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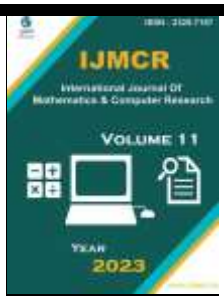

Classification of Cities in Europe Based on Smart City Indicators Using Multidimensional Scaling Analysis

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ABSTRACT

A decent life has become a hot issue for discussion as stated in the SDGs points, one of them is Smart City. In this research, the researchers used cities in Europe, a continent with countries that tend to have developed. By using multidimensional scaling analysis techniques, the authors present the mapping from an objective data-based point of view, aiming to analyze the closeness of characteristics between 70 cities spread across Europe, and provide ideas and valuable sources for policymakers. From the results of this analysis using R software, it was found that cities within the same country tend to have similar characteristics, which can take into consideration by the European Union to carry out equitable development for cities that do not have good enough smart city indicators.

KEYWORDS: Smart City, Europe, City, Multidimensional Scaling, Developed Countries

I. INTRODUCTION

Currently, almost 55% of the world's population lives in urban areas, and it is estimated that this number will increase to 66% by 2030 [12]. Since the industrial revolution, cities around the world have developed massively, including in Europe, which started the revolution industry. However, urban areas growth in opposite with environmental sustainability, access to transportation and other supporting things. Therefore, an idea appears in development cities with name smart city.

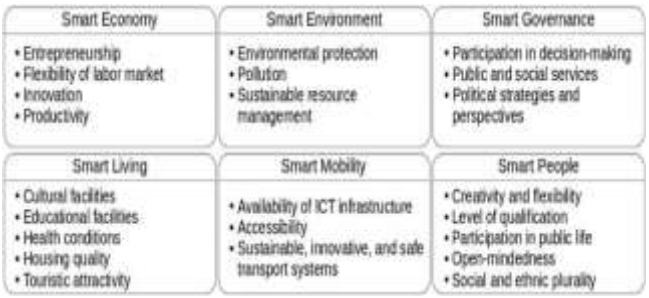

Figure 1. Indicators of Smart City

These indicators in figure 1 explain all the needs of urban communities[1]. So that, the government must pay attention to those aspect.

Multidimensional Scaling (MDS) is a multivariate analysis tool that deals with placing several objects on a multidimensional map determined by research based on the proximities (closeness values) between these objects. Multidimensional Scaling (MDS) is a method used to describe multivariate data transformed into a lower dimensional space. The basic principle and purpose of Multidimensional Scaling (MDS) analysis are to adjust the original data into a low-dimensional coordinate system to minimize distortion in dimension reduction.

Multidimensional Scaling (MDS) relates to making perceptual maps to describe the position of an object with other objects based on the similarity of these objects. Distortion generally refers to similarities or dissimilarities (distance) between the original data points. The hope is that we find out which cities have similar characteristics and become reference material in the future for better and more equitable development.

II. LITERATUR REVIEW

Smart City

Smart cities are innovative efforts made by urban ecosystems to overcome various problems and improve the quality of

human life by using technology to improve service efficiency and meet the needs of city residents.

The concept of a smart city has developed since the 1980s. The reason for the emergence of this concept is the increasing population in urban areas, which has the potential to hurt urban development.

Smart cities are innovative efforts made by urban ecosystems to overcome various problems and improve the quality of human life by using technology to improve service efficiency and meet the needs of city residents. In this study, there are six indicators of a city that is said to be smart, namely

1. Smart Mobility

Technological progress must be distinct from the terms of a smart city. Therefore, information and communication technology infrastructure and a safe and innovative transportation system must be in place to become a smart city. An example of implementing the concept of smart mobility is a city bike (city bike) equipped with a tracking device that anyone, including travellers, can rent. This type of bicycle is available in every corner of the city [11].

2. Smart Government

In addition to technological advances, the government plays an important role in turning a city into a smart city. The government must be ready to serve every citizen according to their needs. In addition, a culture of anti-corruption and transparency is the key to governance that carries the smart city concept.

One example is that, as part of a democratic country, Barcelona also implements an Open Government system. They take advantage of technology in the form of a website containing transparent data on government performance. There is an integrated voting system to determine citizens' support for each proposal. The Open Data system is also applied to government data [7].

3. Smart Environment

A smart city does not only rely on the government and technological advances but must be balanced with environmental sustainability as well. One of them is the low level of pollution.

Carbon emissions are the biggest cause of air pollution in the world. Carbon dioxide emissions are produced from fuel oil. The increasing need for and use of fuel oil tends to produce air pollution in major cities worldwide. Oslo, the capital of Norway, targets to reduce emissions by 36% in 2020 and increase by 95% in 2030.

Oslo is developing electric vehicles and their charging technology to achieve this target. Two thousand charging stations for electric vehicles provide relief to owners, including not having to pay sales tax and being entitled to free parking. This vehicle emission reduction strategy is slowly showing results, namely through sales of electric cars increasing by 48% in 2021 in Norway [10].

4. Smart Economy

Sustainable economic activity is one of the indicators of this smart city concept. And it takes innovation, productivity, and high enthusiasm to make it happen. Based on information references from We Build Value Digital Magazine, 2022, London is the centre of technology companies in Europe. A third of technology-based unicorn companies (start-ups with a value of at least $1 billion) in Europe are in the London area. A total of 46,000 companies employing 240,000 employees generate revenue of 51 billion euros. In the 2006-2016 decade, employment in the digital sector grew by 77%, while the number of companies increased by 90%.

5. Smart People

Remember also citizens who participate in the public interest, have an open mind, and respect societal differences. An example of supporting government programs in Barcelona is open government. Residents can submit ideas and input by submitting proposals through the website. The city council will examine incoming ideas and proposals.

6. Smart living

Education and health are important indicators for the progress of a city. Therefore, the availability of adequate education and health facilities is also one of the conditions for realizing this smart city concept.

To support the government program in Barcelona, namely open government, residents can submit ideas and input by submitting proposals through the website. The city council will examine incoming ideas and proposals[7].

Multidimensional Scaling (MDS)

Definition of Multidimensional Scaling Analysis (MDS)

Multidimensional Scaling is a multivariate technique that can be used to determine the position of an object relative to other objects based on their similarity [8]. Multidimensional Scaling (MDS) aims to provide a visual picture of closeness patterns in the form of similarities or distances between several objects and grouping objects. In this case, we can map cities in Europe based on smart city factors.

Types of Multidimensional Scaling (MDS)

Based on the scale of the data, Multidimensional Scaling is divided into two types, namely as follows:

a. Multidimensional Metrics

Distances are considered to be of interval or ratio type. If $d_{AB} = 2d_{BC} d_{AB} = 2d_{BC}$,, then so is the distance on the map (configuration).

b. Nonmetric Multidimensional Scaling

Distances are considered to be of nominal or ordinal type. If $d_{AB} > d_{BC} d_{AB} > d_{BC}$,, then so is the distance on the map.

Multidimensional Scaling (MDS) Analysis Procedure

Multidimensional Scaling analysis is used to map perceptions (perceptual maps) in multidimensional maps visually. Ginanjar describes several stages of analysis in

conducting Multidimensional Scaling analysis, namely as follows[5]:

1. Calculate the distance matrix using Euclidean distance. The closeness between objects on the perceptual map can be calculated using the Euclidean distance between the first object and the j-th object with the following formula:

$$d_{ij} = \sqrt{\sum_{k=1}^{p}(x_{ih} - x_{jh})^2}$$

Where :

$d_{ij} = d_{ij} =$ The distance between the i-th object and the j th object

$x_{ih} = x_{ih} =$ The result of the i-th object measurement on the h variable

$x_{jh} = x_{jh} =$ The result of the j-th object measurement on the h variable

2. Finding the eigenvalue and eigenvector with the following formula:

$\det(\boldsymbol{B} - \lambda \boldsymbol{I})\det(\boldsymbol{B} - \lambda \boldsymbol{I})$ dan $\det(\boldsymbol{B} - \lambda \boldsymbol{I})\boldsymbol{X}$ $\det(\boldsymbol{B} - \lambda \boldsymbol{I})\boldsymbol{X}$

Where calculate matrix B with elements

$$b_{ij} = -\frac{1}{2}(d_{ij}^2 - d_{i.}^2 - d_{.j}^2 + d_{..}^2)$$

Dimana

$$d_{i.}^2 = \frac{1}{n}\sum_{i} d_{ij}^2$$

$$d_{.j}^2 = \frac{1}{n}\sum_{i} d_{ij}^2$$

$$d_{..}^2 = \frac{1}{n}\sum_{ii} d_{ij}^2$$

3. Forming object coordinates based on the eigenvector $\boldsymbol{X} = [\boldsymbol{x_1}\ \boldsymbol{x_2}]\boldsymbol{X} = [\boldsymbol{x_1}\ \boldsymbol{x_2}]$, then calculating $\widehat{D}\widehat{D}$, which is the Euclidean distance from the coordinates formed.

4. Calculates STRESS (Standardized Residual Sum of Square) and R^2R^2values

STRESS is a measure of the incompatibility of the method with the data used. The smaller the STRESS value, the more suitable it is considered [6].

$$S = \left[\frac{\sum_{i=j}^{n}(d_{ij} - \hat{d}_{ij})^2}{\sum_{i=j}^{n} d_{ij}^2}\right]$$

Table 1. STRESS Value Criteria

Stress Value	Goodness-of-fit
0.200	Poor
0.100	Fair
0.050	Good
0.025	Excellent
0.000	Perfect

R^2R^2 = R *square* (RSQ) is the square of the correlation coefficient which indicates the proportion of variance from the optimal scale of the data, which is contributed by the Multidimensional Scaling procedure for the goodness of fit measure (Simamora, 2005). What is desired is a high R^2R^2 value ($R^2 = 1R^2 = 1$ or 100% the model represents perfectly), however, , $R^2 \geq 0{,}60\ R^2 \geq 0{,}60$ (60% or more) is acceptable, meaning it can represent the input data with pretty good. R^2R^2 can be found using the following formula (Supranto, 2004).

$$R^2 = \frac{\sum_{i,j}^{n}(d_{ij} - \hat{d}_{ij})^2}{\sum_{i,j}^{n} d_{ij}^2}$$

III. DATA AND RESEARCH METHODS

Data and Research Data Sources

This type of research used is quantitative research. The data used in this research is secondary data. Secondary data is a collection of information that previous researchers have collected. The data source in this study uses data from the Kaggle site, namely https://www.kaggle.com/ . The data used is a dataset entitled "Smart Cities Index Datasets"[4].

The IMD-SUTD (Singapore University of Technology and Design) Smart City Index (SCI) assesses citizens' perceptions of issues related to the structure and application of technology available in their city. In 2019, SCI ranked 102 cities around the world randomly and selected 120 residents for each city.

So SCI conducted more than 12,000 surveys. Each survey has 40 questions. In addition, there are three questions assessing attitudes towards the use of personal data, facial recognition and overall trust in local authorities.

However, this study only took countries originating from Europe, namely 70 data or cities. The data that has been obtained will be analyzed using the Multidimensional Scaling method with the help of RStudio software.

Stages of Analysis

Below is a flow chart in the stages of multidimensional scaling analysis [5]:

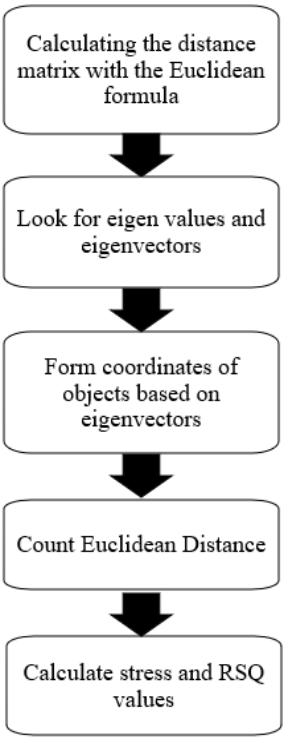

Figure 2. Stages of Analysis

The figure 2 show that the stage of analysis for multidimensional scaling. From the matrix distance until coordinate and RSQ value.

IV. RESULTS AND DISCUSSION

Calculating the Euclidean Distance Matrix

The Euclidean distance matrix in the MDS analysis is calculated using the formula described earlier so that the Euclidean distance matrix with RStudio software is obtained as follows:

Table 2. Euclidean Distance Matrix Result

	1	2	3	4	…	70
1	0	989.426	4594.046	4138.023	…	8188.669
2	989.426	0	4204.707	3509.756	…	8250.205
3	4594.046	4204.707	0	3699.932	…	8102.574
4	4138.023	3509.756	3699.932	0	…	8395.766
…	…	…	…	…	…	,,,
70	8188.669	8250.205	8102.574	8395.766	…	0

Euclidean distance calculates the distance between two real-valued vectors. Can be seen from table 3, The greater value means that the distance is more far away and the diagonal is zero because it is the distance between itself.

Graph Mapping Results

Based on the coordinate stimulus graph above, the output of a spatial map or perceptual map can be produced with the help of R software as follows:

Figure 3. Spatial Map for Cities

The spatial map above shows the similarities and dissimilarities between one object and another. It can be seen from the urban plot as a whole that several groups have similarities among their members. Adjacent points will describe several cities with the same smart city factor characteristics. The closer the point position is, the more similar it is. The farther the point position, the more different it is.

For example, Moscow and St.Petersburg are both located in Russia. Another example is Berlin, Munich, Hannover and Hamburg in Germany. This shows that in large countries with many developed cities, such as Russia and Germany, developed cities in these countries tend to have similar characteristics.

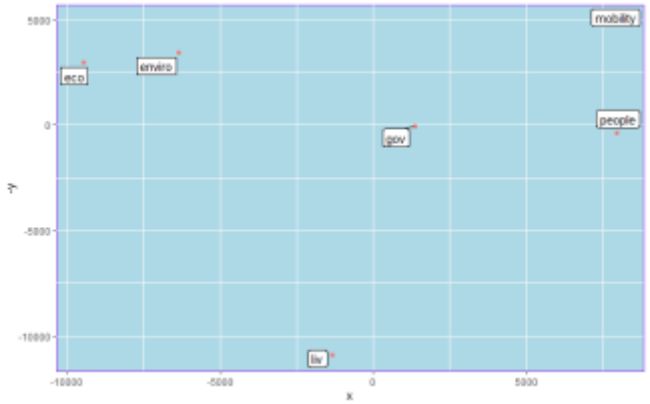

Figure 4. Spatial Map for Factors

Similar to city spatial maps, spatial factor maps also have the same properties, namely proximity is indicated by the position of points that are getting closer. An example is the mobility and people factors which have closeness and a fairly strong correlation.

Furthermore, the government factor, which tends to be in the middle of other factors, shows that if the government is good,

other factors will also be high, except for economic factors, which have a very small correlation.

Calculating STRESS and RSQ Values

Table 3. STRESS and RSQ Values

Stress	**RSQ**
0,14	0,911

Based on the Rstudio output above, it can be seen that the resulting STRESS value is 0.14, which means it is included in the sufficient criteria. In comparison, the resulting R^2 value is 0.911. Because the value of R^2 is greater than 0.6, the spatial map can be accepted with the assumption of high linearity.

V. CONCLUSSION

Based on the results of research and discussion, it can be concluded that:

- The validity of the stress value obtained is 0.14 or 14.23% which means that the scaling model obtained is included in the sufficient criteria. Then the R^2 value obtained is 0.91 > 0.6, which means that the spatial map and the assumption of linearity in the MDS analysis are acceptable.
- Based on the MDS's characteristics, the closer it is, the more it has the same characteristics as the MDS plot and plot factors. Several cities with one country plot close together, such as St. Petersburg and Moscow, Russia.
- Other results can be drawn from this research. Namely, countries with an advanced economy in Europe tend to be good in terms of the environment.

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