^{y_i-1}}{y_i!} exp\left(-\frac{\mu_i(1+\alpha y_i)}{1+\alpha\mu_i}\right) \quad (11)$$

To $y_1 = 0,1,2, \dots, n$

Mean and conditional variance of Y_i given $x_{1i}, x_{2i}, = x_{2i}, \dots, x_{pi} = x_{pi}$ for GPR is:

$$E(y_i|X_{1i} = x_1, X_{2i} = x_{2i}, \dots, X_{pi} = x_{pi}) = \mu_i$$

$$Var(y_i|X_{1i} = x_1, X_{2i} = x_{2i}, \dots, X_{pi} = x_{pi}) = \mu_i(1 + \alpha\mu_i)^2$$

The GPR model is similar to a model of the Generalized Linear Model (GLM). The GPR Model has the same form as the Poisson form, namely:

$$\mu = e^{(\beta_0+\beta_1 x_{1i}+\beta_2 x_{2i}+\cdots+\beta_p x_{pi})} \quad (12)$$

With $\beta_0, \beta_1, \beta_2, \dots, \beta_p$ declares a parameter vector – an unknown parameter.

2.7 AIC (Akaike Information Criterion)

To get the best model that describes the relationship between the response variable and the predictor variable, look at the AIC value in each model. The model that has the smallest AIC value is the best regression model. AIC (Akaike Information Criterion) is information differences that are considered as the basis of criteria for evaluating the goodness of the model so that the approach to distribution is correct.

One of the selection indicators used to select the best model from several regression models is to look at the AIC value. Calculate the AIC is described as follows [18]:

$$AIC = -2 \ln L(\hat{\theta}) + 2k \quad (13)$$

where $L(\hat{\theta})$ is the likelihood value, and k is the number of parameters. A lower value from the index indicates the preferred model, which is the one with the fewest parameters that still provides adequate fit for the data. So, to choose the best model is to choose the model that has the smallest AIC.

2.8 Goodness of Fit Test

The goodness of fit testing aims to determine whether or not the model used is in accordance with the observed data [19]. This test aims to draw conclusions about the distribution of the population. This test is based on how well the suitability/match between the frequency of observations obtained by the sample data and the expected frequency obtained from the hypothesis distribution. The accuracy test on the Poisson Regression model can be determined based on the deviance value. The deviance value can be estimated using Chi-Square.

Testing the model by looking at the goodness of fit test using the following hypothesis:

H_0 : The samples derived from Poisson distributed populations.

H_1 : The sample did not originate from a Poisson distributed population.

Using a degree of significance $\alpha = 0.05$

The test criteria in this test are H_0 accepted if Pearson Chi-Square is divided the degree of freedom greater than $\alpha = 0,05$ meaning that the model that is in can come from a Poisson-distributed population.

3. RESULTS AND DISCUSSION

The data used in this study is secondary data obtained from the Aceh Tamiang District Health Office. This study used the Generalized Poisson Regression method. The data used is data on the number of maternal mortality rates in Aceh Tamiang Regency in 2021 (Y) and the factors used are the percentage of K1 pregnant women visits (X_1), the percentage of K4 pregnant women's visits (X_2), the percentage of childbirth assistance by workers (X_3), the percentage of TT immunization of pregnant women (X_4), the percentage of pregnant women who get Fe tablets (X_5), and the percentage of puerperal service (X_6).

3.1 Poisson Distribution Test

In this study, the Poisson distribution test in regression analysis was using the Kolomogrov-smirnov Test.

Hypothesis:

H_0 : Poisson distributed data
H_1 : Poisson undistributed data

With a degree of significance $\alpha = 0.05$

The test statistics are p-value. with the test criteria in the Kolomogrof-Smirnov test is H_0 rejected if significance value $< \alpha = 0.05$.

Based on the SPSS 23 output, the signification value from the test was 0.999, so it can be concluded that the Poisson distributed response variable is due to *p-value* $0.999 > \alpha = 0.05$, then the data on the number of maternal mortality rates in Aceh Tamiang Regency in 2021 is distributed Poisson.

3.2 Multicollinearity Test

In this study, one of the test requirements in regression analysis is that there is no occurrence of multicollinearity, so a multicollinearity test is carried out on the data using VIF and Tolerance values.

Table 1. VIF and Tolerance Variable Predictor Multicollinearity Test

Predictor Variables	Tolerance	VIF
X_1	0.130	7.713
X_2	0.171	5.832
X_3	0.216	4.630
X_4	0.815	1.228
X_5	0.583	1.715
X_6	0.199	5.030

In Table 1, it can be seen that the VIF value and Tolerance value of each of the predictor variables in the multicollinearity test in the regression model do not experience multicollinearity. Each variable has a VIF value < 10 and a Tolerance value > 0.1. So, all variables can be used on generalized Poisson regression models.

3.3 Overdispersion or Underdispersion Test

Overdispersion and underdispersion tests are performed using residual deviation values divided by degree of freedom (*df*).

Table 2. Overdispersion or Underdispersion Test

Criterion	Value	Df	d/df
Deviance	5.407	8	0.676
Pearson Chi Square	4.749	8	0.594

Table 2 shows that the data underdispersed by looking at the residual deviation value divided by the free degree < 1 which is 0.676 and also the pearson square value divided by the free degree < 1 which is 0.594. From the results of the overdispersion / underdispersion test, it can be stated that the data of this study

under dispersed so that it uses generalized Poisson regression to overcome the occurrence of equidispersion in this study.

3.4 Generalized Poisson Regression Model

3.4.1 Shape and Selection of the Best Model of a Generalized Poisson Regression Model

From the results of the model parameter signification test, it can be seen what variables affect maternal mortality in Aceh Tamiang Regency.

Table 3. Parameter Signification Test of Generalized Poisson Regression Model

Variables	Parameters	Standard Errors	P-Value
Constant	4.378	6.9743	0.530
Visit K1 (X_1)	0.206	0.1063	0.053
Visit K4 (X_2)	-0.193	0.0976	0.047
Health Workers (X_3)	0.110	0.0570	0.055
TT Immunization (X_4)	-0.164	0.0623	0.009
Fe Tablets (X_5)	0.103	0.0608	0.092
Puerperal Ministry (X_6)	-0.247	0.1226	0.044

Based on Table 3 obtained, a significant GPR model is $\beta_2, \beta_4, \beta_6$ with a p-value of < 0.05. In the table, a significant variable was obtained, namely the K4 visit variable (X_2), TT immunization (X_4), and puerperal ministry (X_6). Significant variables are combined with predictor variables, so that the Poisson regression model is generalized as follows.

$$\hat{\mu} = \exp\left(4.378 + 0.193X_2 - 0.164X_4 - 0.247X_6\right)$$

In the study, several models were obtained and after that they were selected based on the AIC value. Based on the parameter estimation value in 3 significant variables, the variables entered into the model are 3 variables 7 possible models, and the smallest AIC value is seen to determine the best model in each combination of variables.

Table 4. Selection of the Best Model in Maternal Mortality Cases in Aceh Tamiang Regency with AIC value

Type	AIC
$\exp(\beta_0 + \beta_4 X_4)$	44.863
$\exp(\beta_0 + \beta_4 X_4 + \beta_6 X_6)$	46.653
$\exp(\beta_0 + \beta_2 X_2 + \beta_4 X_4 + \beta_6 X_6)$	48.297

Based on Table 4, it can be seen that the generalized Poisson regression model has the smallest AIC value which is the best model. In this study, the Poisson regression model was generalized, namely a model of 1 predictor variable X_4 with an AIC value of 44.863.

3.5 Goodness of Fit Test

Furthermore, a test of the suitability of the model used is carried out to find out whether the model used is appropriate or not in accordance with the observed data. The model conformity test can be seen using the goodness of fit test.

Table 5. Goodness of Fit Test

Criterion	Value	df	Value/df
Pearson Chi Square	14.166	13	1.090

In Table 5, it can be seen that the value of Pearson Chi Square is $1.090 > \alpha = 0.05$. Then it means that the model already corresponds to the observed data. So, it can be concluded that the generalized Poisson regression model can be used on data on the number of maternal death cases in Aceh Tamiang Regency in 2021.

3.6 Parameter Estimation of the Best Model of Generalized Poisson Regression

The best model of GPR is from the TT Immunization variable (X_4). The parameter results in **Table 6** are obtained.

Table 6. Parameter Estimation of the Best Model of Generalized Poisson Regression

Variables	Parameters	Standard Errors	*P-Value*
Constant	4.378	6.9743	0.530
TT Immunization (X_4)	-0.164	0.0623	0.009

In the **Table 6** above, it states that all variables are significant, so the GPR model formed is as follows.

$$\hat{\mu} = \exp\left(4.378 - 0.164X_4\right)$$

Based on the research obtained, factors on variables that affect the maternal mortality rate in Aceh Tamiang Regency in 20221 is TT Immunization (X_4) with a $\mathrm{p} - \mathrm{value} = 0.009 > \alpha$ which means that there is an effect of TT immunization on the number of maternal deaths in Aceh Tamiang Regency. Based on the estimated value of parameter β_4 states that every additional number of mothers who get TT immunization is 1%, then the average maternal mortality rate also decreases by $100\left(1 - e^{-0.164(1)}\right)\% = 15.13\%$.

4. CONCLUSIONS

The conclusion from the results of the study conducted on the factors that affect the maternal mortality rate in Aceh Tamiang Regency with GPR modeling is that the right GPR model was obtained for the case of maternal mortality in Aceh Tamiang Regency 2021 is the visit of pregnant women K1 (X1), childbirth assistance by workers (X3), pregnant women who get Fe tablets (X5), and puerperal service (X6) with an AIC value of 44,311. With the form of the equation, namely $\hat{\mu} = -11{,}643 + 0.287X_1 + 0.98X_3 + 0.095X_5 - 0.321X_6$ and the factors that affect the case of maternal mortality in Aceh Tamiang district 2021, namely TT Immunization (X_4) with a $\mathrm{p} - \mathrm{value} = 0.009$, which means that there is an effect of TT immunization on the number of maternal deaths in Aceh Tamiang Regency. Based on the estimated value of parameter β_4 states that every additional number of mothers who get TT immunization by 1%, then the average maternal mortality rate also decreases by 15.13%.

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