A spatial equity assessment of the public facilities in the greater Jakarta area using Moran’s I spatial autocorrelation

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Abstract. Indonesia has experienced rapid urbanization that has grown vastly in urban areas such as The Jakarta Greater Area. Since 2013, Jakarta Greater Area is also known as a megacity because of its populous population of above 26.7 million. The rapid growth of the population is the government’s responsibility to be able to provide adequate public facilities for society. This research aims to evaluate the spatial equity of 8 public facilities in the Greater Jakarta Area. The spatial equity can be an indicator of the adequacy level of the public facilities provided. This study used Moran’s I Spatial Autocorrelation (LISA Method). The research was divided into 5 stages consist of spatial data collection, layer creation process, count point in polygons, LISA, and spatial equity analysis. The goal of this research is to help urban planners to analyze which areas still need more public facilities. As a result, more than 700 areas are in the low-high area category, which indicates that the area has a high population, but the number of facilities provided is still insufficient.

1. Introduction
The United Nations (UN) in 2019 stated that Indonesia had been the fourth most populous country in the world, with 271 million people living there[1]. Indonesia’s tremendous population growth is mostly concentrated in urban areas such as Jakarta Greater Area that is commonly abbreviated as Jabodetabek that consist of Jakarta, Bogor, Depok, Tangerang, and Bekasi [2]. Furthermore, Jakarta Greater Area is also known as a megacity with a total population is above 26.7 million people and has become the center of Indonesia’s economic development [3]. Urbanization in Indonesia has grown vastly caused by some driving factors such as theoretical physics and socio-economic. The theoretical physic includes the geographical conditions in the region and socio-economic driving factors consisting of economic, political, and demographic conditions [4].

The rapid development of urbanization brought tremendous challenges to Jakarta Greater Area’s government to suitably provide adequate public facilities. Moreover, sufficient public facilities are also expected to support Jakarta to become a livable area, which means that the site has a high level of comfort to be lived by society. In 1970, the World Health Organization (WHO) initiated 4 main pillars that can be used as criteria for assessing the livable area of a city, consisting of convenience category, amenities category, health category, and safety category. The convenience category is a pillar that emphasizes the concept where people can feel comfortable when running live in a city. This pillar concerns the availability of public facilities such as educational facilities, public transportation, and entertainment venues. The healthy category is a pillar that emphasizes the concept where people can have a healthy environment, and the citizens can easily access clean water and the environment is far
from air pollution. This pillar concerns the accessibility of public facilities such as hospitals or other medical facilities. The amenity category is a pillar that emphasizes the concept where people can enjoy the natural landscapes. This pillar concerns the availability of greenspace in a city. The safety category is a pillar that emphasizes the concept where people can live in a city without the burden of scared of crime or natural disasters [5]. On the other hand, some organizations have different criteria for assessing the quality of a city. Most measures are identical to those stated by WHO, and only a few are different [6].

Furthermore, the unequal availability of public facilities in urban areas will be a problem of spatial inequity that has been happening for the last two decades. Various research organizations in the world formulate different parameters for evaluating spatial equity. The differences that occur, for example, some researchers use distance as a measure to assess whether the public facilities spread across a city are evenly distributed or not, but some researchers use the total number of available public facilities such as the number of educational facilities, cultural events, and transportation public facilities that are provided by the government [7]. Spatial equity in public facilities plays a vital role in an urban city with a very large population. The government in Jakarta Greater Area has provided public facilities for the fulfillment of the 4 pillars stated by WHO. However, the problem of public facilities that have not been unevenly distributed still occurs. Depok, for example, according to Kompas Newspaper, the government's green space in Depok is still very limited and does not proportional to the population. Therefore, this paper will evaluate the spatial equity of public facilities in the Greater Jakarta Area using Moran’s I Spatial Autocorrelation method.

2. Literature Review

2.1. Urban Livability

The spatial equity for public facilities provided by the government can be used as an assessment of urban livability in each region in a country. In 1970, WHO created 4 main pillars that must be assessed as the urban livability assessment tool. The 4 main pillars consist of convenience, amenities, health, and safety as the basis for determining the level of urban livability in every country. The pillar then began to be implemented by researchers and urban planners in several countries, especially China, which is one of the countries that has adopted the concept of urban livability [5].

The convenience category emphasizes the concept where the citizen can enjoy running their lives in a city. The idea of convenience category also uses the higher accessibility indicator as part of the pillar, which means that the facilities provided by the government must also be easily accessible to the society in the area. The convenience categories that are included in this pillar consist of public transportation facilities, educational institutions such as schools and universities, and the entertainment venues where people can feel enjoyable when living in a city [5].

The amenity category emphasizes the concept where people in a city can enjoy the beauty of the public infrastructure. The amenity category that is included in this pillar consists of the green space accessibility where society can enjoy natural beauty, even living in an urban city. The objective of this category is to increase the sense of comfort and satisfaction of living in that region [5].

The health category emphasizes the concept where people can live in a healthy and livable environment. They can breathe air that is free from pollution, easy to access clean water, and the government provides accessible health facilities in each region such as hospitals which are one of the main facilities that every area should have [5].

The safety category emphasizes the concept where people can live in a city without feeling scared of the low level of security or the natural disaster that might happen in the town where they are living. The safety category that is included in this pillar consists of the distance to the police. The distance to gas stations and toxic chemical facilities also can be the criteria for assessment [5].

The parameters for assessing urban livability in each country can be different. Several studies in Australia use 11 parameters to determine urban livability. In this case, the researchers use employment and income, social cohesion, and local democracy as a parameter of urban livability assessment. EIU
Global Livability also has a different assessment index where the researchers use 39 factors with 10 dimensions as a parameter for assessing the livability area in a country [6].

2.2. Spatial Autocorrelation of Urban Facility

Public facilities provided by the government are used for the public interest and are not limited to specific individuals. Public facilities in each country generally consist of health, facilities, schools, social, and economic that will be used to support the society that lives in that urban area. The development of facilities will affect the public response when living in a city[8].

Spatial autocorrelation is a method of spatial analysis that is used to determine the correlation between the locations being studied, which in the end the researcher will get an output in the form of a map and graphic of the distribution pattern of an attribute in a certain area. Moran’s I and Local Indicator of Spatial Association (LISA) are two methods that can be used in conducting spatial autocorrelation analysis. Spatial autocorrelation is divided into two results, namely positive spatial autocorrelation, and negative spatial autocorrelation [7]. Positive indicates the level of significance at the distribution point has the same characteristic and is located close to one point to another [9]. Negative indicates that the level of significance at the distribution point has different properties even though it is located close to one point to another [10].

Spatial autocorrelation refers to data that is located far away will tend not to be similar in the result. On the other hand, for data that are located close to each other, the resulting data tends to be equal. Local spatial autocorrelation makes factors such as topography, population, and other local factors as calculation parameters [8].

2.3. Spatial Clustering Pattern using Global Moran’s I Tests and Local Indicator of Spatial Association (LISA)

Global autocorrelation analysis involves a process of clustering the entire map under study. Global autocorrelation analysis also aims to observe differences or similarities that occur in data locations that are located close to each other and at data locations that are located far apart. Global autocorrelation analysis consists of 6 types of tests, such as Moran’s I, Geary’s C, Ord’s G, etc [11].

Moran’s I is a method used for testing spatial dependencies, and the result is the development of the Pearson method. The weighted matrix W has the element \( x_{ij} \) representing the relationship in a spatial data set in unit i. The value of \( x_{ij} \) can be assumed in any value, but it is generally assumed that the binary matrix's weighing consists of 2 hypotheses, namely \( I = 0 \), and \( I = 1 \). That is equal to 0, indicating that there is no spatial autocorrelation between the locations being reviewed, while \( I = 1 \) demonstrates spatial autocorrelation between the locations being tested.

\[
I (d) = \sum \sum \frac{\omega_{ij}z_i z_j}{S_0 m_2} \\
S_0 = \sum \sum \omega_{ij} \\
m_2 = \sum \frac{z_i^2}{I} \\
z_i = x_i - \bar{x} \\
I (d) = \left( \frac{m_2}{m_2} \right) \sum \omega_{ij} z_i
\]

Global Moran’s I is also known as inferential statistics, where the null hypothesis will be the context for the discussion of analysis carried out. The null hypothesis shows that the attributes are randomly distributed among the other attributes that are being tested. The standard spatial weight matrix for the number of rows is also part of Global Moran’s I, stated by researcher Day in 2008[11].
Local Indicator of Spatial Association (LISA) is a method of Spatial Autocorrelation which is used to group the same values in the observations that are being carried out which will then be identified whether there is a spatial relationship. LISA is classified into 4 spatial types, namely high-high means the area that is been identified has the same high LISA value with the surrounding area, low-high means the area that is been identified as the lower LISA value compared with the surrounding area, high-low means the area that is been identified as the higher LISA value compared with the surrounding area, and low-low means that the area that is been identified has the same low LISA value with the surrounding area[7].

3. Data Sources and Methods

3.1. Data
The spatial data used in this research are area boundaries, population density, and public facilities location in Greater Jakarta Area that is divided into 10 regions (Central Jakarta, East Jakarta, North Jakarta, South Jakarta, West Jakarta, Bekasi, Bogor, Depok, Tangerang, and Thousand Island). Figure 1 shows the population density and the public facilities location data, obtained from Badan Informasi Geospasial, Badan Pusat Statistik, and OpenStreetMap.

3.2. Methods
This research aims to evaluate the spatial equity of public facilities in the Greater Jakarta Area. The methods used in this research was divided into 5 stages by using QGIS and GeoDa as shown in Figure 2. The first stage is spatial data collection consists of area boundaries, population density, and public facilities location. The second stage is the layer creation process; in this stage, all the spatial data will be changed into the UTM zone 48S format, merged, and clip by using QGIS. The third stage used the count point in the polygons method to calculate the number of public facilities in a specific location using QGIS. The fourth stage uses GeoDa to create the cluster map and Moran scatters plot (LISA). The last step is to analyze the result of spatial equity.
4. Results and Discussion

4.1. The Determinant Factors and The Distribution of Public Facilities in the Greater Jakarta Area

Table 1 represents 4 main categories consisting of 8 public facilities used as determinant factors consisting of school, university, public transportation, religious place, sports area, green park, hospital, and police station, according to several references. The number of public facilities will be one of the parameters to determine which areas are still not proportional to the number of populations in each area.

| Main Category | Public Facility | Explanation | Reference |
|---------------|-----------------|-------------|-----------|
| Convenience Category | School | School is one of the facilities reviewed regarding the relative equity status of the facility distributions in Taiwan that has been published by journal [7] using GIS and spatial analysis models which will be one of the authors' references. | [7] |
| University | University | University is one of the facilities reviewed regarding the relative equity status of the facility distributions in Taiwan that has been published by journal [7] using GIS and spatial analysis models which will be one of the authors' references. | [7] |
| Public Transportation | Public Transportation | Public transportation is one of the facilities reviewed regarding the effectiveness and spatial coverage of public transport networks in tourist destinations that has been published by journal [12] which will be one of the authors' references. | [12] |
| Religious Place | Religious Place | Religious place is one of the facilities reviewed to offer an integrated index of spatial equity that has been published by journal [13] which will be one of the authors' references. | [13] |
| Sport Area | Sport Area | Sport area is one of the facilities reviewed regarding the relative equity status of the facility distributions in Accra that has been published by journal [14]. | [14] |
| Amenities Category | Green Park | Hospital is one of the facilities reviewed to offer an integrated index of spatial equity that has been published by journal [13] which will be one of the authors' references. | [13] |
| Health Category | Hospital | Hospital is one of the facilities reviewed to offer an integrated index of spatial equity that has been published by journal [13] which will be one of the authors' references. | [13] |
| Safety Category | Police Station | Police station is one of the facilities reviewed regarding the livability assessment that has been published by journal [15] which will be one of the authors' references. | [15] |

Figure 3 represents the distribution of public facilities in the Greater Jakarta Area created using the QGIS software. Districts with denser populations are visualized as polygons in darker blue, while others with smaller populations are in light blue. The colored dots represent the locations of public facilities for each category. As shown in Figure 3, visually it can be concluded that each category of public facilities in the Greater Jakarta Area is not evenly distributed. Some districts with densely populated areas have few facilities for daily activities. For example, the green park facilities as the part of amenities category are still very limited in the Greater Jakarta Area. After creating the layer, the count point in the polygons method is used to calculate the number of availability of the public facilities in each area.
Figure 3. The Distribution of Public Facilities: (a) School, (b) University, (c) Public transportation, (d) Religious Place, (e) Sport Area, (f) Green Park, (g) Hospital, and (h) Police Station

4.2. Weight Matrix

There are two choices in determining the contiguity weights, namely rook, and queen. The rook defines the state in which the counted number of neighbors is only in the common edge of the area being tested. Meanwhile, the queen defines a condition in which the number of neighbors counted is the whole area that touches all sides of the tested area. In this research, the selected contiguity weight uses a queen matrix with the order of contiguity is 1, as seen in Figure 4.
The queen matrix will produce the number of neighbors with bigger value or at least the same as when using the rook matrix. The number of connectivity histograms can be seen in Figure 5. Based on Figure 5, there are 10 neighborless observations, and more than 750 areas have the number of neighbors in the range 5-6.

4.3. Local Indicator of Spatial Association’s Test

The objective of the Local Indicator of Spatial Association (LISA) method is to classify and group the area that has the same value, which will be identified the spatial relationship between the area that is being observed. LISA is grouped into 4 types consisting of high-high, low-high, high-low, and low-low. In determining Moran’s I’s value, a positive value means that the attributes are spatially clustered. In contrast, a negative value means that the features are not spatially clustered, otherwise known as dispersed. The results of the Moran’s I value can be seen in Table 2 and the results of the scatter plot and cluster map by using the LISA method can be seen in Figures 6-13.

| Facility             | Moran’s I |
|----------------------|-----------|
| School               | 0.021     |
| University           | 0.033     |
| Public Transportation| 0.008     |
| Religious Place      | -0.004    |
| Sport Area           | 0.011     |
| Green Park           | 0.011     |
| Hospital             | 0.005     |
| Police Station       | 0.002     |

Figure 6. Scatter Plot and Cluster Map of School
Figure 7. Scatter Plot and Cluster Map of University

Figure 8. Scatter Plot and Cluster Map of Public Transportation

Figure 9. Scatter Plot and Cluster Map of Religious Place

Figure 10. Scatter Plot and Cluster Map of Sport Area
Figure 11. Scatter Plot and Cluster Map of Green Park

Figure 12. Scatter Plot and Cluster Map of Hospital

Figure 13. Scatter Plot and Cluster Map of Police Station

A positive value suggests that the features are spatially clustered; a negative value indicates that the elements tend to be dispersed. Parts are randomly distributed when $I = 0$. Based on Table 2, the relationship between all facilities and the number of residents except for religious places has positive Moran’s I, which means that it is spatially clustered. Based on Figures 6-13, it is shown that there are still many areas with high population numbers, but the number of facilities provided by the government is still low. There are 868 areas with a low number of hospitals, but the locations are classified as high population areas (low-high). There are 777 areas with a low number of school, but the areas are classified as high population area (low-high), 874 locations with the low number of the university but are classified as high population area (low-high), 706 areas with a low number of public transportation facilities but the areas are classified as high population area (low-high), 768 areas with a low number of religious places but the areas are classified as high population area (low-high), 880
areas with a low number of sports area but the areas are classified as high population area (low-high), 880 areas with a low number of the green park but the areas are classified as high population area (low-high), 868 areas with a low number of the hospital but the areas are classified as high population area (low-high), and 846 areas with a low number of the hospital but the areas are classified as high population (low-high).

5. Conclusion

This study used the LISA method to determine the spatial equity of public facilities provided by the government in the Greater Jakarta Area. As a result, more than 700 areas are in the low-high area category, which indicates that the area has a high population, but the number of facilities provided by the local government is still insufficient. All of the methods that have been used in this research is also inspired by some researchers in Taiwan that also used this LISA method to analyze the spatial equity in urban public facilities in their country [7]. As mentioned before in the abstract, this research can help urban planners to analyze the 700 areas so that the government can provide equally distributed public facilities in the Greater Jakarta Area.

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