Journal of Midwifery and Nursing, 8 (1) (2026) pp. 13-18

Published by: IOCSCIENCE

Journal of Midwifery and Nursing

Journal homepage: www.iocscience.org/ejournal/index.php/JMN

Modeling the number of infant and maternal mortality rates in East Java in 2021 using the BPLNR model

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ARTICLE INFO

Article history:

Received Dec 13, 2025
Revised Dec 22, 2025
Accepted Jan 7, 2026

Keywords:

BPLNR;
Infat Mortality;
Maternal Mortality.

ABSTRACT

Poisson regression may be used to describe count data in the form of positive integers as it often follows a Poisson distribution. Poisson regression requires that the response variable's mean and variance be equal (equidispersion). In practice, however, it is more typical to find data with overdispersion, or variation larger than the mean. The number of newborn and maternal fatalities are the response variables, and the units of analysis are the East Java Province's regencies and cities. Because of the correlation between these two variables and the overdispersion that results, the Poisson regression model has to be further developed. One such model development that blends the Poisson and Lognormal distributions is called Bivariate Poisson Lognormal Regression (BPLNR). In order to predict the factors thought to be impacting the number of infant deaths and maternal deaths in East Java Province in 2021, this study attempts to produce parameter estimators and test data for the BPLNR model. According to the modeling results, the number of infant and maternal fatalities is significantly impacted by a variety of variables, including the proportion of cases treated by health personnel and the percentage of K4 antenatal visits by expectant women, among others. Furthermore, the dispersion parameter indicates that overdispersion in the data on newborn and maternal mortality in East Java in 2021 has been taken into account by the model.

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1. Introduction

The Poisson distribution has an assumption that must be met, namely that the mean of the response variable must be equal to its variance (equidispersion) (Orellana et al., 2022). However, violations of this assumption often occur in some cases, which can result in underestimation of the standard error, thus leading to errors in decision making during hypothesis testing. One method that can be used to overcome this problem is Poisson Lognormal (PLN) regression, which is constructed based on the mixed Poisson distribution (Matz et al., 2013). The bivariate regression model is a development of the univariate regression model, used to explain the relationship between two intercorrelated response variables and one or more predictor variables, with five parameters: the expectations and variances of each random variable, and the correlation coefficient between the two variables (Jang et al., 2023).

This study uses the EM algorithm to estimate parameters. The EM algorithm is performed by maximizing the likelihood function, with the basic idea of finding parameter values that provide the greatest probability of obtaining the observed data as estimators (Panić et al., 2020). The equations produced by the EM algorithm are not necessarily in closed form, so their solutions are obtained numerically through iterative numerical methods to obtain parameter estimates (Roberton et al., 2020).

East Java Province has the highest maternal mortality rate in Indonesia, especially since the COVID-19 pandemic, with the numbers rising sharply. The Dean of the Faculty of Medicine at Airlangga University, Prof. Dr. Budi Santoso, SpOG (K), stated that while East Java usually records around 600 to 670 cases, by November 2021, that number had already reached 1,127, indicating that COVID-19 has contributed significantly to the increase in maternal deaths. There are several factors causing maternal mortality, including hypertension during pregnancy, bleeding, and heart disease (Yirmiya et al., 2021). Additionally, the high maternal mortality rate is also due to delays in decisions to refer mothers to the hospital. Early detection of heart disorders, hypertension, and bleeding risks is often delayed, leading to late intervention (Mahmood et al., 2021).

Infant mortality is the term used to describe the death of a living newborn before they turn one year old. Perinatal mortality, neonatal mortality, and postneonatal mortality are the three categories of infant mortality. The number of newborn fatalities under one year old per 1,000 live births in a particular year is known as the newborn Mortality Rate (IMR) (Lorenz et al., 2016) (WHO, 2015). Maternal mortality is referred to by a number of distinct words at the World Health Organization (WHO). The first term is maternal death, defined as "the death of a woman while pregnant or within 42 days of termination of pregnancy, regardless of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes." (Kumar et al., 2021).

This concept differs from the maternal mortality ratio, which is more commonly known as the Maternal Mortality Rate (MMR). High MMR and IMR indicate low quality of maternal and child healthcare services and cause social and economic setbacks in society (Bango, n.d.). There are many factors causing maternal deaths, both direct (such as hemorrhage, preeclampsia/eclampsia, and infection) and indirect, which result from delays in treatment and decision-making starting at the household level up to referral health services (Bryce et al., 2020). When a mother dies during childbirth, the baby's chance of survival becomes significantly lower. Neonatal mortality cannot be meaningfully reduced without concerted efforts to lower maternal mortality and improve maternal health (Babughirana et al., 2020). The direct causes of maternal deaths in Indonesia are hemorrhage, hypertension during pregnancy, and abortion (Stevenson et al., n.d.).

The distribution used in this study is the Poisson Lognormal with two response variables: the number of infant deaths and the number of maternal deaths, as well as five independent variables: percentage of births assisted by healthcare workers, percentage of K4 antenatal visits, percentage of obstetric complication management, percentage of poor population, and percentage of households with adequate sanitation. This study also uses an exposure variable, namely the number of pregnant women in each Regency/Municipality in East Java. The response variables used in this study have been proven to be strongly positively correlated. In addition, a multicollinearity test was conducted using the Variance Inflation Factor (VIF), resulting in no multicollinearity found in this study (Kumbeni et al., 2021). Based on the aforementioned explanation and the data used in this study, modeling will be carried out using Bivariate Poisson Lognormal Regression (BPLNR) on the data for Number of Infant Deaths and Number of Maternal Deaths in East Java in 2021. Through this modeling, parameter estimators and test statistics for hypothesis testing of the BPLNR model will be obtained. Furthermore, it will identify the factors that significantly affect the number of infant deaths and the number of maternal deaths in East Java Province in 2021.

2. Methods

The data source for this research is a case study in East Java Province. All regencies/cities serve as research units, resulting in a total of 38 regencies/cities for observation in this study. This research uses

secondary data obtained from the Health Profile Report, which can be accessed at https://dinkes.jatimprov.go.id/, and BPS Publications for the year 2022.

The research variables used in this study consist of five predictor factors and two response variables. The answer variables are the number of maternal and newborn deaths in East Java. The percentage of K4 prenatal care visits, the percentage of obstetric problems managed, the percentage of households with adequate sanitation, the percentage of the population living in poverty, and the percentage of births assisted by health professionals are all predictor variables.

The stages of this research consist of parameter estimation for the BPLNR model using the EM algorithm with BHHH numerical iteration (Kabir et al., 2021). The steps to obtain parameter estimation are: determining the BPLNR model, forming the likelihood function of the BPLNR model, determining the log-likelihood function of the BPLNR model, finding the first derivative of the log-likelihood function with respect to each estimated parameter and setting it equal to zero. The maximum value is obtained when the result of the first derivative forms an equation that does not have a closed form, so the parameter estimators for the BPLNR model can be obtained using the BHHH numerical iteration method. The final step is hypothesis testing for the BPLNR model.

3. Results

Description of Research Data

The number of maternal and newborn fatalities in East Java in 2021 served as the study's response variables. The mean or average of the number of maternal fatalities and newborn deaths in East Java in 2021 is 33.66 cases and 88.3 cases, respectively, according to the descriptive analysis of the response variables. The ratio, stated as a percentage, between the average value and the standard deviation is known as the coefficient of variation. The spread or dispersion of data using various units is seen using this number. The variable number of newborn deaths has a higher coefficient of variance than the variable number of maternal deaths. In comparison to the variable number of maternal deaths, the variable number of infant deaths by regency/municipality in East Java in 2021 is more diverse (heterogeneous). Similarly, the descriptive analysis for the predictor variables shows that the averages of (1) the percentage of deliveries attended by health workers, (2) the percentage of K4 antenatal visits, (3) the percentage of obstetric complication management, and (5) the percentage of households with proper sanitation, are all above 80%. The highest average value for the exposure variable "percentage of deliveries attended by health workers" (107.3%) is found in Bondowoso Regency, while the lowest percentage (83%) is found in Malang City. The highest percentage of K4 antenatal visits (100%) is found in Pasuruan Regency and Madiun City, while the lowest percentage (71.3%) is found in Situbondo Regency, and so on for the remaining variables.

Relationship Patterns Between Research Variables

The pattern of the relationship between the variables of infant mortality and maternal mortality with their predictor variables can be seen in the figure below.

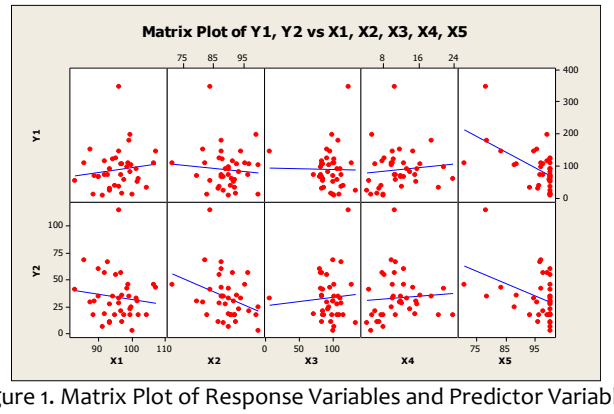

Figure 1. Matrix Plot of Response Variables and Predictor Variables

As shown in Figure 1, the direction of the relationship between the variables (1) the percentage of deliveries assisted by health professionals, (2) the percentage of pregnant women with K4 visits, (3) the percentage of obstetric complication cases managed, and (5) the percentage of households with proper sanitation toward their respective response variables is negative. This aligns with the theory indicating that an increase in these predictor variables will decrease the response. Meanwhile, the direction of the relationship for variable (4), the percentage of the population living in poverty, is positive. This is consistent with the theory suggesting that an increase in this predictor variable will increase the response.

Correlation Examination Between Response Variables

The testing method used in this study is the Pearson Correlation test. The statistical calculations for the test to determine the correlation between the number of infant deaths and the number of maternal deaths in East Java in 2021 are as follows.

$$\hat{\mathbf{R}} = \begin{bmatrix} 0,670 & 1 \\ 1 & 0,670 \end{bmatrix}$$

Figure 2. Test results Pearson Correlation

The Pearson Correlation test yielded a value of 0.671 and a p-value of 0.000, leading to the decision to reject H_0. Therefore, it can be concluded that there is a correlation between the number of infant deaths and the number of maternal deaths in East Java in 2021.

Overdispersion Testing

Overdispersion testing was conducted using the Lagrange Multiplier (LM) method. The results of the overdispersion test can be seen in Table 1.

Table 1. Overdispersion Testing

Variabel	χ^2	$\chi^2_{\alpha,1}$
Number of Infant Deaths	995,756	3,84
Number of Maternal Deaths	372,645	3,84

The response variable exhibits overdispersion, as Table 1 demonstrates. Thus, the data on the number of maternal and infant fatalities in East Java in 2021 may be modeled using the BPLNR model.

Multicollinearity Testing Between Predictor Variables

In this study, the VIF value criteria were used to detect cases of multicollinearity, and the results can be seen in Table 2.

Table 2. VIF Value

Variabel	X_1	X_2	X_3	X_4	X_5
Nilai VIF	2,710	2,500	1,245	1,515	1,675

From Table 2, it can be observed that all predictor variables have VIF values of less than ten. This indicates that there are no cases of multicollinearity among the predictor variables, so all predictors can be used for regression analysis.

Modeling the Number of Infant and Maternal Mortality Rates in East Java in 2021 Using the BPLNR Model

Before conducting modeling using BPLNR, initialization is first carried out for each BPLNR model. The results show that the initial value for the infant mortality model is -1.744 and for the maternal mortality model is -3.579. The models are presented in the table below.

Table 3. BPLNR Model

Respon	Model BPLNR
1	$\hat{\theta}_{i1} = \exp(-1,7442 + 0,0306x_{11} - 0,0526x_{21} + 0,0003x_{31} - 0,0507x_{41} - 0,0097x_{51})$
2	$\hat{\theta}_{i2} = \exp(-3,5798 + 0,0224x_{12} - 0,0565x_{22} + 0,0005x_{32} - 0,0403x_{42} - 0,0091x_{52})$

Table 3 shows that all variables have a significant effect on the number of infant deaths, which can then be interpreted as follows.

a. If all other factors stay the same, an increase of one unit in the proportion of births assisted by medical professionals (1) in East Java will result in a 1,031-fold increase in infant mortality. This is contrary to general theory, which holds that the frequency of newborn fatalities and the proportion of births aided by medical professionals should be inversely correlated.
b. If all other factors stay the same, a one-unit rise in East Java's K4 prenatal visit percentage (2) will result in a 0.9487-fold reduction in newborn fatalities. This is consistent with general theory, which holds that the number of infant fatalities and the proportion of K4 prenatal visits should be inversely related.
c. If all other factors stay the same, an increase of one unit in the proportion of obstetric complication management (3) in East Java will result in a 1.0003-fold increase in newborn mortality. This is contrary to general theory, which holds that the frequency of newborn fatalities and the proportion of obstetric complication treatment should be inversely correlated.
d. If all other factors stay the same, a rise of one unit in East Java's poor population percentage (4) will result in a 0.9505-fold reduction in newborn fatalities. This contradicts the general idea, which holds that the number of newborn fatalities and the proportion of the population living in poverty should be positively correlated.
e. If all other factors stay the same, an increase of one unit in East Java's proportion of homes with adequate sanitation (5) will result in a 0.9903-fold reduction in newborn fatalities. This is in line with general theory, which suggests that the number of newborn fatalities and the proportion of families with adequate sanitation should be negatively correlated.

The same interpretation also applies to the second response variable for each predictor variable.

4. Conclusion

The percentage of treatment by healthcare professionals, the percentage of K4 prenatal care visits, the percentage of obstetric complications management, the percentage of the impoverished population, and the percentage of households with adequate sanitation all had an impact on the response variables, namely the number of infant and maternal deaths, according to the analysis of modeling infant and maternal mortality rates in East Java Province in 2021 using BPLNR. Some of the estimated parameters produced have signs that do not align with the theory, which may be due to the influence of other, stronger variables. Future studies can add variables from other aspects that have not been accommodated in this research. Upcoming research can determine the value of vi using the Monte Carlo algorithm. Further research can make comparisons regarding several iterations used, such as the Newton-Rapshon, Nelder-Mead or other iterations.

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