International Journal of Social and Education (INJOSEDU) e-ISSN: 3047-6151
Vol. 2 No. 5 May 2025, hal., 1556-1566

MAP OF CRIME RATE VULNERABILITY ON JAVA ISLAND

I Wayan Tedy Setiawan *
Mathematics, Faculty of Mathematics and Natural Sciences-Udayana University
e-mail: tedywayan27@gmail.com

Ni Luh Putu Suciptawati
Mathematics, Faculty of Mathematics and Natural Sciences-Udayana University
e-mail: Suciptawati@unud.ac.id

I Made Eka Dwipayana
Mathematics, Faculty of Mathematics and Natural Sciences-Udayana University
e-mail: dwipayana@unud.ac.id

***Abstract*:** *The level of vulnerability to crime in Indonesia remains high, thus effective preventive measures and collaboration from various parties are necessary to create a safer and more orderly environment. According to the Central Statistics Agency in 2022 the number of crimes in Indonesia in 2022 experienced a significant increase from the previous year. Based on Criminal Statistics in 2022 the number of crimes for the police level during 2022 Java Island occupies the top place in the crime rate in Indonesia. Countermeasures related to crime can be done by knowing the areas prone to crime. This study uses analytical methods that can show spatial autocorrelation, including the Moran Index and Local indicators of spatial association (LISA). The results show that there is spatial autocorrelation with a clustered pattern for the crime rate on the island of Java and districts / cities in Java which are classified as crime-prone / hotspot areas, namely Bogor, Gresik, West Jakarta, Central Jakarta, South Jakarta, East Jakarta, North Jakarta, Bekasi City, Depok City, Tanggerang City, South Tanggerang City, and Sidoarjo.*
***Keywords*:** *Spatial Autocorrelation, Moran Scatterplot, Local Indicator of Spatial Association, Crime*

INTRODUCTION

Indonesia is a country that has a fluctuating number of crimes every year. According toCentral Bureau of Statistics (2022) The number of crimes in Indonesia in 2022 will increase quite significantly from the previous year. Based on Criminal Statistics in 2022, the number of crimes at the Polda level during 2022, namely, the East Java Regional Police is the Regional Police with the highest number of crimes in 2022 with 51,905 incidents, followed by the North Sumatra Regional Police with 43,555 incidents, and the

Metro Jaya (DKI Jakarta) Regional Police with as many 32,534 events. This proves that the provinces in the Java Island region dominate the ranking for the number of crime cases, which means that the crime rate in the Java Island region is not small. Research related to crime was carried out by Chrishananda & Chernovita (2020) In this study, we analyzed crime patterns in Salatiga City which resulted in the conclusion that from the spatial autocorrelation analysis, there was no strong correlation and most of the data grouping most likely occurred randomly.

Combating crime can be done by knowing areas that are prone to crime. In-depth understanding of crime can be done using geographic/spatial aspects (Anselin et al., 2000). Spatial statistics is a statistical method used to analyze spatial data that shows geographic locations where each characteristic has a unique position that must be specifically determined (Getis, 1999).In the concept of spatial statistics, analysis that refers to the level of relationship or dependency between values in adjacent geographical locations in a dataset is spatial autocorrelation(Dubin, 1998). A spatial analysis method that shows spatial autocorrelation globally can be using the Moran Index, while to identify autocorrelation locally to see areas that are vulnerable/hotspots you can use Local indicators of spatial association (LISA) (Lee & Wong, 2001).

Research related to spatial autocorrelation was carried out by (Kurek et al., 2021) which examines the demographic patterns of functional urban areas in Poland and produces conclusions All indicators are statistically significant throughout the study period (2005-2016) and show moderate or weak spatial autocorrelation in the tested variables.Jesri et al. (2021) examined the spatial pattern of Covid-19 in Qom Province using LISA which resulted in the conclusion that the spatial distribution pattern of COVID-19 prevalence in Qom was clustered and there were 2 districts that fell into the high-high quadrant.

RESEARCH METHODS

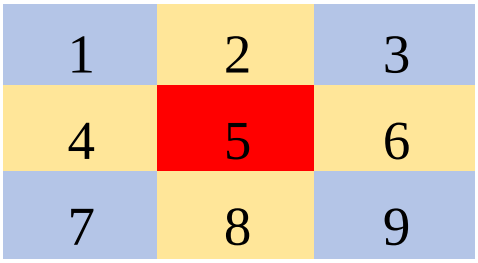
The data used in this research is secondary data on crime rates for each district/city on the island of Java in 2022 obtained from the Central Statistics Agency (BPS). The research unit consists of a total of 119 observations, covering all districts and cities on the island of Java. The data analysis technique used in this research is spatial data analysis using the Moran Index and LISA methods.

In this research, Geoda software was used to process the data. The following are the analysis steps in this research:

1. Describe the distribution of crime rate data on the island of Java in 2022 with a thematic map.

2. Determine the proximity/neighborhood between districts/cities on the island of Java by creating a contiguity matrix. In this study, the spatial weighting used to

determine closeness is queen contiguity. Queen Contiguity Principle, a unit or location is considered a neighbor of another location if both have a common side or corner(Weisburd et al., 2022). The following is an example of applying queen contiguity in calculating the weighting matrix.



Picture1. Queen Contiguity illustration

In the application of queen contiguity, the matrix element is defined as 1 if the geographical unit area is considered adjacent or related if it shares the same side boundary (side) or corner. For other areas, matrix elements with a value of 0 are mentioned.

3. Perform calculations and testing of spatial dependencies using the Moran index. The Moran Index was chosen because of its ability to overcome the issue of spatial randomness, allowing the calculation of autocorrelation between locations(Westerholt, 2023). In simple terms, the Moran index can be described as follows(Lee & Wong, 2001).

$$I = \frac{n}{W} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \quad (1)$$

With,

I : is Moran's index,

x_i, x_j : value at location i and $J; i \neq j$

n : the number of locations where the incident occurred

$\bar{x}$: variable average x

w_{ij} : weighting matrix elements

W : $\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}$

4. Recognizing the distribution pattern of crime rates based on the results of the Moran index. If the value $-1 \leq I < 0$ indicates the presence of negative spatial autocorrelation or which means that adjacent locations have different values, and if the value $0 < I \leq 1$ indicates the existence of positive spatial autocorrelation or that are close together and have similar values and tend to

group together, whereas if A Moran index value of 0 indicates that there is no spatial autocorrelation or no grouping(Lee & Wong, 2001). The following is the hypothesis test for parameter I:

$H_0 : I = 0$(no spatial autocorrelation/spatial dependency)

$H_1 : I \neq 0$(there is spatial autocorrelation/spatial dependency)

5. Create and conduct analysis of Moran scatterplots. Moran scatterplots can indicate outlier data in terms of high or low levels of spatial autocorrelation (Negreiros et al., 2010).

Quadrant II Low-High	Quadrant II High-High
Quadrant III Low-Low	Quadrant High-Low

Picture2. Moran Scatterplot illustration

If all observations have a similar level of spatial autocorrelation, the Moran scatterplot will show observations that lie close to the regression line(Anselin, 2019).

6. Performing calculations and testingsignificanceLocal Indicator of Spatial Autocorrelation (LISA) index. The LISA index is useful for identifying areas that are the center of attention (hotspots) or areas with low values (coldspots) in area data(Anselin, 1995). The LISA index can be defined by the following calculation(Lee & Wong, 2001).

$$I_i = z_i \sum_i w_{ij} z_j \qquad (2)$$

with

I_i : LISA Index

z_i,z_j : deviation from the average or$z_i = (x_i - \bar{x})/\delta$

δ : standard deviation ofx_i

7. Create a vulnerability map and determine crime hotspots and cold spots on the island of Java based on the LISA index.Hypothesis testing in LISA parameters can be done by determining the hypothesis first as follows(Caldas & Singer, 2006):

H_0: $I_i = 0$; $i = 1,2,\ldots\ldots,n$ (There is no autocorrelation between locations or the 1st area is not a hotspot)

H_1:$I_i \neq 0$; $i = 1,2,\ldots\ldots,n$ (There is autocorrelation between locations or the 1st area is a hotspot)

8. Interpretation of results

RESULTS AND DISCUSSION

Description of Crime Rates on the Island of Java

The mapping in Figure 3 was carried out using the Natural Breaks method, by dividing spatial data into homogeneous groups. The aim is to minimize variation within each group and maximize variation between groups so that data visualization is easier and crime vulnerabilities can be seen more dynamically.(J. Chen et al., 2013). The crime incidence rate on the island of Java in 2022 is divided into 3 groups, namely low, medium and high. Each group is shown in yellow, orange and red. Group

Figure 3. Map of the Distribution of Crime Rates on the Island of Java

districts/cities colored yellow are a group of areas with low crime rates, namely from 44 to 784 incidents. The orange district/city group is a group of regions with moderate crime rates, namely from 785 to 2160 incidents. The red district/city group is a group of regions with a high crime rate, namely from 2161 to 5041 incidents. Apart from the crime rate variable, there are also seven variables that are thought to influence the crime rate on the island of Java in 2022.

Spatial Dependency Testing Based on the Moran Index

The research will see whether there is spatial autocorrelation between districts/cities based on the Moran index value, withhypothesis test Moran index parameter (I) as follows:

$H_0 : I = 0$ (no spatial autocorrelation/spatial dependency)

$H_1 : I \neq 0$ (there is spatial autocorrelation/spatial dependency)

In this study, it shows that the Moran's index value is 0.4911, so rejecting H_0 means the Moran's index value $(I) \neq 0$,, and is in the value range 0 < I ≤ 1 indicating positive spatial autocorrelation. Furthermore the test results showed that there was a comparison

between the Moran Index value and the expected value of the Moran index (EI),, the Moran index value was greater than the expected value with a value of -0.0086, thus showing that the distribution pattern of crime rates on the island of Java in 2022 was clustered.

Moran Scatterplot of Crime Rates on the Island of Java

Moran scatterplot is used to analyze the distribution in quadrants between observation locations (Negreiros et al., 2010). Before making a Moran scatterplot, the first thing to do is create an adjacency matrix using the queen contiguity method. The principle of queen contiguity is that a unit or location is considered a neighbor of another location if both have a common side or corner (Lee & Wong, 2001). Next, create a visualization of the Moran scatterplot of crime figures. The observation points in Figure 4 are districts/cities that are spread based on their influence on surrounding districts/cities that are located close to each other. Based on Figure 4, information is obtained that the crime rate for each district/city on the island of Java is in 4 (four) quadrants.

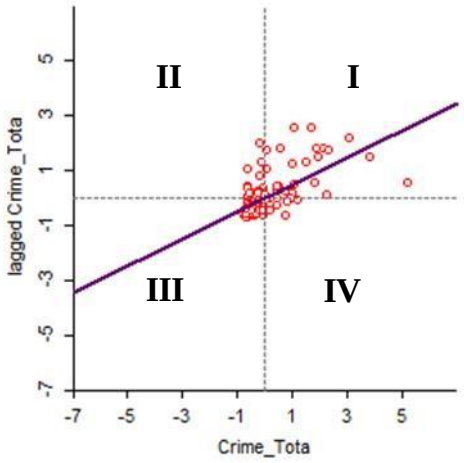


Figure 4. Moran Scatterplot

Quadrant I (High-High) contains 25 districts/cities, indicating that districts/cities with high crime rates are among the districts/cities that have high crime rates. Quadrant II (Low-High) contains 20 regencies/cities, indicating that regencies/cities with low crime rates are among regencies/cities that have high crime rates. Quadrant III (Low-Low) contains 66 regencies/cities, indicating that regencies/cities with low crime rates are among the regencies/cities that have low crime rates. Quadrant IV (High-Low) contains 8 districts/cities, indicating that districts/cities with high crime rates are among districts/cities that have low crime rates.

Crime Rate Vulnerability Map Based on the LISA Index

Moran scatterplot focuses on global spatial autocorrelation analysis and helps identify overall patterns resulting in only one test statistical value(Y. Chen, 2013). Meanwhile, using LISA produces separate test statistics for each unit of analysis so that it is useful for identifying and mapping significant local clusters that indicate hotspots (areas with high values surrounded by high values) or cold spots (areas with low values surrounded by low values(Waller & Gotway, 2004).

Figure 4 shows that there are 5 different colors, 4 different colors for districts/cities that are significant and 1 color, namely white for districts/cities that are not significant. Significant areas are given 4 categories according to different colors. With the LISA index showing a p-value < at a significance level of 5%, it will reject which means that districts/cities have significant spatial autocorrelation between locations.αH_0

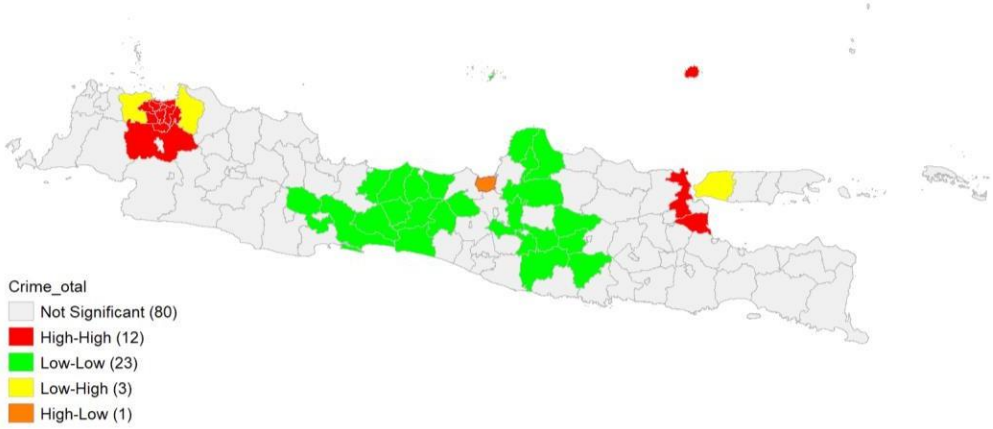


Figure 5. Crime Vulnerability Map

There are a significant number of regencies/cities, 39 of the total 119 regencies/cities on the island of Java. In the High-High (red) category, this means that this category is a hotspot or is prone to crime incidents on the island of Java. In the Low-Low (green) category, this means that this category is a cold spot or area that is safe for crime incidents on the island of Java. Meanwhile, the High-Low (orange) and Low-High (yellow) categories are outliers/refer to locations that show a spatial pattern that is significantly different from the surrounding locations. This occurs because of significant differences in crime rates between the observed area and the surrounding area.

For example, in the High-Low category, there is only 1 district, namely Semarang City, which means that Semarang City has a high crime rate but the surrounding areas, namely Kendal, Demak and Semarang Regency, have a lower crime rate. One of the

factors that causes this to happen is related to the economic growth rate of Semarang City which is higher than the surrounding area with a growth rate of 5.73%. (Semarang City Central Statistics Agency, 2023). When a region has a high economy or is focused on that region, urbanization will go hand in hand (Utomo, 2020). In connection with this matter, there are indications that the city of Semarang is a city area with high urbanization compared to the surrounding areas, therefore, according to (Browning et al., 2010) Urban conditions that are increasingly uncontrolled due to excessive urbanization have caused various new problems, such as high crime.

In the Low-High Category there are 3 districts/cities, namely Bekasi, Bangkalan and Tanggerang, meaning an area that has a low crime rate but the surrounding area has a high crime rate. For example, Bekasi has a low crime rate compared to surrounding areas, namely North Jakarta, East Jakarta, Karawang, Bogor and Bekasi City. In this regard, one of the factors that most differentiates Bekasi from the surrounding areas is related to the Gini ratio in 2022 which is low and has decreased from the previous year, namely 0.34.(Central Statistics Agency, 2023). In connection with what was previously explained, the lower Gini ratio between Bekasi and the surrounding districts/cities can have a significant effect on crime, so that the higher the Gini ratio, the higher the crime rate. (Merton, 1938).

CONLUSIONS AND SUGGESTIONS

Based on the analysis and discussion of research that has been carried out, it is concluded that the Moran Index with a value of 0.4911 is greater than the expected value of -0.0086, thus indicating that the distribution pattern of crime rates on the island of Java in 2022 is clustered. Districts/cities on the island of Java that are classified as crime-prone areas/hotspots, namely Bogor, Gresik, West Jakarta, Central Jakarta, South Jakarta, East Jakarta, North Jakarta, Bekasi City, Depok City, Tanggerang City, South Tanggerang City, and Sidoarjo. In future research, it is recommended to use a weighting matrix other than queen contiguity.

BIBLIOGRAPHY

Anselin, L. (1995). Local indicators of spatial association—LISA. Geographical Analysis, 27(2), 93–115.

Anselin, L. (2019). The Moran scatterplot as an ESDA tool to assess local instability in spatial associations. In Spatial analytical perspectives on GIS (pp. 111–126). Routledge.

Anselin, L., Cohen, J., Cook, D., Gorr, W., & Tita, G. (2000). Spatial analysis of crime. Criminal Justice, 4(2), 213–262.

Central Bureau of Statistics. (2022). Crime Statistics 2022.

Central Bureau of Statistics. (2023). Gini Ratio. https://www.bps.go.id/indikator/indikator/view_data/0000/data/98/sdgs_10/1

Semarang City Central Statistics Agency. (2023). Semarang City Economy 2022.

Browning, C.R., Byron, R.A., Calder, C.A., Krivo, L.J., Kwan, M.-P., Lee, J.-Y., & Peterson, R.D. (2010). Commercial density, residential concentration, and crime: Land use patterns and violence in neighborhood context. Journal of Research in Crime and Delinquency, 47(3), 329–357.

Caldas de Castro, M., & Singer, B. H. (2006). Controlling the false discovery rate: a new application to account for multiple and dependent tests in local statistics of spatial associations. Geographical Analysis, 38(2), 180–208.

Chen, J., Yang, S.T., Li, H.W., Zhang, B., & Lv, J.R. (2013). Research on geographical environment unit division based on the method of natural breaks (Jenks). The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 40, 47–50.

Chen, Y. (2013). New approaches for calculating Moran's index of spatial autocorrelation. PloS One, 8(7), e68336.

Chrishananda, KBT, & Chernovita, HP (2020). Spatial Analysis of Crime Patterns in Salatiga City. Spatial Journal: Research, Applied, Geography Science and Geography Education, 1(7), 22.

Dubin, R. A. (1998). Spatial autocorrelation: a primer. Journal of Housing Economics, 7(4), 304–327.

Getis, A. (1999). Spatial statistics. Geographical Information Systems, 1, 239–251.

Jesri, N., Saghafipour, A., Koohpaei, A., Farzinnia, B., Jooshin, M.K., Abolkheirian, S., & Sarvi, M. (2021). Mapping and spatial pattern analysis of COVID-19 in Central Iran using the local indicators of spatial association (LISA). BMC Public Health, 21, 1–10.

Kurek, S., Wójtowicz, M., & Gałka, J. (2021). Using Spatial Autocorrelation for identification of demographic patterns of Functional Urban Areas in Poland. Bulletin of Geography. Socio-Economic Series, 52.

Lee Jay, & Wong WS David. (2001). Statistical Analysis With Arcview Gis.

Merton, R. K. (1938). pSocial Structure and Anomieq, American Sociological Re# view, 3. October, 672&82.

Negreiros, J.G., Painho, M.T., Aguilar, F.J., & Aguilar, M.A. (2010). A comprehensive framework for exploratory spatial data analysis: Moran location and variance scatterplots. International Journal of Digital Earth, 3(2), 157–186.

Waller, L. A., & Gotway, C. A. (2004). Applied spatial statistics for public health data. John Wiley & Sons.

Weisburd, D., Wilson, D.B., Wooditch, A., Britt, C., Weisburd, D., Wilson, D.B., Wooditch, A., & Britt, C. (2022). Spatial Regression. Advanced Statistics in Criminology and Criminal Justice, 499–535.

Westerholt, R. (2023). A simulation study to explore inference about global Moran's I with random spatial indexes. Geographical Analysis, 55(4), 621–650.

Utomo Yoga. (2020). Analysis of the Relationship Between Urbanization and Economic Growth in Indonesia.