1. Introduction

Every human being needs comfort, especially in doing activities and living. The Indonesian Planning Expert Association (2018) provided data that in 2017, the comfort level of Yogyakarta City was 63.6. Compared to previous years, Yogyakarta's city's comfort level decreased; in 2014, it reached a score of 67.39. Some reasons for the inconvenience were that most urban residents perceived the quality of pedestrian paths to be low, that city dwellers felt insecure with disasters, that congestion got worse, that housing prices were increasingly unaffordable for city dwellers, and that they were not much involved in planning. In line with IAPI's findings, the Government of Yogyakarta City (2017) also caught urban inconvenience issues. There were four strategic issue points, namely: (1) Regional poverty and inequality, (2) Parking and traffic congestion. (3) Waste management, waste reduction, perception, and participation. (4) Green open space.

One of the areas in Yogyakarta that will be developed is the Mangkubumi area, directly connected to the Malioboro area as the main tourist area of Yogyakarta City. (Kusumawanto et al., 2019). Mangkubumi Street is planned as a bicycle park area and an expansion of Malioboro (Yogyakarta, 2012). In the Spatial Plan of Yogyakarta City from 2010-2029, Mangkubumi Street is a city lane that depicts a philosophical image and cultural heritage; image of passive tourism activities; and select areas for pedestrians (Yogyakarta, 2010). Yogyakarta's Regional Government (2018) explained that Tugu station would be developed as a TOD (Setiawan and Ikaputra, 2020). Mangkubumi area, which is located at a radius of 800 meters north of Tugu station, means that Mangkubumi area is oriented to be developed to support the TOD of Station Tugu.

To support the government's steps in realizing a comfortable Mangkubumi area as a support for the main tourist area of Yogyakarta City and to support the TOD of Station Tugu, Kusumawanto, Hartanta, and Hijriyah (2019) research the mobility level in Mangkubumi Area with the Urban Modeling Interface simulation and find the level of mobility, especially for the walkability score of 76 and the bike-ability score of 79. The score levels are less than optimal. According to walk score standards, the maximum mobility value is 100. Based on the findings in this study, Kusumawanto recommended that further research is necessary to find a model of the Mangkubumi area as a representation of the center of Yogyakarta City with a focus on maximum regional mobility. This local model can be input for Yogyakarta City Government in developing the Mangkubumi area and a reference for other mobility-based regions and cities.

Sustainable development is a development concept that integrates the natural, economic, and social environment. Haryadi and Setiawan (2002) emphasized that sustainable development has long been developed in developed countries by exploring and researching its concepts and indicators. In 2015, the United Nations held a general assembly in New York, which resulted in Sustainable Development Goals (SDGs) from 2015 to 2030. Indonesia (2017) has issued a regulation on implementing sustainable development to follow up the UN program. This is a testament to Indonesia’s active role in supporting the targeting of the Sustainable Development Goals set out in this document Transforming Our World: The 2030 Agenda for Sustainable Development.

By 2050, it is estimated that the global population will reach 9 billion people. The challenge of sustainable development is to move forward so that each can enjoy a substantial quality of life without destroying natural resources. Sustainable development aims to minimize non-renewable resources, achieve sustainable use of renewable resources, and control local and global waste (Kusumawanto and Astuti, 2014).
The continuous increase in population development and urbanization, which causes urban population density, requires attention to regulate it. The Minister of Agrarian Affairs and Spatial Planning in 2017 issued guidelines for transit-oriented area development explaining that "Transit-Oriented Development (TOD) is a concept of regional development within and around transit nodes, so there is added value focused on not only integration between mass public transport networks and between mass transit networks and non-motorized transportation mode networks but also reduction of the use of motorized vehicles accompanied by the development of mixed and dense areas with moderate to the high intensity of space utilization. "(Indonesia, 2017: 3)

In the guidelines (Indonesia 2017: 4), it is also explained that the TOD area is in a radius of 400 (four hundred) meters to 800 (eight hundred) meters from the transit node for mass transportation modes. Furthermore, Setiawan and Ikaputra (2020) support this guideline, and, from the results of their research, the land-use formula for TOD areas is 30% -60% for housing and 40% -70% for non-housing.

Morlok (1978) explained that transportation is an inseparable part of a community function. Transportation is an interpretation of the lifestyle, the range, and location of productive activities, variations, and goods and services available for consumption. Transportation plays a vital role in the development of human civilization. Transportation technology continues to develop following times. Morlok further explained that the transportation network is closely related to travel patterns. There are six transportation network patterns—grid, radial, radial ring, spiral, hexagonal, and delta.

Transportation cannot be separated from mobility. A good transportation network also ensures good mobility. The priority for mobility in environmentally friendly areas does not to use motorized vehicles. The comfort of the area for walking and cycling is measured against a standard developed by walk score. Pedestrian comfort is called walkability, and cycling comfort is called bike-ability. The method used by the walk score in determining the level is based on the location of each building, road network, and public facilities such as grocery stores, bookstores, schools, restaurants, coffee shops, and entertainment facilities (karaoke, online games, play station). The Walkscore assesses the distance of each building on the road. The distance with a maximum value of 0.25 miles (402 m) is assumed to be a 5-minute trip. The range of importance in the walk score (walkability & bike-ability) is 0 to 100. The higher the score, the better the mobility.

| Value | Explanation |
|-------|-------------|
| 0 – 24 | Car dependent |
|        | Almost all errands require a car. |
| 24 – 49 | Car dependent |
|        | Most errands require a car. |
| 50 – 69 | Somewhat walkable |
|        | Some errands can be accomplished on foot. |
| 70 – 89 | Very walkable |
|        | Most errands can be accomplished on foot |
| 90 – 100 | Walker’s paradise |
|        | Daily errands do not require a car. |

Table 1. The Range Of Walkability Value In Walkscore

Table 2. The Level Of Bike-ability In Walkscore

| Value | Explanation |
|-------|-------------|
| 0 – 49 | Somewhat Bikeable |
|        | Minimal bike infrastructure. |
| 50 – 69 | Bikeable |
|        | Some bike infrastructure. |
| 70 – 89 | Very Bikeable |
|        | Biking is convenient for most trips. |
| 90 – 100 | Biker’s Paradise |
|        | Daily errands can be accomplished on a bike. |

UMI is a software used for simulation. Thus, the performance of a city / built environment in terms of energy, land use, and accessibility can be known. Simulations at UMI include FAR (Floor Area Ratio), Operational Energy, Embodied Energy, dan Mobility (Nugrahaini, 2016; Mahendra, 2018). The importance of sustainable development, which means maintaining an ecosystem, can meet the current needs without neglecting future generations’ ability. The sustainability of a city can be measured through several parameters, namely compact (efficient land use, minimal use of motorized vehicles, good access, efficient use of resources, minimal pollution and waste, natural improvement systems, suitable housing and living environment, ecological public health, sustainable economy, the participation of community and environment, preservation of culture and local wisdom). The priority for mobility in environmentally friendly areas is not to use motorized vehicles.

The movement of everyone to change places is recommended for walking or cycling. The above description forms the basis of this research. The research to find a sustainable area model through an area model that focuses on regional mobility development is essential in supporting the government to create the Mangkubumi area comfortable for walking and cycling. The high restricted mobility indicates this.

Figure 1. Road Network Pattern
2. Methodology

The experimental method was used through simulations using computer software. The simulation object was obtained from empirical measurements with a measuring instrument to get the existing simulation conditions using the Urban Modelling Interface (UMI) software. The simulation aims to determine the level of mobility of the area. According to Jaedun (2011), experimental research based on the positivistic paradigm generally emphasizes the fulfillment of internal validity, namely by controlling and eliminating the influence of factors outside those experimented, which can affect the experiment results.

The simulation method is handy to use when a study discusses scale and complexity. Simulation research is outstanding when used to simulate actual situations and artificial conditions, both micro and macro (Groat and Wang, 2002). Nugrahaeni (2016) explained that the difference between experimental research and simulation research is simulation research in causal relationships that are usually not visible in the real world and often involve variables and interactions that are difficult to recognize precisely.

Table 3. Research Variable

| Variabel          | Parameter          | Indicator                             |
|-------------------|--------------------|---------------------------------------|
| Road Network      | Grid               | Grid Road Network Pattern             |
|                   | Spiral             | Spiral Road Network Pattern           |
|                   | Hexagonal          | Hexagonal Road Network Pattern         |
|                   | Delta              | Delta Road Network Pattern            |
| Building          | Building Identity  | The name of each building             |
|                   | Type               |                                       |
|                   | Office             | Offices, schools, places of worship   |
|                   | Retail             | Shops, restaurants, stalls, cafes, industrial places |
|                   | Residential        | Residence, hotel / lodging            |
| Mobility Amenities| Grocery Stores     | Minimarkets, supermarkets             |
|                   | Restaurant         | Restaurants, food stalls              |
|                   | Café               | Coffee shop, ankringan                |
|                   | Shopping           | Shops of Engineering supply, building, and painting |
|                   | Banks              | Banks, saving and loan cooperatives   |
|                   | Books              | Bookstore, photocopy                  |
|                   | Entertainment      | Internet Cafes, Play Station, Karaoke  |
|                   | Schools            | Play Group, kindergarten, elementary school, junior high school, high school, places of education and training |

Table 3 describes the variables, parameters, and indicators in this study. The variables used are road network facilities, buildings, and mobility. The variables used are road network, buildings, and mobility amenities. The road network is a basic pattern that functions to shape land-use patterns in an area. The building variable is the building facilities in the area. Meanwhile, mobility amenities are regional facilities that support the creation of population mobility in the region.

3. Result and Discussion

Mangkubumi area, which is located in Jetis District in Yogyakarta City, is strategic because it is north of the Malioboro area and Station Tugu. The total area of the research location is 42.8 hectares. Existing data in the Mangkubumi area as research are shown in Figure 2, Figure 3, and Table 4.

Figure 2. The ground of Mangkubumi Area

Buildings that function as residences are scattered in the middle of the area. Commercial (business) facilities are located on the site's edge, along the main roads, particularly the two main roads: Margoutomo Street and Diponegoro Street. The function of the building as residences is 77.1%. This percentage shows the proportion of the enormous...
building function. The next building function is education at 2.2%, office at 1.5%, and the smallest is worship at 0.4%. Thus, the Mangkubumi area is a residential area that also functions as a trade (business) site. Trade (business) buildings are used for shops, hotels, banks, and offices.

Previous research found findings of the level of mobility in the Mangkubumi area. In the UMI simulation, mobility consists of two analyze, walkability and bike-ability. Walkability is an analysis of regions supporting pedestrian mobility; bike-ability explores areas in people’s mobility. After the simulation, the Mangkubumi area has 76 for walkability level and 79 for bike-ability. Based on the walk score, the walkability value is 76 in Figure 5 in the range 70 – 89, which means that it is very walkable (most tasks/jobs can be done on foot). Meanwhile, the level of bike-ability is 79 (Figure 5). This value is in the range 70 - 89, which means that it is very biking (cycling is comfortable for most trips).

Table 4. the data of the function of buildings

| No | The function of buildings | Quantity |
|----|---------------------------|----------|
| 1  | Office                    | 27       | 1.5%     |
| 2  | Education                 | 41       | 2.2%     |
| 3  | Trade                     | 342      | 18.7%    |
| 4  | Worship                   | 8        | 0.4%     |
| 5  | Residence                 | 1,407    | 77.1%    |
|    | Total                     | 1,825    | 100%     |

The road network condition that connects one place to another in the Mangkubumi area consists of 4 types (Figure 4): (1) 5.1 m to 12 m wide, (2) 3.1 m to 5 m wide, (3) 1.1 m to 3 m wide, and (4) 0.7 m to 1 m wide. The first types of roads include Student Army Street, Diponegoro Street, and Margoutomo Street. The streets are a city street that consists of 2 lanes, with a boulevard in the middle. The three roads are divided into two systems, a two-way system, and a one-way system. Diponegoro Street and Tentara Pelajar Street use a two-way system. Meanwhile, Margoutomo Street uses a one-way system, from North to South.

Figure 3. The function of the building of Mangkubumi Area

Figure 4. Road Network Map for The Mangkubumi Area

Figure 5. Mobility simulation results for the Mangkubumi area

Many residents do mobility by walking and cycling. The travel time from people’s homes to public facilities (grocery, restaurant, coffee, books, schools, shopping, entertainment, and banks) ranges from 300 meters to 600 meters. A distance of 300 meters to 400 meters is still a comfortable number according to the walk score, which assesses pedestrians’ comfort level with a distance of 0.25 miles or 402 m. A distance of more than 400 m to 600 m makes pedestrians less comfortable. This affects the walkability score of 76.

Modeling is done based on the theory of road network patterns (Morlok, 1978). Morlok explained that the road network has six patterns–grid, radial, radial ring, spiral, hexagonal, and delta. This study uses four patterns–grid, spiral, hexagonal, and delta. The radial road network patterns and the radial ring are not used because they refer to the explanation of the theory that both patterns are only suitable for the central business district (CBD). The Mangkubumi area is not a central business district. Based on the building function data, the Mangkubumi area is dominant in residential areas.

Of the four patterns, each is made of 2 types, type A and type B. Type A is an area model with intervention only in residential buildings. Type B is an area model with interventions in all buildings. Thus, this study produces eight regional models, and the best model based on its mobility value was selected. The data of the regional model and its simulation results Table 5 are as follows:

Online version available at http://journal.ugm.ac.id/index.php/ajse
### Table 5. Model Simulation of Mangkubumi Area

| Model | Map of Road Network | Building Function Plan | Simulation Figure | Walkability | Bikeability |
|-------|---------------------|------------------------|-------------------|-------------|-------------|
| Existing | ![Existing Map](image1) | ![Existing Plan](image2) | ![Existing Simulation](image3) | 76 | 79 |
| I A | ![Model I A Map](image4) | ![Model I A Plan](image5) | ![Model I A Simulation](image6) | 90 | 92 |
| I B | ![Model I B Map](image7) | ![Model I B Plan](image8) | ![Model I B Simulation](image9) | 91 | 92 |
| II A | ![Model II A Map](image10) | ![Model II A Plan](image11) | ![Model II A Simulation](image12) | 90 | 92 |
| II B | ![Model II B Map](image13) | ![Model II B Plan](image14) | ![Model II B Simulation](image15) | 91 | 92 |
| III A | ![Model III A Map](image16) | ![Model III A Plan](image17) | ![Model III A Simulation](image18) | 90 | 92 |
| III B | ![Model III B Map](image19) | ![Model III B Plan](image20) | ![Model III B Simulation](image21) | 91 | 92 |
| IV A | ![Model IV A Map](image22) | ![Model IV A Plan](image23) | ![Model IV A Simulation](image24) | 91 | 92 |
A rela
efficient.
distance travel
Azmi’s opinion, Nugraheini (2016) stated that opening road
connectivity between one facility and another. In line with
that accessibility is an
finding
delta pattern
road network patterns
settlements
other facilities get
a residential area, the distance between the settlement and
the highest walkability value. With th
This statement is an
less than or equal to a quarter
distance
Impresa (2009) state
functions. The arrangement is carried out
building facilities
value is the Delta road network pattern.
the road network pattern that produces the best mobility
the Delta road network pattern. From this,
walkability value of 92 and bike-ability of 92. This model uses
the Delta road network pattern. In model IV B,
building facilities are carried out by intervening in all building
functions. The arrangement is carried out with a centralized
design where the area's center is a residential building.
Impresa (2009) stated that the maximum point is obtained if
the distance between the settlement and other facilities is
less than or equal to a quarter-mile (400 m).

There are no points if the distance is more than a mile.
This statement is an essential factor for model IV B to obtain
the highest walkability value. With the center of the area as
a residential area, the distance between the settlement and
other facilities gets closer. People who live in settlements will
find different facilities easier and quickly. Not only are
settlements in the center of the area, but another factor
supporting the high mobility value is the road network
pattern. This can be compared with other models that also
apply settlement layouts which become regional centers.

Model IV B has higher scores due to the differences in
road network patterns; therefore, it can be seen that the
delta pattern can provide a lot of access to the area. This
finding follows the opinion of Azmi et al. (2013), which states
that accessibility is an essential factor for measuring
walkability in an area. Accessibility is the key to building
connectivity between one facility and another. In line with
Azmi’s opinion, Nugraheini (2016) stated that opening road
access to several building functions can reduce the time and
distance traveled from one building to another, so it is more
efficient.

Abley & Turner (2011) state about the walkable
characteristics: connected (access network for pedestrians
related well to public transport); legible (a road network that
is easy to understand and to find on the map); convenient
(efficient route); accessible. In line with this opinion, Spoon
(2005) added that walkable elements are also formed with
continuity (design patterns and land use that unite pedestrians).
Mangkubumi area, by applying the IV B model,
will fulfill the elements of being connected, legible,
comfortable, and easy to reach. The delta road network
pattern has these elements. This can be seen clearly by
comparing the existing road network with the road network
in model IV B. The road network can connect the area with
public transportation. The road network is also easy to
understand, efficient, and easy to reach.

4. Conclusion

Mangkubumi Yogyakarta area is a strategic area in
Yogyakarta, which lies on a philosophical axis. This area is a
densely populated area with offices, education,
trade/service facilities, worship, and settlements. The
dominant land use is used for settlement (77.1%), trade
(18.7%), while the rest is for other facilities.

After the research, several findings were obtained:
a. The road network pattern that supports creating a high
level of mobility is the Delta road network pattern. This
road network pattern produces large nodes that
facilitate access within the area. Travel routes in this
area become more effective and efficient. With the
existence of these large nodes, regional accessibility
can be created well.
b. The maximum mobility value in the Mangkubumi area
is 92. This applies to both walkability and bike-ability.
Compared to existing mobility scores, a score of 92
indicates increased walkability by 16 points and bike-
ability by 13 points. This score is the highest level in the
walking score methodology. It is in Walkers Heaven's
category (daily affairs not requiring a car) and Biker
Heaven (daily experiences done by cycling).
c. The factors that influence the formation of a value of
92 are applying the Delta road network pattern and
intervention in the layout of the building function. Land
use is carried out centrally, where the center of the area
is a settlement, and other facilities are arranged on the
area’s edge.

References

Abley, S. & Turner, S. (2011) Predicting Walkability. NZ
Transport Agency Research Report 452.114 pp.
Azmi, D.I., Kaya, F., & Ahmad, P. (2013). Comparative Study
of Neighbourhood Walkability to Community Facilities
between two precincts in Putrajaya. Asia Pacific
International Conference on Environment-Behaviour
Studies. London: Elsiver.
Bappeda Kota Yogyakarta. (2017). Perencanaan
Pembangunan Kota Yogyakarta Tahun 2018.
An Improvement in The Mobility … (FA Galih Sih Hartanto et al.)

Disampaikan pada forum gabungan kabupaten/kota, 6 April 2017
Groat, L., & Wang, D. (2002). Architectural Research Methods. Canada: John Wiley and Son.

Haryadi & Setiawan, Bakti. (2002). Penyusunan Indikator-indikator Keberlanjutan Kota di Indonesia. Jurnal Manusia dan Lingkungan. Vol. IX. No. 3. November 2002, hal. 115 – 125.

IAP (Ikatan Ahli Perencanaan Indonesia). (2017). Indonesia Most Livable City Index 2017. Jakarta: IAP

Impresa, Joe Cortright. (2009). Walking the walk: How Walkability Raises Home Values in U.S. Cities. CEOs for Cities

Indonesia, Menteri Agraria dan Tata Ruang/Kepala Badan Pertanahan Republik. (2017). Peraturan Menteri Agraria dan Tata Ruang/Kepala Badan Pertanahan Nasional Nomor 16 Tahun 2017 tentang Pedoman Pengembangan Kawasan Berorientasi Transit.

Indonesia, Presiden Republik. (2017). Peraturan Presiden Republik Indonesia No. 59. Tahun 2017 tentang Pelaksanaan Pencapaian Tujuan Pembangunan Berkelanjutan.

ITDP (2013). Indicators for Sustainable Mobility.

Jaedun, Amat. (2011). Metodologi Penelitian Eksperimen. Yogyakarta: Fakultas Teknik UNY

Kota Yogyakarta. Peraturan Daerah Kota Yogyakarta No. 2 Tahun 2012 Tentang Bangunan Gedung

Kota Yogyakarta. Peraturan Daerah Kota Yogyakarta No. 2 Tahun 2010 Tentang Rencana Tata Ruang Wilayah Kota Yogyakarta

Kusumawanto, Arif dan Astuti, Zulaika Budi. (2014). Arsitektur Hijau dalam Inovasi Kota. Yogyakarta: Gadjah Mada University Press

Kusumawanto, Arif., dkk. (2019). Menuju Yogyakarta yang Berkelanjutan. UGM: Proposal Rispro

Kusumawanto, Arif., Hartanta, FA Galih Sih., Hijriyah, Linda. (2019). Tingkat Floor Area Ratio (FAR) dan Mobilitas Ramah Lingkungan pada Kawasan Mangkubumi Yogyakarta. UGM: Penelitian Studio Riset 2.

Morlok, Edward K. (1978) Pengantar Teknik dan Perencanaan Transportasi. Jakarta: Erlangga

Nugrahaini, Fadhila Tri. (2016). Titik Nol Kilometer Yogyakarta Menuju Pusat Kota Yang Berkelanjutan Melalui Simulasi Urban Modelling Interface (UMI). Tesis S2 Teknik Arsitektur Jurusan Teknik Arsitektur dan Perencanaan Fakultas Teknik Universitas Gadjah Mada.

Setiawan, Agus & Ikaputra. (2020). Tipologi pengembangan kawasan berbasis transit di kawasan station Maguwo, Yogyakarta. Jurnal Arteks. Vol. 5 – 402

Spoon, Steven Chadwick. (2005) What Defines Walkability: Walking Behavior Correlates. A Master of Regional Planning of the University of North Carolina

Yogyakarta, Pemerintah Daerah. (2018). Pemda DIY Sepakat Kembangkan Station Tugu Berbasis TOD https://www.jogjaprov.go.id/berita/detail/pemda-diy-sepakat-kembangkan-station-tugu-berbasis-tod. Diakses: Senin, 09 September 2020

Yogyakarta, Pemerintah Kota (2017). Isu Strategis Kota Yogyakarta.