**DIMENSI**: Journal of Architecture and Built Environment, Vol. 47, No. 2, December 2020, 71-86 DOI: 10.9744/dimensi.47.2.71-86
ISSN 0126-219X (print) / ISSN 2338-7858 (online)

# URBAN GEOMETRY: CITY SHAPE AND SPATIAL LAYOUT OF 6 INDONESIAN GOVERNMENT CENTERS

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## ABSTRACT

Indonesia is one of the fastest-growing countries. It has about 50% of the population in the ASEAN region. The country is currently evolving and changing. The recent highlight is the country's plan to create a new capital city – moving from the megalopolitan Jakarta in the Java island to a new remote area in East Kalimantan. However, research on Indonesian cities remains very limited to provide an evidence base for planning a new capital city. A fundamental question arises: Should we plan Indonesia's new capital city following western models, or should we plan the city using traditional Indonesian city patterns? This paper examines urban geometry to show similarities and differences in the government centers in 6 Indonesian provincial capitals. They are Jakarta, Bandung, Medan, Palembang, Surabaya, and the Special Region of Yogyakarta. The six capital cities will be analyzed and categorized using street grid patterns, street centrality, built-up area and open space distribution, and government center distances. This systematic and quantitative comparison of Cities will define the underlying traits and footprint in these Indonesian cities, and the findings could be considered suggestions and guidelines for the new Indonesian capital city. This study utilizes methods and measures using automation techniques to analyze and classify Indonesian government centers based on street networks and urban geometry. The methods include land use recognition techniques using satellite images; OpenStreetMap (OSM) processed using OSMnx; GIS multi-platform applications to run the spatial analysis. On the one hand, the study should contribute to urban design and capital city planning in Indonesia. On the other hand, it should provide methods for comparative studies of cities in developing countries.

**Keywords**: Government centers; urban geometry; street network; geometric and network centrality.

## INTRODUCTION

In 2019, The Indonesian government decided to move Indonesia's capital city from Jakarta to a more remote location in *Kutai Kertanegara* and *North Penajam Paser* in Kalimantan. Changing the capital location was a bold decision, but it was deemed necessary due to extensive problems that Jakarta has as a megalopolis. These problems include, but are not limited to, environmental pollution, traffic congestion, annual floods, and also the fact that Jakarta is one of the fastest sinking cities in the world(Kimmelman, 2017; LYONS, 2015). Indonesian capital relocation from Jakarta to Kalimantan indicates an extreme change from a Megalopolis city with a complex shape and layout to a new empty environment located on a remote island.

The design for the new Indonesian capital was selected through a national architecture and urban design competition. The winning project was based on the concept of "*Negara Rimba Nusa*," which roughly translates as "forest and island hilltop." The Indonesian archipelago inspired the project with unity in diversity as the central theme[1]. Nevertheless, one wonders if a research-based understanding of Indonesian cities' urban geometry, especially Indonesian government centers, could have prepared Indonesian urban designers better for such a nationally significant competition. In many cases, capital cities are shaped by physical and political, technological, and economic forces (Gordon, 2006). In this regard, existing capital cities can provide valuable information about these forces and the nature of urban centrality and resiliency of these cities as government centers. Therefore, learning about existing capital cities may provide valuable knowledge for designing a new capital city (Gottmann, 1985).

Therefore, this study aims to study the shape and spatial layout of several Indonesian provincial capitals describing their symbolic contents, hierarchical relations, and structural patterns. It is hoped that such a study would help us understand and explain the physical, functional, historical, morphological, psychological, and/or sociological significance of these cities in the Indonesian context (Rashid, 2017).

### Analysis of Urban Morphology

This study used a sample of 6 prominent Indonesian cities—Bandung in West Java, Jakarta, Medan in North Sumatera, Palembang in South Sumatera, Surabaya in East Java, and Yogyakarta in the Special Region of Yogyakarta. The study

[1]An International scale competition with 755 participants. The competition winner concept "*negara rimba nusa*" source: https://www.thejakartapost.com/news/2019/12/23/nagara-rimba-nusa-announced-as-winner-of-new-capital-city-design-contest.html

considered each city in its entirety and an area of twosquare-miles around the government center of each city. The study included various properties of the street grid, street centrality, built-up area, open space distribution**,** and the relationship of the government center with the geometric center in each city and city area. The study then compared these cities and city areas based on historical, functional, and demographic differences.

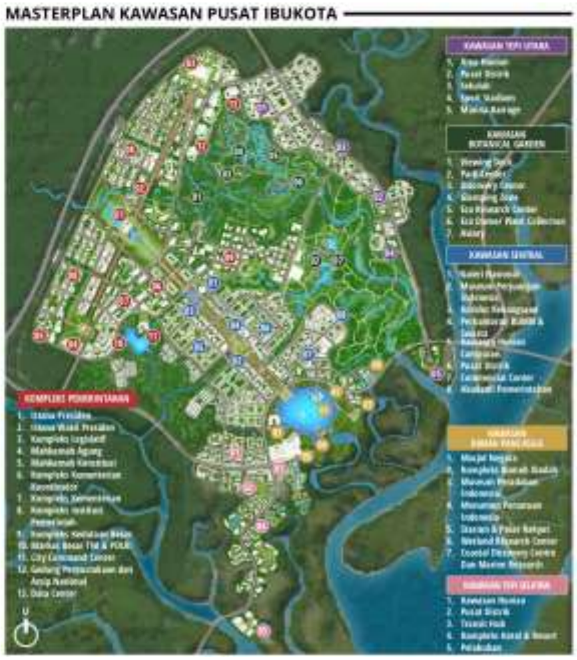


**Fig. 1.** Masterplan of Indonesia new capital winner – concept "negara rimba nusa" (Source: property.kompas.com)

Street grids and street orientations are essential, for they help us understand the degree of coherence in city shape. They can also provide a broad idea of how the navigation system works in a city (Boeing 2019). Street centrality is important because it can reveal the hierarchical organization of street networks. It is also useful for predicting human activities in urban areas (Hillier, 1996; Jiang, 2009). Built-up areas and open space distribution are important to understand urban patterns (Langford, 1991; Li & Weng, 2005; Lu, Weng & Li, 2006; Wu & Murray, 2007; Yuan, Smith & Limp, 1997). Finally, to understand the relationship between city centers and geometric centers, the distance between geometric centers and government centers are measured. It is assumed that urbanity at each center will decrease with increasing distance.

### *Open Street Map and OSMnx*

To study urban network, Open Street Map (OSM) has been a useful resource for up-to-date and actual vector street maps of the entire world. It is a collaborative mapping project for free, editable maps. The OSM project started in 2004 and has grown to over two million users today. The OSM imported the 2005 TIGER/Line (Topologically Integrated Geographic Encoding and Referencing system) roads as base data (Zielstra, Hochmair & Neis, 2013). The TIGER map was a public domain data source provided by the US Census Bureau. There have been corrections and improvements to the open-source data, and research has shown that the accuracy of the map and data quality is quite high(Haklay, 2010; Barron, Neis & Zipf 2014; Girres & Touya, 2010). The OSM is continuously corrected and improved. Beyond TIGER/line files, the OSM includes pedestrian paths, passageways between buildings, bike lanes, and routes. It has richer attributes of data describing the characteristics of features such as the classification of arterial roads, collector streets, residential streets, alley, parking lots, etc.

With the advances of the internet, the availability of big data and open data has become convenient. Many tools can be used to extract this data (Bennett, 2010), and python programming language has given technologies and benefits for this research. OSMnx is one such platform. It uses a python programming language that allows researchers to download street networks from OSM data to analyze and visualize the street grid (Boeing, 2017). OSMnx gives a researcher the ability to better understand the spatial order, the street network orientation, and configuration and calculate entropy's value for a given street network (Boeing, 2019).

### *Natural Street and Space Syntax*

Street centrelines from OSM can be further utilized using GIS-based software to analyze the network properties. Connectivity and street nodes are analyzed and calculated using *space syntax*(B. H. Hillier and Hanson 1984) to define the relationship between space and society. Axial line and axial segment are the popular topological model that represent linear spaces in the urban environment. Recently, improving efficiency and ease of use line-segment maps and natural-street maps have been used as alternatives for axial maps in space syntax analysis (Stavroulaki et al., 2017).

Natural streets are joined road segments based on the gestalt principle of good continuity. Available techniques use a 45-degree threshold to define continuity from one street segment to another (Jiang, Zhao & Yin, 2008). Studies show that space syntax analysis based on natural-street methods is an excellent way to understand traffic flow and movement on street networks (Xia, 2013).

Using ArcMap 10.4 and Axwoman 6.3 (Jiang, 2015), this research uses the natural street method to understand the potential for human use in the six government street centerline to run the analysis. For this study, the analysis of street centrality in natural street systems is done using global integration, local integration, and street connectivity indicator values of space syntax.

In space syntax, global integration defines the integration pattern on a large scale; local integration defines the integration pattern for a certain radius, and connectivity defines the number of streets directly connected to a street. The integration is a measure of syntactic accessibility - high integration value indicates high density and movement in urban areas (Hillier, 2007; Hillier & Hanson, 1984). This study uses these measurements to reveal any hierarchical network patterns in the 6 Indonesian government centers' spatial layouts.

### *Built Up Area and Open Space Distribution*

This paper's Satellite images are taken from SAS-Planet, a multi-satellite application that uses Google, Bing, and Landsat images. This study uses the rational linear regression method, and the linear spectral mixture analysis is used to estimate impervious surfaces (Wu & Murray, 2003). The study also uses the VIS (vegetable, impervious material, and soil) model to determine the greenness component from ETM+ images. The method allows us to distinguish land use with five different groups of land uses into land grass, residential, trees, roads, mixed urban built up, and water, which can then be used to have a clear ratio between built-up area and open space in each city.

### *Relationship of Government Center and Geometric Center*

The phenomenon of political relationship with the urban growth could be revealed by looking at the relationship between government-buildings core, the distribution of other public functions, and the city's spatial structure. The government center represents the highest level of political hierarchy in the city and could also dictate the city's hierarchical spatial structure. The relationship between the government center and the syntactic core has been studied and highlighted using several morphological frames (Rashid & Shateh, 2012). This relationship and spatial characteristics can be examined from the city's historical morphology and political impact and revealing the distribution of spatial and functional morphology of the city. A study has also shown a correlation between government buildings' distribution, syntactic core, and intense urban growth. The overlapping between the syntactic core with governor's place will result in the high development and growth in the government core (Shateh & Rashid, 2014).

The measurement of the government center distance related to the present syntactic core of every study area reveals every city's growth. The city's initial urban planning tends to associate the political center as the syntactic core, but over time, the city will grow. The growth of the syntactical properties will show the urban development distribution of the city. The further the syntactical core shifted from its political core shows an even distribution of the city. At the same time, the closer of those two components will result in a high intensity of urban development.

## METHODOLOGY

The methodology used in this research is mix method analysis and map overlay using the map of the whole city as well as a two-square-miles comparative study between the case studies. The main analysis is to understand the 1). geometric properties of the case studies, 2). the overall socio-demographic factor in Indonesian cities and 3). the study of city shape and spatial layout. The city shape and spatial layout consists of 5 parts including A). street grid, B). street centrality, C). built-up area, D). open space distribution, and E). pattern in the geometric center of each case studies. This is an exploratory research to find the similarities and differences between the case studies.

## RESULTS AND DISCUSSION

### Analysis of Geographic factors

The 6 Indonesian cities are chosen because of their importance in Indonesian history, population size, and administrative significance. Table 1 shows some necessary information on these cities. Each of the cities included in the study has a population higher than four million people in a combination of the urban and metro areas. Each city in this study is also mentioned in the World Cities 2018, which has a high average of Annual rate change of 1.0 percent. Each city will have a significant increase in expectations from 2018 – 2030 of the city's urban population proportion (Nations, 2018). From table 1, we could understand the city density by the data measurement that is showing the size of urban and metro areas in square-kilometer. The population column in Table 1 is the number of people residing in the city's urban area. In contrast, the population metro is the number of people in the surrounding area, labeled as the metro area. The two populations data is from the 2016 Indonesian census, and it is showing the size and density of the study areas.

The six cities of the study fall into two categories, large metropolitan, and megalopolis. The metropolitan cities are Bandung, Medan, Palembang, and Yogyakarta, whereas the two megalopolises are Jakarta and Surabaya, where the urban and metro area's total population exceeds 10 million people. Even though the city of Yogyakarta's urban population is only 422,732, the metro population of Yogyakarta is very high, 4,010,326, according to Indonesia census data in 2016. We could see that Bandung, Jakarta, Surabaya, and Yogyakarta are highly dense cities with population densities of over 10,000 persons per square kilometer. In comparison, two other cities in the study area of Medan and Palembang have a lesser population density of 8,410 and 3,999 persons per square kilometer. Although Jakarta has the highest density in the urban and metro area, the intensity for population density is followed by Bandung, Surabaya, and Yogyakarta (Table 1).

In addition, to describe the six study areas' demographic conditions, this study also includes the geometrical topological properties of the street network shown in Table 2. The spatial metrics in this study describe the total length of the street, mean length of street, the maximum length of the street, and the total number of street segments. The correlation of spatial metrics was analyzed in correlation to determine the linear spatial density of the six study areas. The linear density in this study is useful to examine the neighborhood density of the study area. The street's total length describes the sum number of street network and shows the amount of coverage of the street network in each city. The mean length of the street is the total length of streets divided by the number of available streets in each city and an indicator of the spatial dimension of movement. In opposition to the mean length, the maximum length of the street network reveals the street network type; the longer the street's length indicates the availability of highways in the city. The total number of the street segment is an indicator of quantifiable intersections related to movement choices and urban blocks.

A high number of street segment provides a high number of street connectivity among the street network. These geometrical properties provide information for the city's linear density better understand the correlation between population density and linear density of the study area. The finding shows that Jakarta has the highest linear density of streets, followed by Bandung, Yogyakarta, Medan, Surabaya, and Palembang. The linear density of streets metric in Palembang is far lower than any other city, indicating that it has more room for urban development. While the whole city's density is clear, the topological value of the government center could have very different geometrical properties.

## Analysis of Socio-economic and Demographic factors

Indonesia is the largest Muslim country globally, a nation home to 12.7% of the world's Muslims, with an overwhelming majority of around 90% of the Indonesian population are Muslims. The spread of

**Table 1.** A Description of the Morphological Elements of the 6 Indonesian cities

| City | Province | Population | Population Metro | Area Urban ($km^2$) | Area Metro ($km^2$) | Density ($km^2$) | Metro Density / ($km^2$) |
|---|---|---|---|---|---|---|---|
| Bandung | West Java | 2,575,478 | 8,201,928 | 167.31 | 1876.8 | **15,393** | 4,370 |
| Jakarta | Indonesia capital | **10,075,310** | **31,689,592** | **662.33** | 6392 | 15,212 | **4,958** |
| Medan | North Sumatera | 2,229,408 | 4,601,565 | 265.1 | 1991.1 | 8,410 | 2,311 |
| Palembang | South Sumatera | 1,602,071 | 3,547,474 | 400.61 | **7586** | 3,999 | 468 |
| Surabaya | East Java | 3,457,409 | 13,123,948 | 326.81 | 5925 | 10,579 | 2,215 |
| Yogyakarta | Special Region | 422,732 | 4,010,436 | 32.5 | 2159.1 | 13,007 | 1,857 |

**Table 2.** A Description of the Street Network Properties of the 6 Indonesian Cities Study Areas

| City | total length of street | mean length of street (meter) | maximum length of street (meter) | total number of street segment | linear street density |
|---|---|---|---|---|---|
| Bandung | 2,949,956 | 69.81 | **8007** | 42253 | 17.63 |
| Jakarta | **12,533,903** | 73.13 | 6908 | **171379** | **18.92** |
| Medan | 4,160,857 | 72.1 | 7292 | 57704 | 15.70 |
| Palembang | 2,155,230 | **113.18** | 6004 | 56117 | 5.38 |
| Surabaya | 4,639,693 | 82.35 | 7816 | 56341 | 14.20 |
| Yogyakarta | 569,330 | 84.2 | 2099 | 6761 | 17.52 |

Islam in Indonesia was believed to be originated from Gujarat, India. Since the 16th century, Islam has quickly risen and adapted to Indonesian culture and earlier religious beliefs. Hindu and Buddhism once dominated the Island of Sumatera and Java as the earlier religion in Indonesia, but the majority converted to Islam. Bali is the only island in Indonesia that has kept the majority of Hinduism, while the eastern part of Indonesia was adopting animism but later influenced more by Christianity.

The socio-economic and demographic factors have influenced the transformation of Indonesia's modern architecture. The historical aspect of transplant, adaptive, and hybrid architecture in Indonesia is highly influenced by religion, culture, trade, and commerce (Widodo, 2009). There are three stages of demographic, historical changes in Indonesia that happens before the modern era. The first stage occurs around the 13th century; there were trades between the region with Indian and China. Trade was proven by the use of Sanskrit languages and the use of Chinese coins and currency as the primary means of commerce. The second stage was the protomodern stage that happens in the 15th and 16th centuries. This stage shows the hybrid between Islamic beliefs and values with those of Hindu cosmology. Islamic mosques in Indonesia were designed to combine these two religious ideas as an adaptive method to spread Islam in Indonesia culturally. The third stage is the Colonialism and European influenced by the spice trading in the 16th to 18th century. European architecture was brought to Indonesia and was then adapted to the tropical climate, high humidity, and temperature profoundly influenced the architecture form. The third stage of Colonialism in Indonesia was very influential, and not only it affected architecture and city planning, but it also shaped the socio-cultural and created a hybrid between European and local architecture.

Indonesian architectural has been influenced by global ideas but also derived and adapted with a strong locality. Influenced by trade, travelers, Colonialism, modern ideas from the European continent has shaped a strong trait and similarity in universal architectural style. But under that global influence, the socio-economic and demographic factors also played an essential role in shaping how people lived in Indonesia. Local and small economic commerce has been a tradition in the Indonesian trade and is supported by the Islamic beliefs that trade is a dignified profession. Historically, this has been shown that Indonesian stilt houses near the river are a practical location for trade while using boats as the primary means of transportation. The micro-economic trade continues today but later on the site and means of trade diversified, adapting, and hybrid with other microeconomic conditions.

Demographically, Indonesia's current population is 272,858,643 people and equivalent to 3.51% of the total world population[2]. Indonesia has an average yearly growth of 2.25% in the population. Currently, Indonesia is number four in the most populated country globally, but with this increase, it is expected that Indonesia will have the same population as the United States in the next 30 years. With the changes in population, surely it will have a various demographic impact. One of these will influence the number of Muslim populations shown on (Figure 1), The largest Muslim populations will change drastically, and it is expected that in the future, Indonesia will no longer be the largest Muslim country (Center, 2015). The urban designer should take note of the fact that demographical differences could affect the morphological features in Indonesian cities, among those affecting the public center, land use pattern, street flow, and other characteristics. This correlation could provide an intangible impact, and there is a need to study the relationship between evidence-based urban design planning in the future.

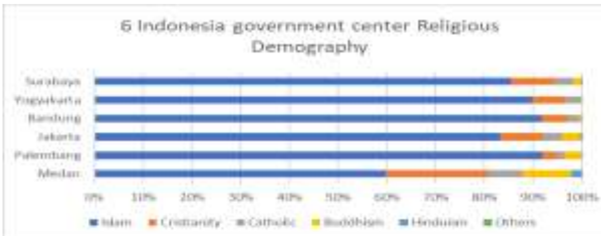


**Fig. 2.** Study Area of the 6 Indonesian Government Religious Demography.

## City Shape and Spatial Layout

### *Street Grid and Angularity*

The study of street patterns in government centers uses the typology of Southworth and Owens. They are *speculative gridiron*, *interrupted parallel*, *incremental infill*, *loops*, *and* lollipops (Southworth & Owens, 1993). This study uses the two-square-miles area of the government center, shown in Figure 2. According to the figure, Jakarta, Medan, and Surabaya have a *hybrid gridiron* pattern, while Bandung, Palembang, and Yogyakarta have the *incremental infill* pattern. The finding confirms the finding reported in a previous study indicating that Asia and Oceania cities show *Hybrid Gridiron* and *Incremental Infill* patterns (Louf & Barthelemy, 2014).

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[2] Source:https://www.worldometers.info/world/population/indonesia-population/ accessed on April 7th, 2020 1.00 pm

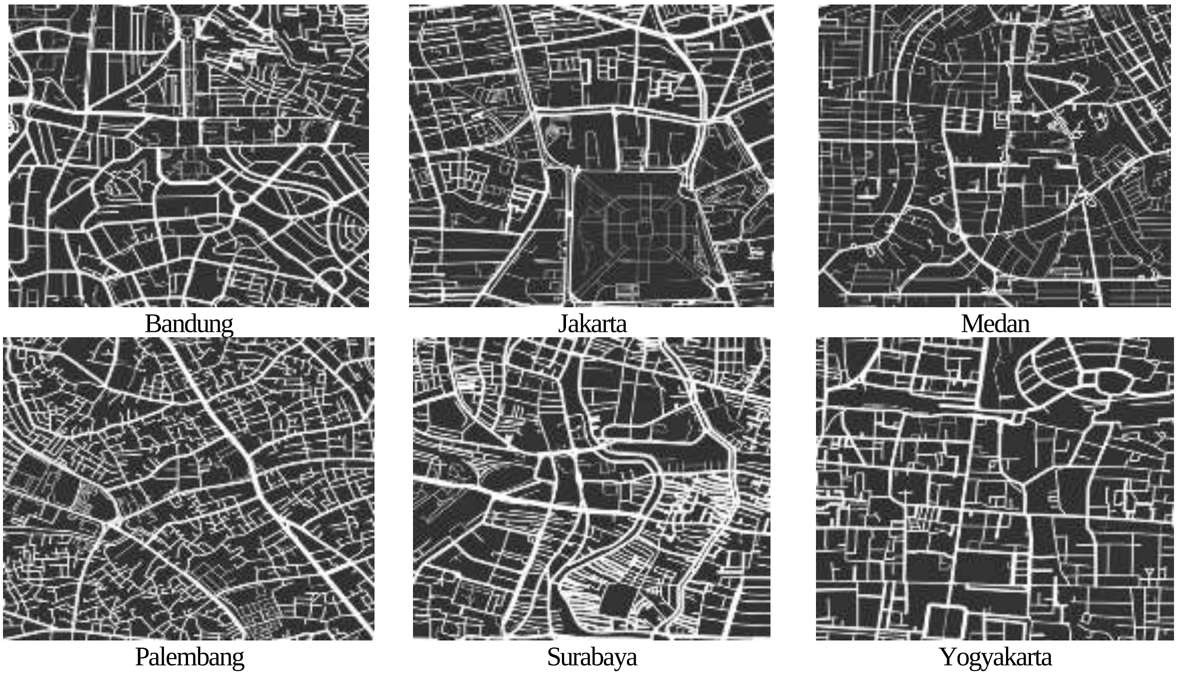


**Fig. 3.** Street Pattern and Spatial Layout of the 6 Indonesian government centers. The government center / government office is located at the center of the two-square-miles map.

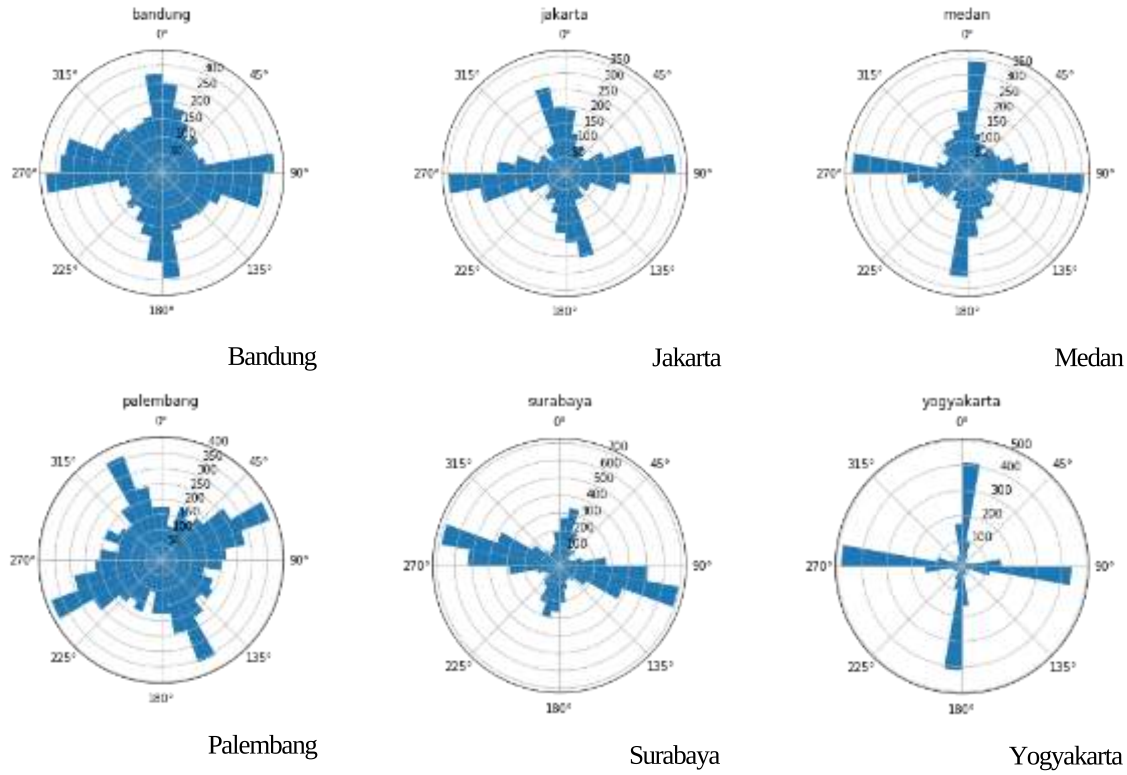


**Fig. 4.** Street Angularity to determine the street grid value of the 6 Indonesian government centres.

The black and white map block shows primary and secondary street using the bolder white line, while the slightly thinner lines indicate the tertiary road system and pathways. The hierarchical combination of the street network from the study areas in some way is showing the topological layering as a result of movement and network transformation. Visually we could see that Jakarta has a robust formal design, with a centric pattern in the center and surrounding facilities circling the open space. Other cities such as

Bandung and Yogyakarta are also showing a smaller centric pattern where the government center or governor office has an open space known as "*alun-alun*[3]" located at its center.

Figure 3 shows the grouping of street lines into 360 degree's polar histogram bins; this method is a simple way to understand the street grid network's entropy value. We can see that the city with the most grid street angularity is Yogyakarta from the polar histograms. This was reported in a previous study comparing street angularity and patterns in Palembang and Yogyakarta (Romdhoni and Rashid 2019). According to these diagrams, a grid pattern defined by north-south and east-west streets is present in Yogyakarta's street system. While in Surabaya, streets have a predominant east-west orientation. The other polar histograms indicating a grid-like pattern is apparent in Jakarta and Medan, while an irregular street orientation pattern appears in Bandung and Palembang. The irregular street pattern in Bandung and Palembang suggests that the city might have grown more naturally than the others.

Urban Design Suggestions: The finding shows a grid and less grid angular shape in the government center, but incremental fill and hybrid gridiron street patterns are equally evident in all the study areas. The urban development and urban form adaptation to changes will be very important to maintain the city form and initial design. In the case of the Indonesian context, the planning for the government center shows a correlation between the government's core grid shape with the street pattern development of the entire city. The study area's street pattern transformation has been shaped into a certain degree of the street grid. However, there could be other factors in play that could affect the skew angle of the street grid pattern, i.e., geographical, conceptual, intangible. The similarity from four out of six study areas is an essential finding that a certain formality of grid pattern and high entropy value grid is a government center trait. The study area's urban street grid transformation is physical adaptation and hybridity so that the government center is functioning as it is today. Future design for the government center needs to be carefully planned and better understanding the importance of the formal street grid form for the capital city. Further study and more sampling in Indonesian cities needed to be initiated to reveal more traits and spatial pattern footprints in Indonesian cities' street grid and angularity.

[3] *Alun-alun* is a large, central, open lawn / land grass square, common to villages, towns, and cities in Indonesia. In modern-day Indonesia, it is referred to the open squares for *kraton* palace compounds

***Street Centrality***

Global Integration, Local Integration, and Connectivity are being used to describe the street centrality from these study areas. Global integration was measured for a 26km x 26km area in each city comprising both urban and metro areas to get a clear understanding of the city size. The whole city street centerlines were extracted from OpenStreetMap and providing coherent city shapes. Figure 4 is providing information with a layer of red and blue lines. The blue lines are low closeness street networks, while the red lines are streets that inherently attract more movement because of their high syntactical accessibility. The red lines in Jakarta, Medan, Surabaya, and Yogyakarta apparently has a grid network, while the red lines in Bandung and Palembang are a more natural and centrical pattern. Interestingly, this finding shows a correlation of grid pattern between the two-square-miles government center with the street integration of the whole city.

On the other hand, Figure 5 shows Global Integration, Local Integration, and Connectivity of the two-square-miles from the Indonesian government center's 6 study areas. In the Global Integration map displayed by the red lines, we could see that Bandung and Palembang have a centric street network integration, with the outer ring street network. In contrast, Surabaya has a dispersed linear integration. Jakarta, Medan, and Yogyakarta are showing a strong grid-like Global integration pattern. The Local Integration map column in Figure 5 shows the hierarchy of street network integration, locally for the two-square-mile. The evidence from this map is manifesting that Jakarta, has a dynamic and connected integration represented by the red lines, while the other cities are visibly showing scattered integration. This local integration confirms that the Jakarta government center's design is more contained and less radical changes compared to the other study areas. The connectivity column in Figure 5, the connectivity value of each study area government centers are located in the street with high connectivity (red line). Although street network growth and experienced morphological changes, the study area consistently places the government center in the highest integration and syntactic accessibility. The intelligibility analysis (Table 3) shows the association between local and global integration values in a street layout. A Strong linear correlation generally indicates that street connectivity can better predict global accessibility. The intelligibility value of the six government center study areas is relatively similar. Medan and Yogyakarta, which has a hybrid gridiron and a strong street

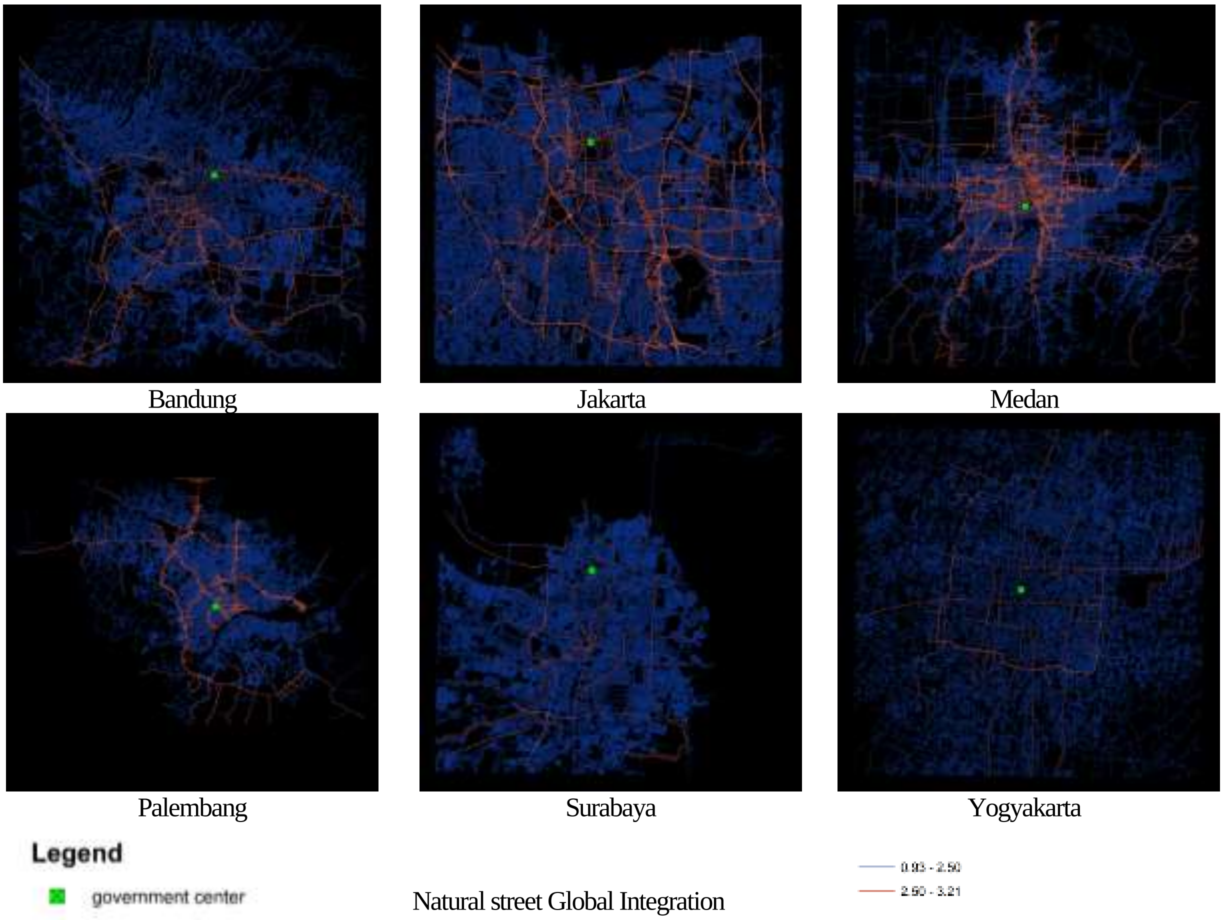


**Fig. 5.** Global Integration Rn. of the whole urban and metro area for the 6 Indonesian cities (Bandung, Jakarta, Medan, Palembang, Surabaya, and Yogyakarta).

grid, show a slightly higher intelligibility value of .330 and .321, respectively. Surabaya has the lowest intelligibility value .185, indicate a low value for a cognitive understanding of the street network. Both hybrid gridiron and incremental infill are showing the high number of local integrations.

**Table 3.** Correlational Coefficients of Intelligibility Value and Mean Syntactical Measures for the 6 Government Center of the Study Area

| City government center | Intelligi-bility | Mean Global Integration | Mean Local Integration | Connectivity |
|---|---|---|---|---|
| Bandung | .238 | 1.49 | 2.16 | 3.26 |
| Jakarta | .291 | 1.77 | 2.32 | 3.40 |
| Medan | **.330** | **1.99** | 2.45 | 3.44 |
| Palembang | .293 | 1.75 | 2.03 | 2.85 |
| Surabaya | .185 | 1.86 | **2.55** | 3.10 |
| Yogyakarta | .321 | 1.69 | 2.23 | **3.41** |

*Urban Design Suggestions*: From the two-square-miles study areas, the correlation value using Rn for global integration, local integration, and natural street connectivity shows similarities value and pattern (Table 3 and Figure 5). Street centrality in this study is showing the high correlation between a high connected street network with the government center. This study's finding and value could be used as a quantitative result for the new government center design to avoid a massive difference in shape and spatial layout. This consideration for centrally distributed street network patterns for future cities will be necessary.

### *Built Up area*

This study uses OSMnx to identify the building plot patterns and sizes to describe the built-up areas. This plot layout shows not only the density but also revealing the characteristics of Indonesian government centers. Despite the missing building plots in parts of Medan and Palembang map, the availability and quality of Indonesian OpenStreetMap data. By comparing the output map, with other satellite images, such as google map or Bing map, we could conclude that the missing building plots mostly comprise small landed housings with high density. The government

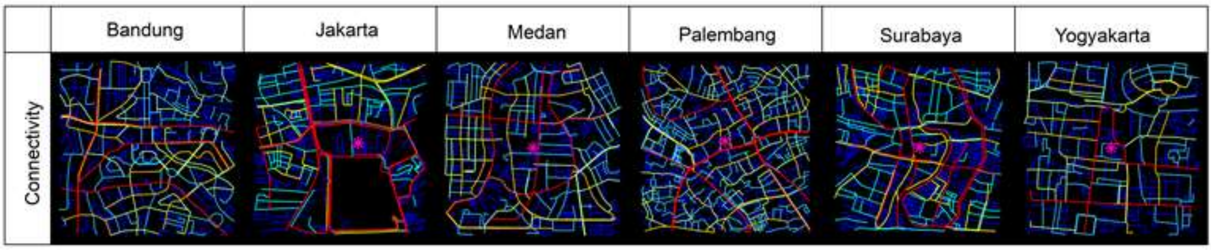


**Fig. 6.** Global Integration, Local Integration and Connectivity of the two-squared-miles Government Center of the 6 Study Areas in Indonesia.

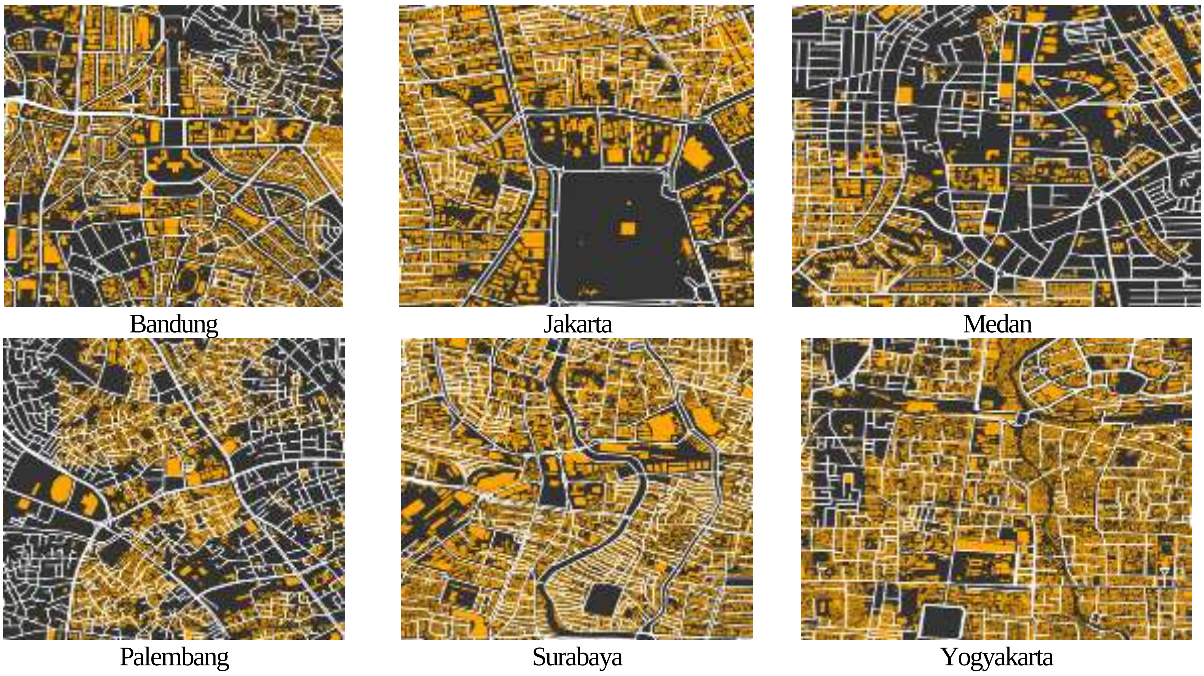


**Fig. 7.** Land Use Pattern of 2-square-miles Area at the 6 Government Centres Study Area.

**Table 4.** A Description of the Street Network Properties of the 6 Government Centres of the 2-square-miles Study Areas

| City gov center | linear density | total length of street | mean length of street (meter) | maximum length of street (meter) | total number of street segment | area size of 2 sq miles in (km2) |
|---|---|---|---|---|---|---|
| Bandung | 19.88 | 102973 | 76.5 | **855.86** | 1346 | 5.17998 |
| Jakarta | 19.43 | 100671 | 81.58 | 655.77 | 1234 | 5.17998 |
| Medan | 20.16 | 104420 | 70.98 | 385.5 | 1471 | 5.17998 |
| Palembang | **23.68** | **122660** | 58.91 | 562.7 | **2082** | 5.17998 |
| Surabaya | 23.27 | 120555 | 68.26 | 590.6 | 1766 | 5.17998 |
| Yogyakarta | 15.96 | 82649 | **85.11** | 457.18 | 971 | 5.17998 |

center in Figure 6 is precisely located at the center of the two-square-miles map. The building plots size in the government centers in the study areas indicates a mixture of residential housing with more significant buildings with mixed-use functions. Bandung and Jakarta government centers are surrounded by other governmental institutions, while Medan Palembang, Surabaya, and Yogyakarta are mixed with other commercial functions such as Supermalls and privately own shops.

Measurements of the street network properties from Table 4 reveal the density of the built-up areas. The result of linear density shows that Bandung and Jakarta, with the designed governmental center, have an average percentage of linear density with 19.88 and 19.43. Except for Yogyakarta that has the lowest density of 15.96 and the fewest number of street segments, these findings reveal that the Special Region of Yogyakarta is indeed different from the other study areas. Another valuable finding is that the provincial capital cities of Medan, Palembang, and Surabaya linear density are highly affected by the mixture between government centers and residential housing. This reliable indicator shows that Medan, Palembang, and Surabaya provincial capitals have a high total length of the street, a short mean length of the street, and the high number of the street segment. These three cities likely have more intensity of urban development on the government core.

*Urban Design Suggestions*: The built-up area's spatial metrics suggest that it will be logical for future Indonesian capital city to avoid long highways in the government center and the street length will not exceed longer than 800 meters. The study revealed that Indonesian government centers have a range value of linear density that resulted from the correlation of street length and study area size. According to this study, the similarity in density is a result of the underlying urban development in each of the study areas. This density and closeness trait should also be applied to the new capital city to reduce a contrast change and difference of the spatial metrics.

***Open Space distribution***

The open space distribution has been an essential policy in Indonesian cities. Since 2007, Indonesian cities should provide at least 30% ROS / Ratio of Open Space, according to *UU no26 Tahun 2007 tentang penataan ruang*[4]. In the open space distribution study, we separate the land use into six different categories (land grass, residential, trees, road, mixed urban built-up, and water) acquired from Satellite images and processed using GIS. According to the Land Cover Land Use map of the study area, the finding shows two distinctive government center, map groups. The first would be a map showing many distributed green spaces, while the second is showing the scattered distribution of residential and mixed urban built-up in the two-square-miles government center study area (Figure 7).

The distributed green areas in Bandung and Medan are composed of green strips with continuous green spaces while Jakarta shows concentrated and centralized greenery. On the other hand, the second

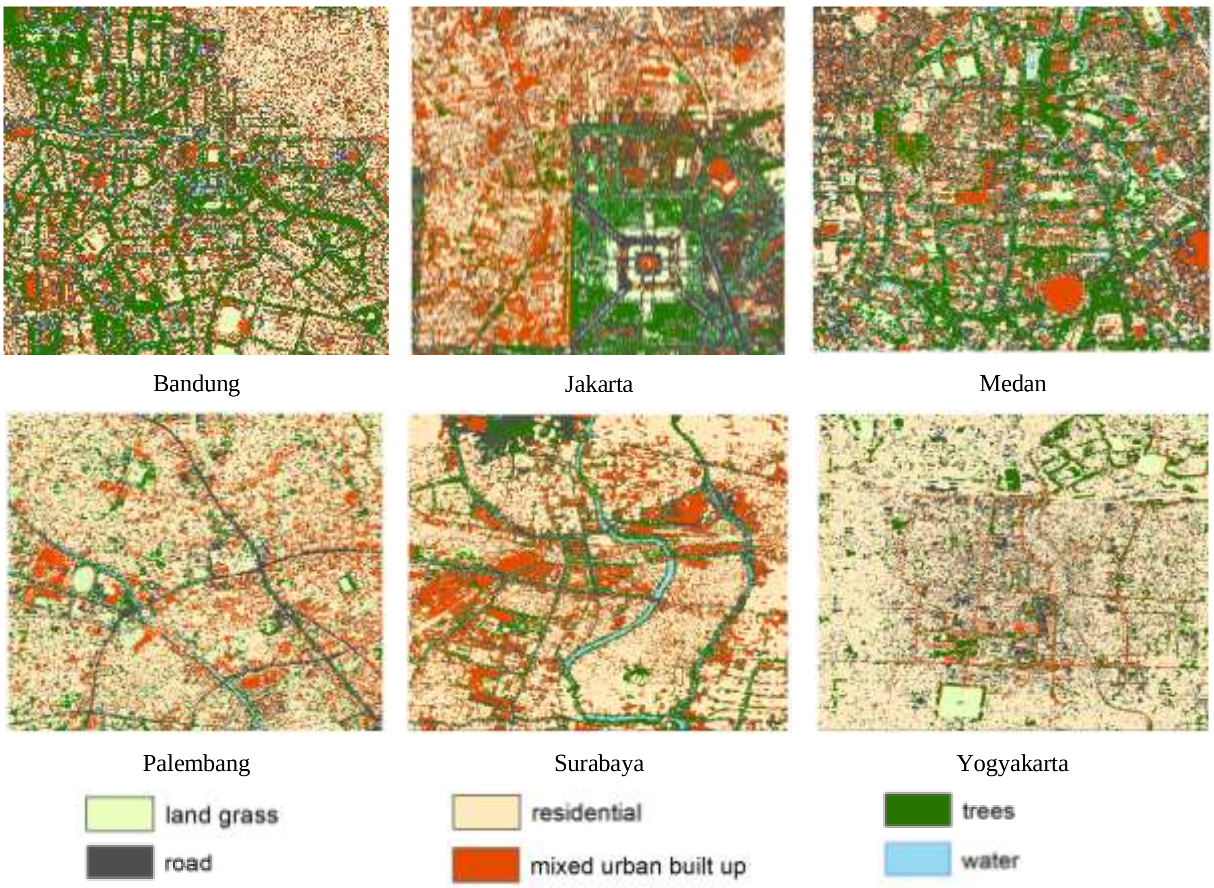


**Fig. 8.** LULC / Land Use Land Cover map of the 6 Indonesian Government Center.

[4] Indonesian Law that regulates spatial planning, source: https://www.atrbpn.go.id/Publikasi/Peraturan-Perundangan/Undang-Undang/undang-undang-nomor-26-tahun-2007-1849

group of Palembang and Surabaya shows a map with less green trees and land grass areas, scattered and patches around the government center. In comparison, Yogyakarta shows patches of land grass areas but less volume of trees and dominant residential areas in the government center. The finding indicates that Palembang has the most significant ratio of land grass open space compared to other cities with 12,41%. In comparison, Medan and Surabaya show a tiny percentage of land grass open space with 2.87% and 2.08%, respectively (Table 5). The ratio of land grass open space in Palembang indicates that the government center is less intensely developed than the other government centers. The other study areas also show that the land grass open space ration could be decreased during the time, showing more intensity in the government center development. However, the trees map in the city shows a stark contrast, where Bandung and Medan are showing a ratio of 23.36% and 24.62%, respectively. Jakarta and Surabaya have a ratio of trees space with a percentage of 14.89% and 13.93%, while Palembang and Yogyakarta have 8.27% and 8.47%. The trees map in this finding will be affected by the condition of seasons and the satellite image's vegetation condition. Still, the result shows that Bandung and Medan government center has more nurtured vegetation than the other government center.

Table 5 also shows the ratio of residential, road, and mixed urban built-up map for the study areas. High-density residential patterns are shown in Yogyakarta, where 62.20% of the government center is dominated by residential land use with a low ratio of mixed urban built-up. The overall map of government center study areas shows a ratio of residential in the government centers, with a ratio of low residential patterns around 20%, medium residential patterns 40%, and high residential patterns > 60%. The ratio of residential in the government center provides information about how the government center was initially designed and how the mixture of land uses is creating the density of function in the neighborhood. The presence of residential ratios in the government center is also creating an intensity of population density in the study area. The dynamics, spread, and correlation of the residential of these study areas are unique and distinctive pattern on its own. The residential land uses in the map shows large blocks of residential patterns in Palembang, Surabaya, and Yogyakarta, while Bandung, Jakarta, and Medan are showing smaller blocks of residential land uses and showing correlation with the mixed urban built-up land use (Figure 7).

*Urban Design Suggestions*: According to the study shown on Figure 8, the ratio of open space varies but, it is still under the threshold of 30% ROS required open space for the city, even though some study areas are quite significant on the Open space ratios and showing a percentage of 20%. At the same time, it is difficult for two cities that have more densification and lower ROS, i.e., Surabaya and Yogyakarta, the future development for cities with such conditions needed to have more strict policy to retain the open spaces required for the city. The city's residential density played an important role in containing the ratio of land uses in the city. As a study area, Yogyakarta has shown that the high density of residential will reduce other land use ratio, and policy-wise slum and squatter houses will be very highly likely in this scenario. It will be difficult for the government to contain residential land use in the future. Bandung, Medan, and Jakarta, in this case, would be the ideal ratio of residential with the percentage around medium and high 20%, and there would be enough land use for other functions such as mixed urban built up to support the government center. The ratio of road network indicates the density of the open spaces provided by the road. Bandung, Jakarta, and Medan show an equal value compared to the other cities of Palembang, Surabaya, and Medan. The later cities' road street network ratio shows the densification resulted from the medium and high ratio of residential land use. The densification will be challenging to control since land uses the majority will be privately owned and used for residential and housing purposes. It will also be difficult to de-densify the road network.

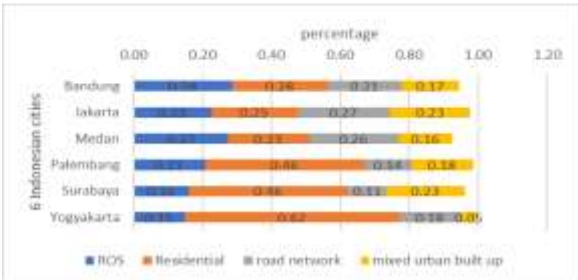


**Fig. 9.** Different Land Uses as Percentage of the Study Area.

### ***Relationship between government center and geometric center***

The final property in this study analyzes the relationship between the street network of the 6 study areas with the position of the government center and its geometrical core. To analyze this correlation, this study uses an overlay of the center and core areas with the linear density of the city in its entirety and the two-square-miles government center. Using GIS techniques in measuring the distances of the government center and the line density of the study area. Comparison between the street centerlines that represent the street network, City line density that visualizes the city's dense cores in its entirety and the linear density of the government center reveals the amount of urban intensity and growth in each of the study areas (Figure 9).

**Table 5.** Government Center Distance to City Center and Outer City Boundaries

| City | Distance of city center with government center (meter) | Distance to outer boundaries (meter) |
|---|---|---|
| Bandung | 2,993 | 16,191 |
| Jakarta | 5,460 | 16,361 |
| Medan | 1,026 | 18,160 |
| Palembang | 2,671 | **20,475** |
| Surabaya | **5,685** | 16,191 |
| Yogyakarta | 1,769 | 14,389 |

The measurement distance between the study areas shows values between 1km to 5.6 km range. In comparison, the distance between the government center to its outer syntactic boundaries shows values between 14.3 km to 20.4 km. The government center distance is then classified into three groups of Low, Medium, and High distance to simplify the analysis where under 2km falls in the Low distance category, 2km to 5km falls in the Medium distance category, and over 5km falls into the High distance category. While the distance of the government center with syntactic core acts to verify the intensity of urban development, it is logical that the syntactic boundaries could be used to verify the city's historical growth. Another critical issue on the syntactic boundaries other than the distance and size is the boundaries' shape. Political and administrative shape and size are determinably the primary categories that affected the shape of urban growth. Still, other factors, such as topographical features and layers of historical zones, could also play an essential role in the city shape.

The findings show that two cities of Medan and Yogyakarta have low government center distance to the geometrical core. Both of the city shows an evenly distributed urban growth on the syntactical network. Because of the closeness relationship of the political distance, Medan shows a similar result to the theory where the urban density is centralized in the geometrical center of the city and creating a centrically growth of the city shape. In this case, Yogyakarta shows the opposite result and has a dispersed intensity, shown by the group of red color on the Yogyakarta City Line density column in Figure 9. Both of the Low distances government center cities show an even balance of urban intensity on the two-square-miles Government Center column map.

The second category is the Medium distance of government center are represented by Bandung and Palembang, where it ranges from 2km to 5km of distance. From the City Line Density represented with the red color map in Figure 9, indicating that both cities have a dispersed urban density. It is also important to note that both cities have different Topographical features, where Bandung is located in a hilly area, and sloping contour, Palembang, on the other hand, is located in a plain area, and the city is divided by river. The Government Center map of Medium density is showing that it has less intensity compared to the Low distance of government center. This result supports the theory for the High intensity of the syntactic structure for the low-distance government center. The intensity will reduce with the urban growth and position changes of the syntactic or geometrical core of the city.

The final category is the High distance of government center that ranges over 5km distance and is represented by Jakarta and Surabaya. Both Megalopolis cities have a very high density of urban and metro areas. This population density is also an

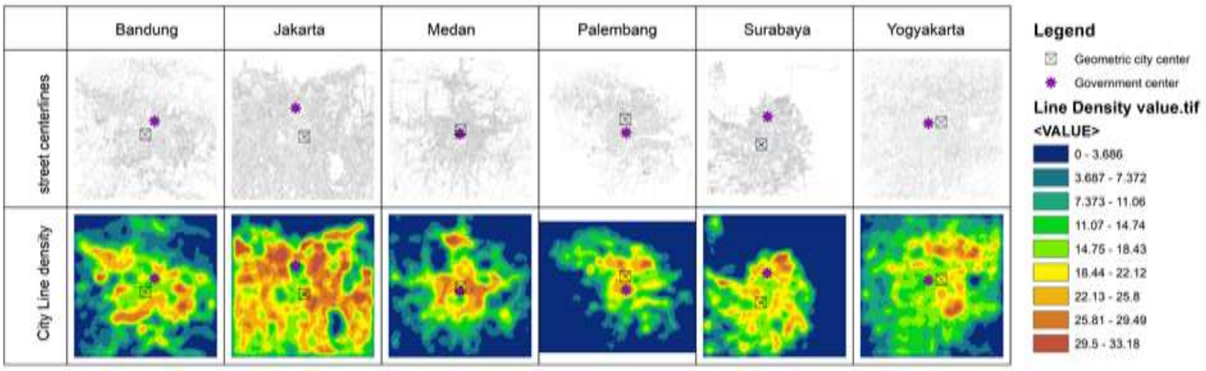


**Fig. 10.** Government center and Geometric Center Distances, with City Linear Densities Map.

indicator that these two cities also have a high intensity in its syntactical structure and street network. Jakarta is showing a highly dispersed density core in the city. We could see that there are multiple red areas in the city line density column in figure 9. Surabaya, on the other hand, is showing similar results but differ in the quantity of density cores. The map result in Surabaya shows a high intensity in the Northern / coastal part of the city, and the urbanity decreases from the increasing distance to its Political core. The result in Surabaya should be accounted for the topographical feature where the study area used in this research contains around 40% of the map is water. The government center map of Jakarta in figure 9 is showing that Jakarta has the lowest quantity of street centerline density in its two-square-miles government center. The political and historical growth of this area has been maintained to be showing these results. While Surabaya in the government center map is showing a very high intensity surrounding its two-square-miles government center, this is an indicator of the fast development and growth in Surabaya, where the political center is very intense compare to the urban spread.

*Urban Design Suggestions*: Although the findings in this section give some clues regarding the underlying relationship, urban intensity, and growth from the government core with the geometrical center of the city. Several intangible values need to be further studied to have a deep understanding of each study area's condition. The morphological intensity for the future capital city should be well designed and planned. Government regulation should have long-term policy stability to avoid the city's negative growth that would eventually create an undesired urban blunder.

## CONCLUSION

The quantitative comparison of the 6 study areas of Indonesian provincial capitals and Jakarta's current Indonesian capital revealed various similarities and traits of the city shape and spatial layout. These Indonesian cities' street grid shows a strong grid pattern of north and south orientation street layout. Although the grid layout's angle is not identically similar, and some cities have an angle skewed 10 degrees of orientation. Still, this city shape shows an indication that the majority of the studied cities are consistent in using the grid pattern layout. Two other cities that do not show a grid pattern are Bandung and Palembang, where both cities have a more natural city shape pattern. Further analysis of the spatial layout reveals that Hybrid gridiron and incremental infill street patterns are commonly used in this government center. This spatial layout is the result of urban growth and the continuation of the initial pattern that has been layout for these cities.

The results on street centrality show an interesting finding where there is a correlation between the government center spatial layout pattern with the global integration Rn of the entire city. The city with a grid-like globally integrated street network shows similar results in its government center grid spatial layout. Those cities are Jakarta, Medan, Surabaya, and Yogyakarta, respectively. At the same time, Bandung and Palembang are consistent in the natural street layout for its government center street angularity (Figure 3) and global integration map of its entirety (Figure 4).

From this study, we could conclude that all the study areas are showing high linear density and built-up areas. Table 5 and Figure 8 give a clear indicator of the study areas' spatial distribution and land uses. The logical assumption for the high density in the built-up area is that it is common in Southeast Asian cities were adapting and readapted with the pattern of new town developments. The layering of the urban pattern was primarily driven by trade and micro-economic and the need for new settlements due to the high population increase. A study has mentioned that the Southeast Asian cities are notwithstanding governmental decentralization of development, political and economic forces. Albeit the high built-up density, four out of six study areas show ROS / Ratio of Open Space higher than 20% in its government center. The percentage of this open space is considered to be an essential urban feature, as well as architecture aesthetics and identity. Furthermore, this Ratio of Open Space needed to be considered lightly, since an overwhelming number of ROS could result in dead spaces rather than creates functional open spaces.

The study areas' government distances are also indicators of how the city has grown and developed over time. New city planning must be able to account for the growth and intensity that will be applied in the city. The careful and meticulous city planning needs to be done to avoid land speculation resulting in sporadic land ownership in the new capital city in East Kalimantan.

This study is a way to represent the city shape and spatial layout of Indonesian provincial capitals, where the result can also be seen as fingerprints for other Indonesian cities (Table 7). Even though the new Capital for Indonesia has been designed with the "Forest and Island Hilltop" concept, but it seems reasonable to think that there are traits of commonality of shape and layouts that have been applied in

**Table 6.** A description of City Shape and Spatial Layout Patterns in the 6 Indonesian Government City Centers.

| city | Street grid | Street centrality | Built-up area | Open space distribution | Government center geometrical distance |
|---|---|---|---|---|---|
| Bandung | Natural street pattern with Incremental infill | Evenly distributed Medium value of intelligibility Located on a strong connectivity street network | High linear density Medium number of mixed use buildings and residential | High percentage of ROS | Medium distance |
| Jakarta | Strong grid centric pattern with Hybrid grid iron | Evenly distributed Medium value of intelligibility Located on a strong connectivity street network | High linear density High number of Large buildings | High percentage of ROS | High distance |
| Medan | Strong grid patter Hybrid grid iron with lollipops infill | Not evenly distributed Medium value of intelligibility Located on a strong connectivity street network | High linear density Medium number of mixed use buildings and residential | High percentage of ROS | Low distance |
| Palembang | Natural street pattern with Incremental infill | Not evenly distributed Medium value of intelligibility Located on a strong connectivity street network | High linear density Medium number of mixed use buildings and residential | medium percentage of ROS | Medium distance |
| Surabaya | Strong grid with street connection of east to west Hybrid gridiron with interrupted parallels | Topographical boundaries lowest value of intelligibility | High linear density Medium number of mixed use buildings and residential | Low percentage of ROS | High distance |
| Yogyakarta | Very strong street grid with incremental infill street pattern | Evenly distributed Medium value of intelligibility Located on a strong connectivity street network | High linear density Medium number of mixed use buildings and residential | Low percentage of ROS Residential ratio is the highest among the study area | Low distance |

Indonesians provincial centers. These traits hint that there are common causes behind the shape of the networks in these similar categories. This study understood that reality is more complex, and further classification of Indonesian cities is needed to reveal neighborhoods' spatial correlations in Indonesian cities.

Despite the simplification used in this study to understand the shape and layout, this study encourages further research toward the quantitative and systematic comparison of city shape and spatial layouts of different cities. In order to have a broad understanding of this spatial layout, new research of Indonesian cities needs to be carried out, studying cities in the Southeast Asia region that share geographical closeness and historical similarities.

## REFERENCES


Barron, Christopher, Neis, P. & Zipf, A. (2014). "A Comprehensive Framework for Intrinsic Open Street Map Quality Analysis." *Transactions in GIS*, 18(6), 877–895.

Bennett, J. (2010). *OpenStreetMap*. Packt Publishing Ltd.

Boeing, G. (2017). "OSMnx: New Methods for Acquiring, Constructing, Analyzing, and Visualizing Complex Street Networks." *Computers, Environment and Urban Systems* 65,126–139.

———. (2019). "Urban Spatial Order: Street Network Orientation, Configuration, and Entropy." *Applied Network Science* 4 (1), 67.

Center, Pew Research. (2015). *The Future of World Religions: Population Growth: Projections, 2010-2050*. Pew Research Center.

Girres, Jean-François, & Guillaume T. (2010). "Quality Assessment of the French OpenStreetMap Dataset." *Transactions in GIS* 14(4), 435–459.

Gordon, D. (2006). *Planning Twentieth Century Capital Cities*. Routledge.

Gottmann, J. (1985). "The Study of Former Capitals." *Ekistics*, 541–546.

Haklay, M. (2010). "How Good Is Volunteered Geographical Information? A Comparative Study of OpenStreetMap and Ordnance Survey Datasets." *Environment and Planning B: Planning and Design* 37(4), 682–703.

Hillier, B. (1996). *Space Is the Machine UK*. Cambridge University Press.

Hillier, B., Hanson, and Hanson, J. (1984). "J. 1984 The Social Logic of Space." *Cambridge University*.

Hillier, Bill. (2007). *Space Is the Machine: A Configurational Theory of Architecture*. Space Syntax.

Jiang, B. (2015). *Axwoman 6.3: An ArcGIS Extension for Urban Morphological Analysis. University of Gävle, Sweden*.

Jiang, Bin. (2009). "Street Hierarchies: A Minority of Streets Account for a Majority of Traffic Flow." *International Journal of Geographical Information Science* 23(8), 1033–1048.

Jiang, Bin, Sijian Zhao, and Junjun Yin. 2008. "Self-Organized Natural Roads for Predicting Traffic Flow: A Sensitivity Study." *Journal of Statistical Mechanics: Theory and Experiment* 2008 (07): P07008.

Kimmelman, M. (2017). "Jakarta Is Sinking so Fast, It Could End up Underwater." *The New York Times* 21.

Langford, M. (1991). "The Areal Interpolation Problem: Estimating Population Using Remote Sensing in a GIS Framework." *In Handling Geographical Information: Methodology and Potential Applications*, 55–77.

Li, G., & Weng, Q. (2005). "Using Landsat ETM+ Imagery to Measure Population Density in Indianapolis, Indiana, USA." *Photogrammetric Engineering & Remote Sensing* 71(8), 947–958.

Louf, R., & Barthelemy, M. (2014). "A Typology of Street Patterns." *Journal of The Royal Society Interface* 11(101), 20140924.

Lu, D., Weng, Q., & Li, G. (2006). "Residential Population Estimation Using a Remote Sensing Derived Impervious Surface Approach." *International Journal of Remote Sensing* 27(16), 3553–3570.

LYONS, S. (2015). "The Jakarta Floods of Early 2014: Rising Risks in One of the World's Fastest Sinking Cities." *Liège Université, Viewed 15 October 2018*.

Nations, United. 2018. *The World's Cities in 2018*. https://www.un-ilibrary.org/content/publication/c93f4dc6-en.

Rashid, M. (2017). "The Geometry of Urban Layouts."

Rashid, M., & Hadi, S. (2012). "The Dialectics of Functional and Historical Morphology in the Evolution of a City: The Case of the Stone Town of Zanzibar." *The Journal of Architecture* 17(6), 889–924.

Romdhoni, M. F., & Rashid, M. (2019). "Street Angularity and Patterns in Palembang and Yogyakarta, Indonesia." *Proceedings of Indonesia Focus* 1(1).

Shateh, H., & Rashid, M. (2014). "The Relationship between the Governmental and Syntactic Cores: The Case of Tripoli, Libya."

Southworth, M., & Owens, P. M. (1993). "The Evolving Metropolis: Studies of Community, Neighborhood, and Street Form at the Urban Edge." *Journal of the American Planning Association* 59(3), 271–287.

Stavroulaki, I., Marcus, L., Berghauser Pont, M., & Nilsson, L.C.S. (2017). "Representations of Street Networks in Space Syntax towards Flexible Maps and Multiple Graphs." In *11th International Space Syntax Symposium, SSS 2017, Lisbon, Portugal, 3-7 July 2017*, 5,174–1.

Widodo, J. (2009). *Arsitektur Indonesia Modern, Transplantansi, Adaptasi, Akomodasi Dan Hibridisasi in Nas, PJM (Ed.) Masa Lalu Dalam Masa Kini, Arsitektur Di Indonesia*. Jakarta: Penerbit PT Gramedia Pustaka Utama.

Wu, C., & Murray, A.T. (2003). "Estimating Impervious Surface Distribution by Spectral Mixture Analysis." *Remote Sensing of Environment* 84(4), 493–505.

———. (2007). "Population Estimation Using Landsat Enhanced Thematic Mapper Imagery." *Geographical Analysis* 39(1), 26–43.

Xia, X. (2013). *A Comparison Study on a Set of Space Syntax Based Methods: Applying Metric, Topological and Angular Analysis to Natural Streets, Axial Lines and Axial Segments*.

Yuan, Y., Smith, R.M., & Limp, W. F. (1997). "Remodeling Census Population with Spatial Information from Landsat TM Imagery." *Computers, Environment and Urban Systems* 21(3–4), 245–258.

Zielstra, D., Hochmair, H.H., & Neis, P. (2013). "Assessing the Effect of Data Imports on the Completeness of OpenStreetMap–AU Nited S Tates Case Study." *Transactions in GIS* 17(3), 315–334.