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Modelling the Count of Diphtheria in West Java in 2022 using Geographically Weighted Zero-Inflated Poisson Regression

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Abstract
The number of death cases caused by infectious diseases, that is to say diphtheria, especially in West Java so that it is categorized as an Extraordinary Event (KLB) generally attacks from the age of toddlers to the elderly. To model diphtheria cases in West Java in 2022 containing over dispersion using Geographically Weighted Zero-Inflated Poisson Regression (GWZIPR). Parameter estimation uses Expectation Maximization (EM) algorithm with spatial weight using Adaptive Gaussian Kernel. The resulting models include a Poisson state model that shows the chance of diphtheria cases occurring with relevant factors of the percentage within the population who apply Hygienic and Healthful Lifestyle (PHBS), who have been vaccinated against DPT-HB3, the number of health workers at Puskesmas, and the percentage of active posyandu and a Zero state model that shows the chance of no diphtheria cases occurring with relevant factors of the percentage who have been vaccinated against DPT-HB3, the number of health workers at Puskesmas, and the percentage of active posyandu.

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1. Introduction

The problems being faced in developing countries today is morbidity and mortality (Ali and Aziz, 2021) [1]. Morbidity is an unhealthy or sick condition, and mortality is a death that occurs in a population. Diphtheria is one of the causes of morbidity and mortality, especially in children. This infectious disease can be spread through coughing, sneezing and open wounds caused by the bacterium *Corynebacterium diphtheriae* which attacks the mucous membranes of the nose and throat and can affect the skin. Diphtheria can affect toddlers, young people and the elderly. Symptoms of diphtheria include sore throat and breathing which, if not treated properly, can be life-threatening (Kemenkes RI, 2022) [2].

WHO (2024) [3] reported that were 8,819 cases of diphtheria worldwide, about contribution of diphtheria cases from Indonesia. Research by Clarke *et al*. (2019) [4] explained that in countries with the highest number of diphtheria cases, 66% of patients did not receive the DPT-HB3 vaccine with 63% of patients who did not receive the DPT-HB3 vaccine came from patients aged less than 15 years. About 90% of people who contract diphtheria do not have a complete history of diphtheria vaccination.

Over time, diphtheria cases in Indonesia tend to decrease with a total of 495 cases in 2019 and 235 cases in 2020. Since 2011, diphtheria cases have become the biggest problem in Indonesia, making Indonesia second only to India in 2016. Diphtheria cases in Indonesia fluctuate every year, in 2016 there were 415 cases with 24 cases that died from diphtheria. In 2017 the number of cases increased to 954 cases with the number of cases who died was 44 cases. Based on the data, the province with the highest number of diphtheria cases is East Java with 331 cases and West Java with 167 cases (Kemenkes RI, 2017) [5]. In 2018 the number of diphtheria cases further increased to 1,386 cases and the number of cases who died from diphtheria was 29 cases (Kemenkes RI, 2018) [6].

However, in 2020 there was a relevant decrease in diphtheria cases compared to 2019, that is to say 259 cases with 13 cases of death. There were 12 provinces where no diphtheria cases were found in 2020 (Kemenkes RI, 2020) [7]. Diphtheria disease increased in 2021 with 34 cases. In 2022, there was a relevant spike where the number of cases increased by four times compared to the cases that occurred in the previous year, that is to say 125 cases (Kemenkes RI, 2022) [2].

Public Relations of Garut Regency Government (Humaspemkab Garut, 2023) [8] stated that West Java Province is the highest of diphtheria cases in Indonesia in 2022 with 87 cases. The Garut Regency Government declared diphtheria cases into an Extraordinary Event (KLB). In dependent to this, to anticipate the widespread spread of diphtheria cases, the Garut Regency Health Office and the West Java Regency Government took action in the form of mass diphtheria vaccinations, especially for children under 15 years of age. Geographically, West Java has of 27 regencies/town which certainly have different regional characteristics such as population density and area. With the high of diphtheria cases in West Java and the differences in characteristics in each district / city, it is hoped that this study can find out the relationship and relevant factors that affect the number of death cases due to diphtheria.

Research by Mudia Sari and Robinson Sihombing (2021) [9] stated that the method used to the regression analysis model of diphtheria. Enumerated data is states the number of events that occur in period of time. Enumerated data must be positive because an event does not occur in negative numbers (Herindrawati, Latra and Purhadi, 2017) [10]. Modeling using enumerated data can be done with poisson regression.

Poisson regression is a model used to the correlation (relationship) of the dependent variable which is Poisson distributed with one or more independent variables with the assumption that the mean is equal to the variance value of the dependent variable (Myers *et al.*, 2010) [11]. However, it is often encountered data where the variance value of the dependent variable is higher than the mean value of the dependent variable, so this problem is called overdispersion. Fittriyah *et al*. (2014) [12] explains the cause of overdispersion is that there are more zeros than expected in the data (excess zeros), therefore it is necessary to do an appropriate modeling in overcoming overdispersion containing excess zeros.

According to Ismah *et al*. (2020) [13], statistical models that are often used to overcome overdispersion or underdispersion problems are the Zero Inflated Poisson (ZIP) model. ZIP is a method that is widely used to overcome overdispersion in data with a zero proportion of data around 63.7%. Data on the number of cases caused by infectious diseases such as diphtheria may be geographically oriented. Ismah *et al*. (2020) [13] explains that data that focuses on geographical location or has a description of the area can be known as spatial data. Spatial data is suitable for handling cases caused by natural disasters, poverty, the spread of disease, postnatal maternal mortality, access to clean water, and so on. Data on the number of cases due to the spread of disease is often obtained in excess zero, so modeling using ZIP is still not appropriate for data involving spatial impacts. It is necessary to develop a method to determine the correlation among one or more variables by including spatial impacts, that is to say by applying the Geographically Weighted Regression (GWR) method is a regression model formed to solve spatial cases such as there are characteristics in the average value based on location (Ramadayani, Fariani Hermin Indiyah and Ibnu Hadi, 2022) [14].

Previous research related to diphtheria cases conducted by (Mustika and Nooraeni, 2019) [15] using Geographically Weighted Negative Binomial (GWNB) shows that the factors that affect the number of diphtheria cases in East Java in 2016 are the percentage of drug and vaccine availability while the percentage of DPT-HB3 vaccinated is Irrelevant in all observation zones. However, research by Adi Pradana and Eni Lestari (2020) [16] using Zero-Inflated Negative Binomial shows that the factors that affect the number of diphtheria cases in West Java in 2019 include the percentage of patients who received DPT-HB3 vaccinated, the percentage of people who have access to clean drinking water, the percentage of food management places that meet hygenie sanitation specifications and the number of health centers. Based on the background, this study was conducted using Geographically Weighted Zero-Inflated Poisson Regression (GWZIPR) to model The count of diphtheria cases in West Java during 2022.

Research Method

The data type is secondary, taken from official website of West Java Health Office, that is to say the West Java Health Profile. The data taken is data including of 27 region / town in West Java Province in 2022 (Kemenkes RI, 2022) [2]. The dependent variable in the study is the number of diphtheria cases in West Java Province taken from the West Java Health Profile. The independent variables used were taken from the West Java Health Office including the percentage within the populationthat implements Hygienic and Healthful Lifestyle. percentage of the population who have been vaccinated against DPT-HB3, the number of health workers at Puskesmas and the percentage of active posyandu.

Table 1: Research Variables

Variables	Description	Data Source
Y	Number of Diphtheria Patients	West Java Health Office in 2022
X_1	Percentage of population who apply Hygienic and Healthful Lifestyle (PHBS)	West Java Health Office in 2022
X_2	Percentage of population vaccinated against DPT-HB3	West Java Health Office in 2022
X_3	Number of health workers	West Java Health Office in 2022
X_4	Percentage of active posyandu	West Java Health Office in 2022

The analysis steps conducted in this study are as follows

1. Perform descriptive statistics.
2. Form a Poisson regression model.
3. Testing significance of Poisson regression parameters simultaneous and marginally.
4. Conduct Multicollinearity test on dependent variables using the Variance Inflation Factor (VIF) value.
5. Overdispersion test on Poisson regression. If the data does not experience overdispersion, then modeling is sufficient using Poisson regression. If the data has

overdispersion, ZIP regression can be performed.

6. Establishment of the ZIP regression model.
7. Testing significance of ZIP parameters simultaneous and marginally on parameter β and parameter γ.
8. Spatial dependency test is done with *Moran's I* test and heterogeneity test is done with Koenker-Basset test statistic. If there is heterogeneity, GWZIPR modeling can be continued and if there is no heterogeneity, ZIP regression is sufficient.
9. Formation of spatial weight matrix. Spatial weighting has a very important role in spatial data that represents the location of observations from one another (Caraka and Yasin, 2017) [17].
10. Calculating the Euclidean distance among observation locations.
11. Calculation of the weight matrix using the Adaptive Gaussian Kernel function.
12. Determining the GWZIPR model.
13. Estimation of GWZIPR model parameters using log-likelihood function on spatial weights.
14. Test the fit of the GWZIPR model with ZIP using the F-count test statistic.
15. Significance test of the GWZIPR parameters with simultaneous with the LRT and marginally with the t test.
16. Form groupings based on variables that relevantly affect each district/city in West Java Province.
17. Model interpretation.

Result and Discussion

Descriptive Statistic

The statistical analysis in this study used R software which is

Table 2: Descriptive Statistics Outcomes of Variables

Variables	Mean	Min	Max	Variance
Y	3.222	0	22	3.630
X_1	63.63	43.88	81.59	1486.087
X_2	105.8	87.7	141.1	17.846
X_3	66	25	174	19.717
X_4	83.48	58.6	98.2	207.7029

Poisson Regression Model

To find out the parameter coefficients and relevant parameters in poisson regression are shown in Table 3.

Table 3: Estimation Result of Poisson Regression Model

Parameter	Estimate	SE	Pr (>|z|)
β_0	12.0257	2.0020	$1.89e-09$
β_1	−0.0132	0.0111	0.2323
β_2	0.0841	0.0151	$2.47e-08$
β_3	−0.0042	0.0023	0.0737
β_4	12.0257	2.0020	$1.89e-09$

In Table 3, there are parameters that relevantly affect the poisson regression model, that is to say X_2. So that the poisson model is formulated below:

$$\ln(\hat{\mu}) = 12.0257 - 0.0132X_1 - 0.0841X_2 - 0.0042X_3 - 0.0142X_4$$

Significance Test of Poisson Model Parameters

The significance test of the Poisson regression by simultaneous model parameters seeks to assess the impact of the independent variables on the dependent variable. The simultaneous test uses LRT with hypothesis:

$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$
H_1: at least one $\beta_1 \neq 0, j = 1,2,3,4$

The test results obtained statistical value is $G^2 = 46.43 > \chi^2_{(0.05;5)} = 11.07$, then the decision to reject H_0 which states that at least one of the factors is the percentage within the population that applies PHBS, the percentage within the population that has been vaccinated against DPT-HB3, the number of health center health workers and the number of numbers that affect the count of diphtheria cases in West Java during 2022.

Furthermore, a marginally parameter significance test was conducted on the data on the number of diphtheria cases in West Java in 2022 using the t test with the criteria to reject H_0 if $t_j > t_{0.025;21} = 2.08$.

Table 4: Significance Test Results of Poisson Regression Model

Parameters	Test Statistic t	Description
$\hat{\beta}_0$	$t = \frac{12.025728}{2.002023} = 6.0067$	Relevant
$\hat{\beta}_1$	$t = \frac{-0.013292}{0.011129} = -1.1943$	Irrelevant
$\hat{\beta}_2$	$t = \frac{-0.084191}{0.0151} = -5.5755$	Relevant
Parameters	**Test Statistic t**	**Description**
$\hat{\beta}_3$	$t = \frac{-0.00422}{0.002359} = -1.7888$	Irrelevant
$\hat{\beta}_4$	$t = \frac{-0.014201}{0.008561} = -1.6588$	Irrelevant

Table 4 shows that the marginally parameter significance test for the Poisson model is concluded to reject for variable X_2 which means that marginally testing of the poisson model shows the percentage within the populationwho have been vaccinated against DPT-HB3 relevantly affects The count of diphtheria cases in West Java during 2022.

Multicollinearity Test

The basic assumption involved in regression analysis that must be met is the absence of multicollinearity because it causes the weak affect of the independent variables on the model that has been formed so that the regression coefficient is difficult to estimate. To determine whether or not the regression model used contains multicollinearity, the Variance Inflation Factor (VIF) value can be tested (Hocking, 2003) [18]. Table 5 shows the results of the VIF value among one predictor variable and several other independent variables.

Table 5: VIF Values of Independent variables

X_1	X_2	X_3	X_4
1.1720	1.1830	1.1296	1.0293

Over dispersion Test

The overdispersion test is aims to detect the variance value is higher than the mean. Used the pearson chi-square test using R software, the pearson chi-square test value is $6.209 > 1$, which means that the data on the count of diphtheria cases in West Java in 2022 contains overdispersion (Pateta, 2005) [19].

Zero-Inflated Poisson Regression Model

Zero-Inflated Poisson (ZIP) is a model used to handle data that contains many excess zeros. ZIP produces two models, that is to say Zero state and Poisson state. The Zero state model is a model that shows the chance of an event not occurring and only produces a zero value. The model that shows the chance of an event occurring is called Poisson state.

Table 6: Estimation Parameter β by ZIP Regression

Parameters	Estimator	SE	t_{count}
$\hat{\beta}_0$	18.7224	4.4973	$3.14e-05$
$\hat{\beta}_1$	−0.0285	0.0175	0.103194
$\hat{\beta}_2$	−0.1139	0.0303	0.000173
$\hat{\beta}_3$	−0.0121	0.0036	0.000755
$\hat{\beta}_4$	−0.0356	0.0105	0.000684

Table 7: Estimation Parameter γ by ZIP Regression

Parameters	Estimator	SE	t_{count}
$\hat{\gamma}_0$	−2.1374	12.8537	0.868
$\hat{\gamma}_1$	0.0190	0.0644	0.768
$\hat{\gamma}_2$	0.0324	0.0830	0.696
$\hat{\gamma}_3$	−0.0081	0.0132	0.54
$\hat{\gamma}_4$	−0.0296	0.0415	0.476

Based on Table 6 and 7, the relevant variables in the Poisson state model are X_2. This means that every increase of 1% percentage of the population who apply PHBS will reduce the average diphtheria case by exp (-0.11394) = 0.8923 times compared to before assuming that other variables are constant. Table 5 for the Zero state model shows that there are no variables that relevant affect the dependent variable. The ZIP model can be written as follows:

$$\ln(\hat{\mu}) = 18.72249 - 0.02851X_1 - 0.11394X_2 - 0.01219X_3 - 0.03565X_4$$

$$logit(\hat{\omega}) = -2.137488 + 0.019019X_1 + 0.032438X_2 - 0.008108X_3 - 0.029643X_4$$

Significance Testing of ZIP Model Parameters

The simultaneous significance test of the poisson model parameters aims to see the impact of the independent variables on the dependent variable. Parameter significance tests can be with simultaneously or marginallyly. The simultaneous test uses LRT with the following hypothesis:

$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$ and $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$
H_1: at least one $\beta_1 \neq 0$ and $\gamma_1 \neq 0, j = 1,2,3,4$

The results obtained statistical value is $G^2 = -2\,(Log - likelihood) = 112.14 > \chi^2_{(0.05;10)} = 18.307$ then the decision rejects H_0 which states that at least one of the factors is the percentage within the population that implements PHBS, the percentage within the population that has been vaccinated against DPT-HB3, the number of health workers at the Puskesm as and the total number that affects the count of diphtheria cases in West Java during 2022.
Furthermore, a marginally parameter significance test was conducted on the data on the count of diphtheria cases in West Java in 2022 using the t test with the criteria to reject H_0 if $t_j > t_{0.025;21} = 2.08$.

Marginally Significance Test of Parameter β

The hypothesis used for the parameter β is as follows:

$H_0: \beta_j = 0$
$H_1: \beta_j \neq 0, j = 1,2,3,4$

Table 8: Parameter Significance Test β

Parameters	Test Statistic t	Description
$\hat{\beta}_0$	$t = \frac{18.7224}{4.4973} = 4.162$	Relevant
Parameters	**Test Statistic t**	**Description**
$\hat{\beta}_1$	$t = \frac{-0.0285}{0.0175} = -1.629$	Irrelevant
$\hat{\beta}_2$	$t = \frac{-0.1139}{0.0303} = -3.755$	Relevant
$\hat{\beta}_3$	$t = \frac{-0.0121}{0.0036} = -3.367$	Relevant
$\hat{\beta}_4$	$t = \frac{-0.0356}{0.0105} = -3.395$	Relevant

Table 8 shows that the marginally parameter significance test for the Poisson state model is concluded to reject H_0 for variables X_2, X_3, X_4 which means that marginally testing of the Poisson state model shows that the percentage within the population who have been vaccinated against DPT-HB3 (X_2), the number of health workers at the Puskesmas (X_3) and the percentage of active posyandu (X_4) relevantly affect The count of diphtheria cases in West Java during 2022.

Marginally Significance Test of Parameter γ

The hypothesis used for the parameter γ is as follows:

$H_0: \gamma_j = 0$
$H_1: \gamma_j \neq 0, j = 1,2,3,4$

Table 9: Parameter Significance Test γ

Parameters	Test Statistic t	Description
$\hat{\gamma}_0$	$t = \frac{-2.1374}{12.8537} = 0.0276$	Irrelevant
$\hat{\gamma}_1$	$t = \frac{0.0190}{0.0644} = 0.0871$	Irrelevant
$\hat{\gamma}_2$	$t = \frac{0.0324}{0.0830} = 0.1527$	Irrelevant
$\hat{\gamma}_3$	$t = \frac{-0.0081}{0.0132} = 0.3756$	Irrelevant
$\hat{\gamma}_4$	$t = \frac{-0.0296}{0.0415} = 0.5084$	Irrelevant

Based on Table 8, the marginally parameter significance test for the Zero state model concluded that H_0 was accepted for all variables, which means that marginally in the Zero state model there are no variables that relevantly affect the count of diphtheria cases in West Java during 2022.

Spatial Dependence Test

Spatial dependence aims to see whether or not there is a relationship among one observation location and another location that is located close to each other. In this test, Moran's I test is performed using $\alpha = 0.05$. The results of the Moran's I test show a $p-value = 1.497216e-06 < 0.05$, which means reject H_0 which indicates that the number of diphtheria cases in one district/city is affectd by the number of diphtheria cases in another district/city.

Spatial Heterogeneity Test

The spatial heterogeneity test is to determine whether or not there is variance among one observation location and another observation location. The results of testing spatial heterogeneity using Koenker-Basset obtained a $p-value = 3.15e-08$ using a significance level of $\alpha = 0.05$ so that p-value $< \chi^2 = 9.488$. Then the decision to reject H_0 so that there is spatial heterogeneity among region / town. Based on the results of the spatial impacts test on the number of diphtheria cases in West Java in 2022, there is spatial dependence and spatial heterogeneity among region / town. So that the Geographically Weighted Zero-Inflated Poisson Regression (GWZIPR) method is suitable for analysis.

Model Fit Test

Testing the suitability of the model is conducted with the aim of knowing whether the model involving spatial impacts, that is to say GWZIPR, is relevantly different from the ZIP model. Based on the results of ZIP and GWZIPR modeling at a significance level of 0.05, the value of $F_{count} = 3.767 > F_{table} = 2.97$. So, the decision to reject H0 means that there is a relevant difference among the ZIP and GWZIPR models.

Geographically Weighted Zero-Inflated Poisson Regression Model (GWZIPR)

GWZIPR is advancement of GWR and ZIP that produces a local model so that it gives different estimation results depending on the location of observation. The results of marginally parameter testing in the GWZIPR model were obtained in each district/city. For example, the marginally parameter significance test conducted in Bogor Regency below:

Table 10: Estimation Parameter of GWZIPR Model for Bogor Regency

Models	Parameters	Estimator	t_{count}	Description
Poisson state	$\hat{\beta}_0$	17.402	0.609	Irrelevant
	$\hat{\beta}_1$	−0.025	−63.606	Relevant
	$\hat{\beta}_2$	−0.109	−630.13	Relevant
	$\hat{\beta}_3$	−0.009	−501.058	Relevant
	$\hat{\beta}_4$	−0.027	−208.113	Relevant
Zero state	**Parameters**	**Estimator**	**t_{count}**	**Description**
	$\hat{\gamma}_0$	424.296	0.519	Irrelevant
	$\hat{\gamma}_1$	−0.648	−233.49	Relevant
	$\hat{\gamma}_2$	−2.742	−553.93	Relevant
	$\hat{\gamma}_3$	−0.138	−146.467	Relevant
	$\hat{\gamma}_4$	−0.7691	−111.845	Relevant

In Table 10, it is concluded that reject H_0 on variables X_{11}, X_{21}, X_{31} and X_{41} for the Poisson state model and the Zero state model. Furthermore, the GWZIPR involving the Poisson state model and the Zero state model is as follows:

$$\ln(\hat{\mu}) = 17.4024 - 0.0255X_{11} - 0.1095X_{21} - 0.0097X_{31} - 0.0275X_{41}$$

$$logit(\hat{\omega}) = 424.296 - 0.6481X_{11} - 2.7420X_{21} - 0.1381X_{31} - 0.7691X_{41}$$

From the marginally parameter significance test, two groupings of region / town can be constructed based on variables that have a relevant impact in West Java in 2022. Grouping in the GWZIPR model for the Poisson state obtained all region / town in West Java in 2022 with the percentage within the population implementing Hygienic and Healthful Lifestyle (X_1), the percentage within the populationthat has been vaccinated against DPT-HB3 (X_2), the number of health workers at the Puskesmas (X_3) and the percentage of active posyandu (X_4) relevantly affect the number of diphtheria cases. Grouping in the GWZIPR model for Zero state is as follows:

Table 11: District/City Grouping based on Relevant Variables in the GWZIPR Model for Zero state

No.	District/City	Variables
1	**Regencies:** Bogor, Sukabumi, Cianjur, Bandung, Ciamis, Kuningan, Cirebon, Majalengka, Sumedang, Indramayu, Subang, Purwakarta, Karawang, Bekasi, Pangandaran, **City:** Bogor, Sukabumi, Bandung, Bekasi, Depok, Cimahi, Banjar.	$X1, X2, X3$ and $X4$
2	**Regencies:** Garut, Tasikmalaya, West Bandung **City:** Cirebon	$X2, X3$ and $X4$
3	Tasikmalaya City	$X3$

Based on Table 11, three groupings of region/town were constructed based on variables that had a relevant impact. The first group includes 22 region/town with four relevant independent variables. The second group has 4 region/town with three relevant independent variables, that is to say the percentage within the population that has been vaccinated against DPT-HB3(X_2), the number of health workers at Puskesmas (X_3) and the percentage of active posyandu (X_4). The third group is only Tasikmalaya City with one relevant predictor variable, that is to say the count of health workers at the health center (X_3)

Model Interpretation

After testing the suitability of the model among ZIP and GWZIPR for modeling the number of diphtheria cases in West Java in 2022, further interpretation of the results is conducted as an example in Bogor Regency with relevant variables, that is to say the percentage of residents who apply Hygienic and Healthful Lifestyle (X_1), the percentage of residents who have been vaccinated against DPT-HB3 (X_2), the number of health workers at Puskesmas (X_3) and the percentage of active posyandu (X_4). So that the GWZIPR model for Bogor Regency with relevant independent variables is as follows:

$$\ln(\hat{\mu}) = 17.4024 - 0.0255X11 - 0.1095X21 - 0.0097X31 - 0.0275X41$$

The interpretation of the GWZIPR model for Poisson state explains that:

1. Every 1% adjustment in the number of people who apply Hygienic and Healthful Lifestyle (PHBS) will decrease the mean count of diphteria cases by 0.974 times, with assuming all other variables remain unadjustmentd.
2. Every adjustment 1% in the number of people vaccinated with DPT-HB3 will decrease the mean count of diphteria cases by 0.896 times, with assuming all other variables remain unadjustmentd.
3. Every adjustment of 1 health worker at the Puskesmas will decrease the mean count of diphteria cases by 0.99 times, with assuming all other variables remain unadjustmentd.
4. Every 1% adjustment in active posyandu will decrease the mean count of diphteria cases by 0.972 times, with assuming all other variables remain unadjustmentd.

$$logit(\hat{\omega}) = 424.296 - 0.6481X11 - 2.7420X21 - 0.1381X31 - 0.7691X41$$

The interpretation of the GWZIPR model for Zero state explains that:

1. Every 1% adjustment in the number of people who apply Hygienic and Healthful Lifestyle (PHBS) will reduce the average diphtheria case by 0.523 times, with assuming all other variables remain unadjustmentd.
2. Every adjustment 1% in the number of people vaccinated with DPT-HB3, the average diphtheria case will be reduced by 0.064 times, with assuming all other variables remain unadjustmentd.
3. Every adjustment of 1 health worker in Puskesmas, it will reduce the average diphtheria case by 0.871 times, with assuming all other variables remain unadjustmentd.
4. Every 1% adjustment in active posyandu will reduce the average diphtheria case by 0.463 times, with assuming all other variables remain unadjustment.

Conclusion

The model of the number of diphtheria cases in West Java in 2022 obtained using the Geographically Weighted Zero-Inflated Poisson Regression (GWZIPR) method is twofold, that is to say the Poisson state with the model obtained.

$$\ln(\hat{\mu}) = 17.4024 - 0.0255X_{11} - 0.1095X_{21} - 0.0097X_{31} - 0.0275X_{41}$$

and Zero state with the model obtained

$$logit(\hat{\omega}) = 424.296 - 0.6481X_{11} - 2.7420X_{21} - 0.1381X_{31} - 0.7691X_{41}$$

Relevant factors affecting the number of diphtheria cases in each district / city in West Java Province in 2022 using GWZIPR in the Poisson state model formed a group consisting of all region / town in West Java Province with all relevant influencing variables, that is to say the percentage of residents who apply Hygienic and Healthful Lifestyle (PHBS) (X_1), percentage of population vaccinated against DPT-HB3 (X_2), the count of healthcare professionals at the health center (X_3) and the percentage of active posyandu (X_4).

As for the Zero state model, three groups were formed where the first group consisted of 22 region / town with all relevant variables. The second group consists of four regencies/town, that is to say Garut Regency, Tasikmalaya Regency, West Bandung Regency and Cirebon City with relevant variables of the percentage within the populationthat has been vaccinated against DPT- HB3 (X_2), the number of health workers at Puskesmas (X_3) and the percentage of active posyandu (X_4). The third group is only Tasikmalaya City with one relevant predictor variable, that is to say the count of healthcare professionals at the health center (X_3).

References

1. Ali H, Aziz S. Rising Pediatric Morbidity and Mortality in the Developing World. Cureus; c2021. https://doi.org/10.7759/cureus.14728
2. Kementrian Kesehatan Republik Indonesia. Profil Kesehatan Indonesia Tahun 2022. Jakarta; c2020.
3. World Health Organization. Difteri; c2017. https://www.who.int/news-room/factsheets/detail/diphtheria
4. Clarke KEN, MacNeil A, Hadler S, Scott C, Tiwari TSP, Cherian T. Global epidemiology of diphtheria 2000-2017. Emerging Infectious Diseases. 2019;25(10):1834-42. https://doi.org/10.3201/eid2510.190271
5. Kementrian Kesehatan Republik Indonesia. Profil Kesehatan Indonesia Tahun 2017. Jakarta; c2017.
6. Kementrian Kesehatan Republik Indonesia. Profil Kesehatan Indonesia Tahun 2018. Jakarta; c2018.
7. Kementrian Kesehatan Republik Indonesia. Profil Kesehatan Indonesia Tahun 2020. Jakarta; c2020.
8. Humaspemkab Garut. Pemdakab Garut Tetapkan Kasus Difteri sebagai Kejadian Luar Biasa; c2023. https://jabarprov.go.id/berita/pemdakab-garut-tetapkan-kasus-difteri-sebagai-kejadian-luar-biasa-8506
9. Sihombing PR, Sari FM. Pemodelan Data Kemiskinan Provinsi Sumatera Barat menggunakan Regresi Spasial. Infinity: Jurnal Matematika Dan Aplikasinya. 2021;15(1):51-62. http://ppjp.ulm.ac.id/journals/index.php/epsilon
10. Herindrawati AY, Latra IN, Purhadi. Pemodelan Regresi Poisson Inverse Gaussian Studi Kasus Jumlah Kasus

Baru HIV di Provinsi Jawa Tengah Tahun 2015. Jurnal Sains dan Seni. 2017;2337-3520.

11. Myers RH, Montgomery DC, Vining GG, Robinson TJ. Generalized Linear Models: With Applications in Engineering and the Sciences. 2nd ed. A John Wiley & Sons; c2010.
12. Fittriyah N, Hadi AF, Dewi YS. Pemodelan Jumlah Kematian Akibat Difteri di Provinsi Jawa Timur dengan Regresi Binomial Negatif dan Zero-Inflated Poisson. Prosiding Seminar Nasional Matematika Universitas Jember; 2014:201-214.
13. Ismah I, Sumertajaya IM, Djuraidah A, Fitrianto A. Pendekatan Geographically Weighted Zero Inflated Poisson Regression (GWZIPR) dengan Pembobot Fixed Bisquare Kernel pada Kasus Difteri di Indonesia. Barekeng: Jurnal Ilmu Matematika Dan Terapan. 2020;14(1):39-46. https://doi.org/10.30598/barekengvol14iss1pp039-046
14. Ramadayani MR, Indiyah FH, Hadi I. Pemodelan Geographically Weighted Regression Menggunakan Pembobot Kernel Fixed dan Adaptive pada Kasus Tingkat Pengangguran Terbuka di Indonesia. JMT: Jurnal Matematika dan Terapan. 2022;4(1):51-62. https://doi.org/10.21009/jmt.4.1.5
15. Mustika A, Nooraeni R. Kajian Efek Spasial pada Kasus Difteri dengan Metode Geographically Weighted Negative Binomial Regression (GWNBR). Indonesian Journal of Statistics and Its Applications. 2019;3(1):91-104.
16. Adi PD, Eni LT. Estimasi Parameter Regresi Zero-Inflated Negative Binomial dengan Metode Algoritma Expectation Maximation (EM) (Studi Kasus: Penyakit Difteri di Jawa Barat Tahun 2016). Jurnal Kajian Matematika Dan Aplikasinya. 2020;1(1):18-26. https://doi.org/10.17977/um055v1i1p18-26
17. Caraka RE, Yasin H. Geographically Weighted Regression. 1st ed. Yogyakarta: Mobius; c2017.
18. Hocking RR. Methods and Applications of Linear Models. 2nd ed. Canada: A John Wiley & Sons; c2003.
19. Pateta M. Fitting Poisson Regression Models Using the Genmod Procedure. USA: SAS Institute Inc.; c2005. https://learn.sas.com/course/view.php?id=262