Geographically Weighted Regression Modeling Using Fixed and Adaptive Gaussian Kernel Weighting Functions in The Analysis of Maternal Mortality (MMR)

Geographically Weighted Regression Modeling Using Fixed and Adaptive Gaussian Kernel Weighting Functions in The Analysis of Maternal Mortality (MMR)

Kris Suryowati
Statistics Department
Institut Sains & Teknologi AKPRIND
Yogyakarta, Indonesia
suryowati@akprind.ac.id

Monalisa Ode Ranggo
Statistics Department
Institut Sains & Teknologi AKPRIND
Yogyakarta, Indonesia
monalisaoderanggo@gmail.com

Rokhana Dwi Bekti
Statistics Department
Institut Sains & Teknologi AKPRIND
Yogyakarta, Indonesia
rokhana@akprind.ac.id

Edhy Sutanta
Informatics Department
Institut Sains & Teknologi AKPRIND
Yogyakarta, Indonesia
edhy_sst@akprind.ac.id

Eko Riswanto
Informatics Department
STMIK ElRahma
Yogyakarta, Indonesia
riswantoeko@gmail.com

***Abstract*—The weights have a very large influence on the parameter estimation of the geographically weighted regression (GWR). The weights show the relationship between observations or locations in the model. Types of weights that are often used in GWR are Gaussian kernel. This weighting can also be arranged into two forms. Thera are the fixed Gaussian kernel and the adaptive Gaussian kernel. Fixed is used when each location has the same bandwidth value. Adaptive is used when each location has a different bandwidth value. This study compares the results of the estimated parameters of the GWR model using the two weights. The modelling is carried out using data on maternal mortality in Central Sulawesi Province, consisting of 13 regencies/cities. The data used is secondary data. The result is that the adaptive Gaussian kernel weighting gives better results on the GWR model. It can be seen from the smaller standard error value, the larger coefficient of determination, and the smaller AIC than the model with the fixed Gaussian kernel weighting.**

Keywords — GWR, fixed Gaussian kernel, adaptive Gaussian kernel, Weighting Functions, Maternal Mortality,

I. INTRODUCTION

The Geographically weighted regression (GWR) model is a model that pays attention to the effect of location between regions. This model brings the framework from the OLS linear regression model into a weighted regression model to obtain a model for each location or called a local model [1]. This method has been widely used in research. Research [2] uses the GWR method to analyze economic inequality in the United States (U.S.). Research [3] conducted an analysis in the field of transportation in Athens, Greece. The GWR method is still very relevant today because it can improve the accuracy of models with spatial structures. In addition, it is also able to explain a problem and in more detail from a global to local perspective [4]. Research in Indonesia on GWR includes [5] on the analysis of the Human Development Index. Research [6] analyzes fiscal decentralization that affects economic performance and many more.

The weights have a considerable influence on the GWR estimation parameters. This weight is in the form of a diagonal matrix, which the diagonal elements being a weighting function from each point of observation location. The weighting value also depends on the distance between the observation points. The function of the weighting matrix is to determine or interpret the different parameters at each point of observation location.

One way to determine the weighting matrix is by using the kernel smoothing function. The types of kernel function are Gaussian, Bisquare, and Tricube. Several studies have used these weights.

Research [7] compared fixed and adaptive bandwidth weights for the percentage of poor people in Central Java Province, Indonesia. The conclusion is that the GWR model with fixed exponential is better than adaptive because it meets the model fit test, partially tests the influence of location, tests the assumptions of the GWR model, and has the smallest AIC value.

Research [8] concluded that the GWR used tricube kernel weighting function is the best because the tricube kernel has a smaller AIC value. GWR model with the Gaussian Kernel and the Gaussian Adaptive Kernel is the best function because it has a better determination coefficient. Research [9] states another different result, the GWR with a Gaussian kernel is better than the GWR with a bi-square kernel.

There is a bandwidth parameter in the calculation of the kernel smoothing function. The value of bandwidth is unknown, and it is necessary to estimate the parameter. Bandwidth is a radius (h) of a circle. An observation point located within the radius's circle is still considered influential in forming parameters at other observation points. Optimum bandwidth selection is an essential part because it has a significant impact on the GWR results obtained.

Based on the bandwidth, the kernel weighting function in GWR is further divided into two, namely fixed and adaptive. A fixed kernel function is a function when each location has the same bandwidth value. An adaptive kernel function is a function when each location has a different bandwidth value. The Gaussian kernel is calculated from the exponential distance between observations and bandwidth. Gaussian kernels can also be fixed or adaptive. This study uses these weights and compares them to determine which one is the best in analyzing the factors that influence the Maternal Mortality Rate in Central Sulawesi Province.

Maternal mortality rate (MMR) is helpful to describe the level of awareness of healthy living behavior, nutritional status and maternal health, environmental health conditions, level of health services, especially for pregnant women, childbirth and the postpartum period. The MMR is an indicator of the quality of public health services and the success of development in a country [10]. The development of MMR in Central Sulawesi Province is currently fluctuating. The number of MMR in the regency/city of Central Sulawesi Province in 2018 is 82 deaths. The contributing factors are implementing the delivery planning program and prevention of complications which not optimal, the partnership between midwives and traditional birth attendants, the high level of socio-cultural influence in the community. There are health workers who have not carried out delivery assistance according to standards, and the infrastructure facilities are still inadequate

The healthy characteristics between regions also vary, so it is necessary to study it locally. Such as research [11] on the association between macroscopic factors and identified HIV/AIDS cases among injecting drug users. Furthermore, a study [12] which analyzed birth hospital and racial and ethnic differences in severe maternal morbidity in the state of California

Regencies/Cities in Central Sulawesi Province have different characteristics in terms of geographical, social, economic, and other conditions. It causes the factors that affect MMR to be different in each district/city. Therefore, it is essential to use the GWR method in the analysis of MMR. It uses a fixed Gaussian kernel and adaptive Gaussian, which have different characteristics in estimating GWR. Therefore, this study compares these two weights to get the proper analysis.

II. METHOD

A. Data and Variable

The data used in this study are secondary from the Central Bureau of Statistics (BPS) of Central Sulawesi Province. Central Sulawesi Province consists of 12 regencies and one city (Figure 1).

The analysis uses the dependent and independent variables. The dependent variable (Y) is the number of maternal mortality rates (MMR). At the same time, the independent variables (X) are the number of doctors (X1), health facilities (X2), the percentage of deliveries assisted by health workers (X3) and the percentage of maternal postpartum services (X4) in regencies/cities in Central Sulawesi Province in 2018.

The analysis stages are

1. Explore spatial pattern of MMR
2. Perform global regression analysis, consist of estimating parameters using the OLS method, significantly test of independent variables, and residual assumption test.
3. Perform spatial effect test, consisting of Moran's I for dependencies test and Breusch-Pagan to spatial heterogeneity test
4. Perform GWR modelling with the following steps:
   a. Select the optimum bandwidth for the fixed and adaptive Gaussian kernel with the corected Akaike Information Criterion (AICc) method.
   b. Construct a weight matrix
   c. Estimate the parameters of the GWR in each fixed and adaptive Gaussian kernel using Weighted Least Square (WLS) method.
   d. Perform goodness of fit model
   e. Determine the best GWR model based on standard error, determination coefficient, and AIC

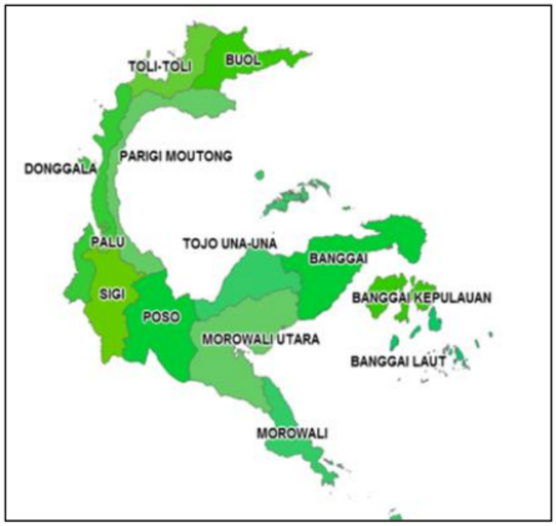

Fig. 1. Map of Central Sulawesi Province

Multiple regression analysis analyses the relationship between variables, namely the dependent variable and one or more independent variables. One of the purposes of regression analysis is to estimate the effect or influence of changes in one event on other events. To estimate the value of the Y variable, it would be better to take into account other variables that influence Y. The form of the regression model with k independent variables and the number of observations n is as follows:

$$Y_i = \beta_0 + \sum_{k=1}^{p} \beta_i x_{ik} + \varepsilon_i ; i = 1,2,\ldots,n \quad (1)$$

where y_i is the dependent variable value of i-th observation, x_{ik} is k-th independent variable at i-th observation, β_o is a constant parameter, β_k is a parameter of k-th independent variable, n is the number of observations, p is a number of independent variables, and ε_i is an error of i-th observation.

One of the multiple regression model estimates is Ordinary Least Square (OLS), which assumes has the assumption are the error of equation (1) is identical, independent, and normally distributed with zero mean and variance σ^2. In spatial data, these assumptions are usually not met. The heterogeneity assumption is not met because each observation or location has different characteristics. An alternative method is Geographically Weighted Regression (GWR) spatial model.

The GWR model develops a linear regression model equation (1) into a weighted regression model. So that, it will obtain a model for each location or called a local model. The general model is as in equation (2).

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i)x_{ik} + \varepsilon_i \quad (2)$$

Where (u_i, v_i) are the longitude and latitude coordinates of the i-th location point at a geographic location. Thus, each parameter value calculated for each geographic location point has a different regression parameter value.

Local parameters $\beta(u_i, v_i)$ are estimated using the Weighted Least Square (WLS) method, assigning different weights to each location based on the data collected. The estimation calculation in the form of a matrix is

$$\beta(i) = (X^T W(i) X)^{-1} X^T W(i) Y \quad (3)$$

$W(i)$= diag[w_{i1}, w_{i2}, … w_{in}] is weight matrix of i-th location.

The role of spatial weighting is very important because the value represents the location of the data with one another, as well as the spatial relationship between locations. The fixed Gaussian kernel is expressed by

$$W_{ij}(u_i, v_i) = \exp(-(d_{ij}/h)^2) \quad (4)$$

where d_{ij} is Euclidean distance and h is bandwidth, which have the same value in all locations.

The adaptive Gaussian kernel is

$$W_{ij} = \exp(-\frac{1}{2}(d_{ij}/h_{i(q)})^2) \quad (5)$$

where $h_{i(q)}$ is the adaptive bandwidth which sets q as the nearest neighbor distance from the i-th observation point.

III. RESULTS

A. *Spatial Pattern of* Maternal Mortality Rate (MMR)

The average percentage of MMR in Central Sulawesi Province is 7.7%. The highest percentage is 17% in Banggai Laut Regency, and the lowest percentage is 2.8% occurred in Palu. Figure 2 shows that regencies/cities have different characteristics.

B. *Parameter Estimation of OLS Model*

The results of the OLS parameters that estimate are presented in Table 1. The model obtained is a global regression model. This model can explain that MMR will increase the number of doctors (X_1) is high, the number of health facilities (X_2) is small, the percentage of deliveries assisted by health workers (X_3) is high, and the percentage of postpartum maternal health services (X_4) is small.

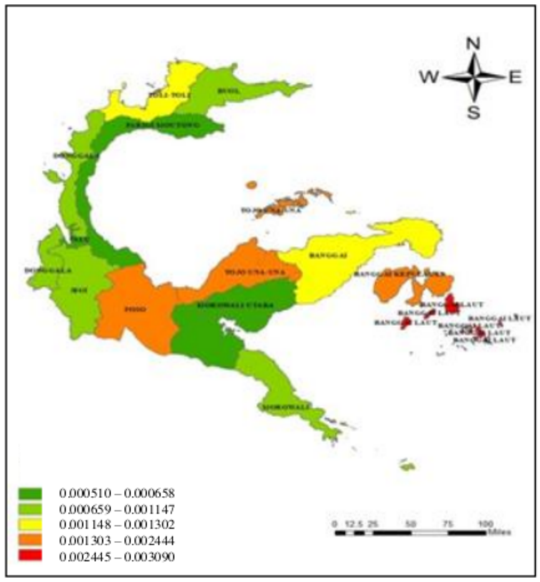

Fig. 2. Spatial Pattern of MMR

TABLE I. PARAMETER ESTIMATE OF GLOBAL MODEL

Variable	*Estimate*	*Std. Error*	t_{hvalue}	P_{value}
intercept	4.232	2.219	1.907	0.0929
X_1	3.739	9.564	0.391	0.7060
X_2	-1.865	2.574	-0.725	0.4893
X_3	2.826	5.487	0.515	0.6204
X_4	-6.730	4.643	-1.449	0.1853

Based on the independent variable significance test, all variables have no significant effect on MMR. Meanwhile, the residual assumption test shows that the residuals are not normally distributed. There is no heteroscedasticity, and there is no autocorrelation. The existence of a normal distribution assumption indicates that this global model is not appropriate to use. An alternative method is needed in analyzing factors that affect maternal mortality in Central Sulawesi Province. One of which is the GWR model. However, it is necessary to test the spatial effect to determine whether there is really a spatial effect on the data.

C. *Spatial Effect Test*

Table 2 shows the results of the spatial effect test, namely the spatial dependency test using Moran's I. By comparing the P-value and significance level (α = 5%), the conclusion is that there is spatial autocorrelation in all variables. It means that between regencies/cities in Central Sulawesi are have interaction in terms of MMR, the number of doctors, health facilities, the percentage of deliveries assisted by health workers, and the percentage of postpartum mother services.

TABLE II. MORAN'S I TEST

Variable	Moran's (I)	E(I)	P_{value}
Y	0.1361	-0.083	0.0339
X_1	-0.1357	-0.083	0.0154
X_2	0.0857	-0.083	0.0302
X_3	-0.1656	-0.083	0.0364
X_4	-0.0763	-0.083	0.0345

GWR spatial modelling becomes essential to do because there are spatial effects in the data. If it continues to use to use the global OLS model, the parameter estimates and the analysis are incorrect.

D. Weight in GWR

The first step before forming the GWR model is to determine and form the type of weights to be used. The weighting value also depends on the distance between locations and the bandwidth value. The distance is calculated from the latitude and longitude coordinate data between regencies/cities center points. The bandwidth value is obtained from the iteration process of the GWR model until the best value is obtained, which is based on the smallest corrected AICc. The type of weight used is the fixed and adaptive Gaussian kernel.

a. Fixed Gaussian Kernel

The optimum bandwidth by fixed Gaussian kernel weighting is presented in Table 3. The optimum bandwidth value for all locations is 5.188133. It is obtained in the 25-th iteration. This value was chosen because it has the smallest AICc -128.9288. The number 5.188133 means that a regency/city will have a major influence on the surrounding regency/city, which are still within a radius of 5.188133 or 577.5 km. Meanwhile, areas outside that radius will have a small effect.

TABLE III. BANDWIDTH AND AICC BY FIXED GAUSSIAN KERNEL

No	Bandwidth	AICc
1	1.984928	-117.8904
2	3.208474	-126.5648
3	3.964668	-127.9442
…	…	…
…	…	…
24	5.188133	-128.9288
25	5.188133	-128.9288

Based on the bandwidth value, the weighting formula becomes

$$W_{ij}(u_i, v_i) = \exp(-(d_{ij}/5.188133)^2) \qquad (6)$$

where i,j = 1,2, …, 13. Euclidean Distance (d_{ij}) is the distance between regions. The weighting matrix between 13 regencies/cities is different. For example, the results of the d_{ij} and W_{ij} values for the Banggai Kepulauan Regency are as in Table 4

TABLE IV. EUCLIDEAN DISTANCE AND WEIGHT VALUE IN BANGGAI KEPULAUAN REGENCY

No	Regency/City	d_{ij}	W_{ij}
1	Banggai Kepulauan	0	1
2	Banggai	0.64505	0.98466
3	Morowali	1.60703	0.90851
4	Poso	2.64878	0.77055
5	Donggala	3.47847	0.63793
6	Tolitoli	3.40216	0.65050
7	Buol	2.92542	0.72764
8	Parigi Moutong	2.91310	0.72959
9	Tojo Una-una	1.59790	0.90950
10	Sigi	3.17209	0.68810
11	Banggai Laut	0.60468	0.98651
12	Morowali Utara	1.79825	0.88680
13	Palu	3.30428	0.66656

The weighting matrix size in Banggai Kepulauan Regency is 13x13. W_{ij} value is the value of the diagonal matrix. If look at the comparison of the values of W_{ij} and d_{ij}, it can be seen that the area closer to the Banggai Islands will have a greater weighting value. A large weighting value means that it has a greater influence.

$$W_{BangKep} = \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ 0 & 0.99466 & 0 & \cdots & 0 \\ 0 & 0 & 0.90851 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & 0.66656 \end{bmatrix}$$

The weighting matrix for the other 12 regencies/cities can be arranged in the same way as the Banggai Kepulauan.

b. Adaptive Gaussian Kernel

The optimum bandwidth by adaptive Gaussian kernel weighting is presented in Table 5. The optimum bandwidth value is different in each regency/city.

TABLE V. BANDWIDTH BY ADAPTIVE GAUSSIAN KERNEL

No	Regency/City	Bandwidth
1	Banggai Kepulauan	3.478427
2	Banggai	2.864056
3	Morowali	3.832978
4	Poso	3.052750
5	Donggala	4.015197
6	Tolitoli	4.006013
7	Buol	3.652508
8	Parigi Moutong	3.485435
9	Tojo Una-una	2.153366
10	Sigi	3.608852
11	Banggai Laut	4.015515
12	Morowali Utara	2.877792
13	Palu	3.807387

Based on the bandwidth value, the weighting formula becomes

$$W_{ij} = \exp(-\frac{1}{2}(d_{ij}/h_{i(q)})^2) \qquad (7)$$

where i,j = 1,2, …, 13. Euclidean Distance (d_{ij}) is the distance between regions as in Table 4. The value of $h_{i(q)}$ is bandwidth in each location, as in Table 5. The weighting matrix between 13 regencies/cities is different. For example, the results of the W_{ij} of Banggai Islands Regency with Banggai Regency are as follows.

$$W_{(Bangkep, Banggai)} = \exp\left(-\frac{1}{2}\left(\frac{0.64505}{2.864056}\right)^2\right) = 0.97496$$

The weighting matrix size in Banggai Kepulauan Regency is also 13x13. In the same way, the weighting matrix for the other 12 regencies/cities will also be obtained.

$$W_{BangKep} = \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ 0 & 0.97496 & 0 & \cdots & 0 \\ 0 & 0 & 0.91586 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & 0.6862 \end{bmatrix}$$

E. The Results of Model GWR

The formation of the GWR model is carried out on each weighted fixed and adaptive Gaussian kernel. The estimation of the GWR uses the Weighted Least Squares (WLS) method as in Equation 3. In this study, the local parameters $\beta_o(u_i, vi)$ and $\beta_k(u_i, vi)$, with i = 1,2, …13 and k = 1, 2,3,4, were estimated by giving different weights for each location based on data on MMR and influencing factors.

a. GWR by Fixed Gaussian Kernel

The results of parameter estimation in 13 regencies/cities are presented in Table 6. It can be seen that the GWR model in each location has different parameter estimation values β_o, β_1, β_2, β_3, and β_4. Based on the significance test of the t-test parameters, there is no independent variable that has a significant effect on MMR in all regencies/cities.

TABLE VI. PARAMETER ESTIMATE BY FIXED GAUSSIAN KERNEL

No	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$
1	0.00429	0.3967	-0.1943	2.6426	-6.5662
2	0.00426	0.3863	-0.1937	2.7263	-6.6279
3	0.00422	0.3544	-0.1992	2.7971	-6.6285
4	0.00415	0.3281	-0.1983	2.9964	-6.7758
5	0.00412	0.3288	-0.1960	3.0882	-6.8710
6	0.00416	0.3630	-0.1907	3.0099	-6.8614
7	0.00420	0.3811	-0.1891	2.9107	-6.7996
8	0.00415	0.3471	-0.1940	3.0122	-6.8319
9	0.00420	0.3614	-0.1948	2.8688	-6.7177
10	0.00412	0.3194	-0.1985	3.0572	-6.8196
11	0.00431	0.4032	-0.1956	2.5763	-6.5135
12	0.00419	0.3466	-0.1975	2.8894	-6.7064
13	0.00413	0.3252	-0.1970	3.0738	-6.8489

As an illustration, the following is the application of equation 3 for the parameter estimation in Banggai Kepulauan.

$$\hat{\beta}_{(BangKep)} = (X^T W_{(BangKep)} X)^{-1} X^T W_{(BangKep)} Y$$

$$\hat{\beta}_{(BangKep)} = \begin{bmatrix} 0.00429 \\ 0.3967 \\ -0,1943 \\ 2.6426 \\ -6,5662 \end{bmatrix}$$

This study also performs standardization data of independent variables and then performs GWR again. Through that model, the percentage of deliveries assisted by health workers (X_3) and percentage of postpartum maternal health services (X_4) are significantly effects on MMR in all regencies/cities.

b. GWR by Adaptive Gaussian Kernel

The results of parameter estimation in 13 regencies/cities are presented in Table 7. As well as by fixed Gaussian kernel, the GWR model in each location has different parameter estimation values β_o, β_1, β_2, β_3, and β_4. Based on the significance test of the t-test parameters, there is no independent variable that has a significant effect on MMR in all regencies/cities.

TABLE VII. PARAMETER ESTIMATE BY ADAPTIVE GAUSSIAN KERNEL

N	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$
1	0.00437	0.4310	-0.2057	2.3577	-6.3187
2	0.00433	0.4216	-0.2117	2.4204	-6.3303
3	0.00422	0.3381	-0.2100	2.7667	-6.5371
4	0.00402	0.2516	-0.2194	3.2257	-6.8106
5	0.00406	0.3034	-0.2028	3.2424	-6.9599
6	0.00411	0.3574	-0.1938	3.1488	-6.9676
7	0.00415	0.3894	-0.1916	3.0258	-6.8968
8	0.00407	0.3200	-0.2036	3.2322	-6.9673
9	0.00408	0.3063	-0.2333	3.0247	-6.6432
10	0.00403	0.2693	-0.2111	3.2424	-6.8832
11	0.00438	0.4271	-0.2030	2.3723	-6.3410
12	0.00411	0.2861	-0.2214	2.991	-6.6230
13	0.00405	0.2898	-0.2063	3.2497	-6.9365

Through that model with standardization of independent variable, the percentage of deliveries assisted by health workers (X3) significantly affects MMR in 11 regencies/cities. Then, the percentage of postpartum maternal health services (X4) are significantly affected on MMR in all regencies/cities.

F. Comparison Model

Table 8 shows the comparison of the GWR between the weighted fixed and adaptive Gaussian kernel. Comparisons were made based on the standard error of the model (S), the coefficient of determination (R^2), and AIC. The GWR model with adaptive Gaussian kernel weighting has a smaller S value, larger R^2, and a smaller AIC than the model with a fixed Gaussian kernel weighting. Therefore, adaptive weighting gives better results.

TABLE VIII. THE COMPARISON OF THE GWR MODEL

Weight	S	R^2	AIC
1. Kernel Fixed Gaussian	0.000433	0.4093	-151.77
2. Kernel Adaptive Gaussian	0.000398	0.5463	-152.52
Global Model OLS	0.000756	0.0551	

CONCLUSIONS

Aaptive Gaussian kernel weighting gives better results on the GWR model to analyze maternal mortality rate (MMR) in Central Sulawesi Province. It because these weights have different bandwidth values which then each regency/city gives a different influence. In accordance with regional characteristics, where each regency/city has different characteristics, both geographically, demographically, socially, economically, and others.

When compared with the OLS global regression model, the GWR model also gives better results. GWR is an alternative when there is a spatial or locational influence on MMR data in Central Sulawesi.

Some recommendations for research can also be made. Further research can compare various weights in the GWR model, including the Bisquare and Tricube kernel weights.

ACKNOWLEDGMENT

The authors would like to thanks the Institut Sains & Teknologi AKPRIND Yogyakarta, Indonesia, that support this research through grant funding and facilities to carry out this research. While, this publication supported by the Ministry of Research, Technology and Higher Education of the Republic of Indonesia under Fundamental Research Grant Funding in 2021.

REFERENCES

[1] A. S. Fotheringham, C. Brunsdon, and M. Charlton, *Geographically weighted regression: the analysis of spatially varying relationships*. John Wiley & Sons, 2003.

[2] F. Tran and C. Morrison, "Income inequality and suicide in the United States: A spatial analysis of 1684 U.S. counties using geographically weighted regression," *Spatial and Spatio-temporal Epidemiology,* vol. 34, p. 100359, 2020/08/01/ 2020, doi: https://doi.org/10.1016/j.sste.2020.100359.

[3] E. Chioni, C. Iliopoulou, C. Milioti, and K. Kepaptsoglou, "Factors affecting bus bunching at the stop level: A geographically weighted regression approach," *International Journal of Transportation Science and Technology,* vol. 9, no. 3, pp. 207-217, 2020/09/01/ 2020, doi: https://doi.org/10.1016/j.ijtst.2020.04.001.

[4] O. D. Cardozo, J. C. García-Palomares, and J. Gutiérrez, "Application of geographically weighted regression to the direct forecasting of transit ridership at station-level," *Applied Geography,* vol. 34, pp. 548-558, 2012/05/01/ 2012, doi: https://doi.org/10.1016/j.apgeog.2012.01.005.

[5] A. Ramadan and R. D. Bekti, "Analisis Indeks Pembangunan Manusia Di Kabupaten Dan Kota Provinsi Jawa Tengah Tahun 2014 Menggunakan Metode Geographically Weighted Regression (Studi Kasus Pada Data Indeks Pembangunan Manusia tahun 2014 di Provinsi Jawa Tengah)," *Jurnal Statistika Industri dan Komputasi,* vol. 2, no. 01, pp. 59-66, 2017.

[6] S. D. Permai, A. Christina, and A. A. Santoso Gunawan, "Fiscal decentralization analysis that affect economic performance using geographically weighted regression (GWR)," *Procedia Computer Science,* vol. 179, pp. 399-406, 2021/01/01/ 2021, doi: https://doi.org/10.1016/j.procs.2021.01.022.

[7] R. A. Pamungkas, H. Yasin, and R. Rahmawati, "Perbandingan model gwr dengan fixed dan adaptive bandwidth untuk persentase penduduk miskin di jawa tengah," *Jurnal Gaussian,* vol. 5, no. 3, pp. 535-544, 2016.

[8] A. V. Mahabbi, "Perbandingan Fungsi Pembobot pada Model Geographically Weighted Regression (GWR) dalam Tingkat Kemiskinan Di Kabupaten Sampang," UIN Sunan Ampel Surabaya, 2019.

[9] N. Lutfiani, S. Sugiman, and S. Mariani, "Pemodelan Geographically Weighted Regression (GWR) Dengan Fungsi Pembobot Kernel Gaussian dan Bi-Square," *UNNES Journal of Mathematics,* vol. 8, no. 1, pp. 82-91, 2019.

[10] A. N. Sari, "Analisis Jalur Faktor-faktor yang Mempengaruhi Angka Kematian Ibu di Jawa Timur," *JMPM: Jurnal Matematika dan Pendidikan Matematika,* vol. 1, no. 2, pp. 119-132, 2016.

[11] Xing, J. N., Wei, G. U. O., Qian, S. S., Ding, Z. W., Chen, F. F., Peng, Z. H., ... & Lu, W. A. N. G. (2014). Association between macroscopic-factors and identified HIV/AIDS cases among injecting drug users: an analysis using geographically weighted regression model. *Biomedical and Environmental Sciences*, *27*(4), 311-318.

[12] Mujahid, M. S., Kan, P., Leonard, S. A., Hailu, E. M., Wall-Wieler, E., Abrams, B., ... & Carmichael, S. L. (2021). Birth hospital and racial and ethnic differences in severe maternal morbidity in the state of California. *American Journal of Obstetrics and Gynecology*, *224*(2), 219-e1.

Geographically Weighted Regression Modeling Using Fixed and Adaptive Gaussian Kernel Weighting Functions in The Analysis of Maternal Mortality (MMR)

ORIGINALITY REPORT

12%
SIMILARITY INDEX

PRIMARY SOURCES

1	www.scribd.com Internet	77 words — 2%
2	S Huda, E S Arbintarso, J Waluyo. "Grain Refinement in Aluminium 1xxx Series as Effect of Vibration Torch Welding", IOP Conference Series: Materials Science and Engineering, 2020 Crossref	39 words — 1%
3	Elli Yane, Stang, Rosmala Nur, Muhammad Ryman Napirah, Alam Anshary. "Social factors that influence the preeclampsia event in Palu City", Enfermería Clínica, 2020 Crossref	33 words — 1%
4	Kris Suryowati, RD Bekti, R Fajiriyah, E Siswoyo. "The Effect of Regional Characteristics and Relationship Among Locations In Air Pollution Using Spatial Autoregressive (SAR) and Spatial Durbin Models (SDM)", Journal of Physics: Conference Series, 2021 Crossref	20 words — 1%
5	Anis Setiyorini, Jadi Suprijadi, Budhi Handoko. "Implementations of geographically weighted lasso in spatial data with multicollinearity (Case study: Poverty modeling of Java Island)", AIP Publishing, 2017 Crossref	18 words — < 1%

6	Shuhui Gong, John Cartlidge, Ruibin Bai, Yang Yue, Qingquan Li, Guoping Qiu. "Geographical and temporal huff model calibration using taxi trajectory data", GeoInformatica, 2020 Crossref	18 words — < 1%
7	E Sutanta, EK Nurnawati, C Iswahyudi, RA Kumalasanti. "The Model Prototype of WebGIS-based for Organizational Asset Management", Journal of Physics: Conference Series, 2021 Crossref	17 words — < 1%
8	engagedscholarship.csuohio.edu Internet	17 words — < 1%
9	f1000researchdata.s3.amazonaws.com Internet	17 words — < 1%
10	gisak.vsb.cz Internet	17 words — < 1%
11	Yuanyuan Zhang, John Bigham, David Ragland, Xiaohong Chen. "Investigating the associations between road network structure and non-motorist accidents", Journal of Transport Geography, 2015 Crossref	16 words — < 1%
12	onlinelibrary.wiley.com Internet	16 words — < 1%
13	F. L. Luo, J. L. Jing, A. N. Wang, L. S. Liang. "RESEARCH ON PM2.5 MASS CONCENTRATION RETRIEVAL METHOD BASED ON HIMAWARI-8 IN BEIJING", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2020 Crossref	13 words — < 1%

14	Nur Chamidah, Toha Saifuddin, Marisa Rifada. "The vulnerability modeling of dengue hemorrhagic fever disease in Surabaya based on spatial logistic regression approach", Applied Mathematical Sciences, 2014 Crossref	13 words — < 1%
15	scicurve.com Internet	13 words — < 1%
16	ns2.thinkmind.org Internet	12 words — < 1%
17	digilib.uinsby.ac.id Internet	11 words — < 1%
18	upmc4.um.ac.ir Internet	11 words — < 1%
19	Dewi Retno Sari Saputro, Rina Dwi Hastutik, Purnami Widyaningsih. "The modeling of human development index (HDI) in Papua—Indonesia using geographically weighted ridge regression (GWRR)", AIP Publishing, 2021 Crossref	10 words — < 1%
20	docplayer.info Internet	10 words — < 1%
21	Greg Rybarczyk. "Toward a spatial understanding of active transportation potential among a university population", International Journal of Sustainable Transportation, 2018 Crossref	9 words — < 1%
22	T W Utami, A Prahutama, A Karim, A R. F Achmad. "Modelling rice production in Central Java using	9 words — < 1%

semiparametric regression of local polynomial kernel approach", Journal of Physics: Conference Series, 2019
Crossref

23	digital.lib.washington.edu Internet	9 words — < 1%
24	www.hindawi.com Internet	9 words — < 1%
25	es.scribd.com Internet	8 words — < 1%
26	research-repository.st-andrews.ac.uk Internet	8 words — < 1%
27	Raymond J.G.M. Florax. "Spatial dimensions of precision agriculture: a spatial econometric analysis of millet yield on Sahelian coversands", Agricultural Economics, 11/2002 Crossref	6 words — < 1%

EXCLUDE QUOTES	ON	EXCLUDE SOURCES	OFF
EXCLUDE BIBLIOGRAPHY	ON	EXCLUDE MATCHES	OFF