Sustainability indicator for resilient city amid the COVID-19 Pandemic in Lowokwaru District, Malang City, Indonesia

S Hariyani*1, F Shoimah1

1Department of Regional and Urban Planning, Faculty of Engineering, Universitas Brawijaya

Email: septianahariyani@ub.ac.id

Abstract. The COVID-19 pandemic brings a big shock to Malang city. Meanwhile, the city is also stressed out due to population development and the high flow of urbanization, especially because of students who continue to live in Malang City and in the suburban areas. Urbanization is the result of planning to develop Malang City as an educational city with various educational institutions. This research aims to formulate the sustainability indicator of Malang City regarding resilient city amid the COVID-19 pandemic. The sample used to measure the sustainability indicator is Lowokwaru District. Regarding the development planning of Malang City as an education city, Lowokwaru District is a very suitable sample because 1/3 of the universities in Malang City are concentrated in Lowokwaru District. Besides, there are also other educational facilities such as 12 elementary schools, 11 junior high schools, nine senior high schools, and eight vocational high schools. Therefore, Lowokwaru District is measured by the sustainability indicator, namely density, diversity, and compactness to formulate a resilient city amid the COVID-19 pandemic. The results of calculations and interpretations from similar studies show that the sustainability of Malang City is at a moderate level of sustainability in terms of resilient city amid the COVID-19 pandemic, with a moderate population density (101.1-200 people/ha); medium building density (20-40 buildings/ha); the level of random diversity (the closest neighbour value is 1.1 and the entropy index is 0.51), where the distribution of facilities and infrastructure is not evenly distributed throughout the districts; and compactness is almost uneven.

1. Introduction
Humans need space in carrying out their activities [1]. The increase in population in an area triggers an increase in space requirements. The need for space is used as a forum for community activities [2]. The need for space in one area requires spatial planning, one of which is the structure of space. Population, land use, and road network are the aspects of urban spatial structure [3]. Rapid population growth and the increasing demands of community needs for land often result in conflicts of interest over land use and a mismatch between land use and its designation plan [4]. Therefore, population growth triggers land use changes from undeveloped land to built land. This change will be broader and higher as the city develops because it is carried out by individual communities and the government. Therefore, the conversion of agricultural land to non-agriculture can have implications in spatial structure changes[5]. The increase in the city population also means an increase in the need for land. While land cannot increase, the impact is a change in land use which tends to reduce the proportion of agricultural land to non-agricultural land [6].
The city development, which results in the city’s expansion, is caused by the growing population and the increasing flow of urbanization. The city’s increasing population causes the community’s need for housing, offices, and other socio-economic facilities to increase. This phenomenon is better known as urban sprawl. This urban sprawl causes a tendency for urban residents to choose to live in suburban areas. As a result, there are pockets of settlements, increasing the need for facilities and infrastructure and inefficiency in providing facilities and infrastructure. The COVID-19 pandemic has impacted the approach to urbanization and spatial planning. The COVID-19 pandemic impacts humankind and modifies the condition of the built environment [7].

A resilient city has developed capacities to help absorb future shocks and stresses to its social, economic, and technical systems and infrastructures to be able to maintain the same function, structures, systems, and identity. Indonesia, in this case, The COVID-19 pandemic brings a big shock to Malang city. COVID-19 pandemic is an event of the spread of disease caused by the Ribo Nucleat Acid virus type SARS-CoV-2, or Coronavirus Disease 2019 (COVID-19) [8]. The COVID-19 shock has impacted several things, such as increased rates of COVID-19 cases and mortality, decreased public consumption, decreased investment, increased government spending, and decreased net exports [9]. The COVID-19 cases in Malang City as of June 23, 2021 were 6,933 cases, with 107 patients receiving treatment, 6,172 patients recovered, and 654 patients died [10]. Meanwhile, the city is also stressed out due to population development and the high flow of urbanization, especially because of students who continue to live in Malang City and in the suburban areas. Urbanization is the result of planning to develop Malang City as an educational city with various educational institutions. The total population of Malang City in 2020 is 874,890 people [11].

This research aims to formulate the sustainability indicator of Malang City regarding resilient city amid the COVID-19 pandemic. The sample used to measure the sustainability indicator is Lowokwaru District. Regarding the development planning of Malang City as an education city, Lowokwaru District is a very suitable sample because 1/3 of the universities in Malang City are concentrated in Lowokwaru District, both state campuses such as Brawijaya University, Malang State University, and Maulana Malik Ibrahim State Islamic University; as well as private campuses such as the University of Muhammadiyah Malang, Islamic University of Malang, Malang National Institute of Technology, and Malang Kucecwara Institute of Economic Science [12]. Besides, there are other educational facilities such as 12 units elementary school, 11 units junior high school, nine units senior high school, and eight units vocational high school [13]. Lowokwaru District is measured by the sustainability indicator, namely density, diversity, and compactness to formulate a resilient city amid the COVID-19 pandemic. This research aims to formulate the sustainability indicator of Malang City regarding resilient city amid the COVID-19 pandemic.

Density is an essential typology in determining sustainable urban forms. In a broader sense, a sustainable city is a matter of density [14]. Density is the ratio of population or buildings to land area. The relationship between density and sustainable urbanization is also based on the concept of a feasible threshold: at a specific density (threshold), i.e. the number of people in an area is sufficient to produce the interactions needed to make urban functions or activities viable. Density and type of occupancy affect urban sustainability through differences in energy consumption; ingredients; and land for housing, transportation, and urban infrastructure [15]. High density and integrated land use conserve not only resources but also provide cohesiveness that encourages social interaction. Some policies can save energy by increasing urban density, strengthen the city centre, expand the proportion of cities that have land use within the area, provide good transit options, curb the growth of private motorized vehicles, and advocate policies for new mass rail transit systems for inefficient cities [16]. Density is closely related to the use of public transport. As density increases, private vehicle ownership decreases, and its movement as measured by gasoline consumption or mileage per capita also decreases, and transport use increases. By maintaining a constant mix of land uses, people living in areas with higher densities are less likely to travel by transit, walking, cycling, or a combination of these, and less likely to use private motorized vehicles than people living in areas with lower densities [17]. Lower density is inversely
proportional to a good transportation system, where lower density encourages private motorized vehicles [18].

The diversity of activities is essential for the sustainability of the city [19]. Lack of concentration of diversity can lead people to use private motorized vehicles for almost all their needs. In dense and diverse urban areas, people can walk. The more diverse and closer the diversity in an area, the more people walk. Therefore, diversity is essential to improve the urban system as a place to live [18]. Diversity is a multidimensional phenomenon that drives desirable urban features based on housing type, building density, household size, age, culture, and income [20]. Diverse developments contain a mix of land use, building and housing types, architectural styles, and leases. If development is not diverse, then the homogeneity of built forms often results in monotonous and unattractive urban landscapes, lack of housing for all income groups, class and racial segregation, and work-housing imbalances that lead to increased driving, congestion, and air pollution [21] [22].

Cohesiveness is an essential strategy to achieve a sustainable urban form [18]. Dense cities serve to protect rural areas; improving the quality of life, including social interaction and ready access to services and facilities; reducing energy consumption by providing a building density that is capable of supporting the use of renewable energy; and reducing greenhouse gas emissions by minimizing the number and length of trips by private motorized vehicle. Cohesiveness also refers to urban proximity and connectivity, suggesting that future urban development must be carried out close to existing urban structures [22]. The compactness of urban space can minimize energy for the movement of goods, services, and people [23]. Intensification is a crucial strategy for achieving cohesiveness, using urban land more efficiently by increasing the density of development and activity. Intensification includes developing previously undeveloped urban land, redevelopment of existing buildings or previously developed sites, subdivision and conversion, and additions and expansions [24]. A sustainable city must be dense, diverse, and highly integrated [25]. Urban forms must be accessible on foot, small enough to eliminate movement by private motorized vehicles, but large enough to provide the opportunities and services that shape rich urban life. Compactness goes hand in hand to be livable and serves to prevent commuting [26].

2. Methods

2.1. Study Area

Lowokwaru District is one of the districts in Malang City, located in the southwest of the city centre at coordinates 112°34'09.48" East Longitude-112°41'34.93" East Longitude and 70°54'52.22" South Latitude-80°3'05, 11". The area of Lowokwaru District is 2,260.48 ha, which is about 20.53% of the total area of Malang City. Lowokwaru District consists of 12 villages (Figure 1), 120 Community Units, and 794 Neighborhood Units with regional boundaries [13].

1. North: Karangploso District, Malang Regency
2. East: Blimbing District and Sukun District
3. South: Klojen District, Sukun District, and Blimbing District
4. West: Sukun District

2.2. Analysis Method

Three analysis methods were used, namely:
1. Population and building density analysis;
2. Nearest-neighbour analysis;
3. Entropy index; and
4. Gini coefficient analysis.
3. Results and Discussion

3.1. Population and Building Density Level
Based on the analysis results, the villages with the highest population and building density are Lowokwaru, Tulusrejo, and Sumbersari Villages (Figure 2). This is because the concentration centres of population development in Lowokwaru District are located in these villages. Therefore, the availability of infrastructure and facilities in these villages serves one district.

3.2. Diversity Level
A. Nearest-Neighbour Analysis
The nearest-neighbour analysis method analyzes the pattern of urban spatial structure and cleans water distribution services quantitatively. The nearest-neighbour index is classified into three values, each of which has a distribution type. If \( T = 0 \) then the distribution pattern is clustered, if \( T = 1 \) then the distribution pattern is random, and if \( T = 2.15 \) then the distribution is uniform [27] [28].

Figure 3 is the distribution of public facilities in Lowokwaru District in education, health, and green open spaces. Each public facility is represented by nodes that are interconnected with other nodes that have the closest distance. The \( T \) value for the spatial structure of Lowokwaru District is 1.11 indicating a random distribution pattern of facilities. This is because each public facility in the residential area is located unevenly, so that the resulting distance varies, namely a short distance of 2 km and a long distance of 7 km. In addition, the residential area in the north of Lowokwaru District has not been served by public facilities. Public facilities in Lowokwaru District are concentrated in Dinoyo Village and Sumbersari Village, thus contributing to the random distribution of public facilities.
B. Entropy Index

The entropy index is used to explain the consistency of the distribution of land use in an area [29]. Equation (1) is the formula for the level of land use heterogeneity (entropy value / EI):

$$EI = - \{[R1*\log(R1)] + [R2*\log(R2)] + [R3*\log(R3)] + [K1*\log(K1)] + [K2*\log(K2)] + [K3*\log(K3)] + [I1*\log(I1)] + [FP*\log(FP)] + [PK*\log(PK)] + [TR*\log(TR)] + [H*\log(H)]\} / \log(k)$$  \hspace{1cm} (1)

Information:
- R1: percentage of land use area for the single/couples/series/townhouses
- R2: percentage of land use area for the flats, apartments
- R3: percentage of land use area for the village houses
- K1: percentage of land use area for the trade and services on a city and regional scale
- K2: percentage of land use area for the trade and services at BWK and district scale
- K3: percentage of land use area for the trade and services at the urban and environmental scale
- I: percentage of land use area for the industry
- FP: percentage of land use area for the public service facilities, social facilities
- PK: percentage of land use area for the government, defence, and security facilities
- TR: percentage of land use area for the transportation facilities (terminals, stations, Etc.)
- H: percentage of land use area for the green open space
- k: the number of land use categories that have been determined (in this study, there were eleven types of land use)

3.3. Compactness Level

Gini coefficient analysis method aims to determine the inequality or gap in an area, especially Malang City. Gini coefficient is a number or index that shows spatial inequality, calculated by the Equation (2). The Gini coefficient value/index is between 0 (perfect equality) to 1 (perfect inequality) [30].

$$GC = 0.5 \sum_{i=1}^{N} |X_i - Y_i|$$  \hspace{1cm} (2)

Information:
- Xi: The value of the spatial variable. In this study, the area used
- Yi: The value of the variable to be measured is inequality (for example, buildings, population, educational facilities, social, economic, Etc.)
From the calculation results, the Gini coefficient in Lowokwaru District is 0.78. Thus, the distribution of facilities and infrastructure in the Lowokwaru District area is not evenly spread throughout the region.

Table 1. Analysis of Sustainability Level for Resilient City amid The COVID-19 Pandemic

| Planning Aspect | Lowokwaru District | Interpretation and Recommendation |
|-----------------|--------------------|-----------------------------------|
| Density         | Population Density | Medium (101.1-200 people/ha)     | Area with high density means it attracts people since it has better infrastructure and facilities. Most of experts in pandemic throughout history have proved that virus can spread through the air. Studies point out that high density means higher possibility for the virus to spread or infect people because of higher number of population and more interaction among people [8]. Working in shifts or working remotely with advancements in digital interaction during the COVID-19 pandemic can minimize the infections, but it can promotes agglomeration economies. |
| Building Density | Medium (20-40 buildings/ha) |                                     |
| Diversity       | Nearest Neighbor   | 1.11 random distribution pattern of facilities | The COVID-19 pandemic has resulted in online learning/courses, online examinations, and assignments submitted online in order not to disrupt learning. The essential facility during COVID-19 pandemics is the health facility, and the lack of health facilities may impact on physical and emotional fatigue of healthcare workers. The future for pandemic resilient cities can be reached by increasing the artificial intelligence (AI) for telemedicine-based treatment and flexible hospital design. In times of COVID-19 pandemic, the need for reachable green open spaces is increasing as people realize the role of green open spaces in mental and physical health. |
| Diversity       | Entropy Index      | 0.51 (medium diversity, where facility spreads unevenly) |                                     |
| Compactness     | Gini Coefficients  | 0.78                              | Compactness is classified as almost uneven |

4. Conclusion

The results of analysis, it is found that the structure of Malang City is included in the moderate level of sustainability in terms of resilient city amid the COVID-19 pandemic, with the description:

1. The level of population density is moderate (101.1-200 people/ha) and have a medium building density (20-40 buildings/ha).
2. The level of random diversity (nearest-neighbour value 1.1 and entropy index 0.51), where the distribution of facilities and infrastructure is unevenly distributed throughout the district.
3. Compactness is classified as almost uneven (Gini coefficient 0.78).

The higher the density in an area, the higher the possibility of the infections because there is more interaction among people. The higher the diversity in an area, the lower the possibility of the infections because it has complete facilities and infrastructure that minimize movement. Therefore, to achieve city’s resilience amid the COVID-19 pandemic, cities must reduce the density level and increase the level of diversity and compactness.

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